Atomic Transition Probabilities for Vanadium, Chromium, and Manganese

(A Critical Data Compilation of Allowed Lines)

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Atomic transition probabilities for about 2700 spectral lines of the elements vanadium, chromium, and manganese through all stages of ionization have been critically evaluated and compiled. All available literature sources have been utilized. Systematic trends along isoelectronic sequences have been extensively exploited to predict oscillator strengths (f-values) whenever no data were available in the literature. The data are presented in separate tables for each element and stage of ionization and are arranged according to multiplets and, when appropriate, also to transition arrays and increasing quantum numbers. For each line, the transition probability for spontaneous emission, the absorption oscillator strength, and the line strength are given, along with the spectroscopic designation, the wavelength, the statistical weights, and the energy levels (when available) of the upper and lower atomic states. In addition, the estimated accuracy and the literature reference are indicated. In short introductions, which precede the tables for each spectrum, the main justifications for the choice of the adopted data and for the accuracy rating are discussed. A general introduction contains some more details on our evaluation procedure.

Key words: Allowed transitions; chromium; f-values; isoelectronic sequence; line strengths; manganese; oscillator strengths; systematic trends; transition probabilities; vanadium.

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1. Introductory Remarks

This work is part of a continuing effort of the Data Center on Atomic Transition Probabilities to critically evaluate and compile data on atomic transition probabilities [1] from the literature. The same format has been maintained as in the earlier NBS compilations, which include f-value data for allowed and forbidden transitions of the first twenty elements [1,2],[2] forbidden transitions of the iron group elements [3], and allowed transitions of scandium and titanium [4].

The literature sources are taken from the bibliographies on atomic transition probabilities [5], which have been published by this NBS data center. In addition, the more recent literature since the issuance of the latest supplemental bibliography has been taken from a master reference list, maintained and continually updated in the data center. This material includes some as yet unpublished results which have been communicated to us by researchers in the field.

For neutral and, to a considerably lesser degree, for singly ionized species of vanadium through manganese, transition probability data are fairly abundant. For the higher stages of ionization, very few data are available in the literature, and they are mainly theoretically derived. For some species no results could be tabulated at all—either because no reliable data existed or because information needed to convert the available data to transition probabilities, such as branching ratios or wavelengths, was unavailable. For many transitions of the highly ionized species, no accurate wavelengths or energy levels are available as yet, but oscillator strength data could be obtained by interpolation procedures and have thus been tabulated whenever we felt that they were known with reasonable accuracy. Theoretically determined line strengths are not included here unless the availability of accurate wavelength data enabled us to convert them to transition probabilities.

[1] Transition probabilities, oscillator strengths (f-values), and line strengths are equivalent quantities. The numerical relationships between these quantities are given in the conversion table (table 2) at the end of this introduction.

[2] Numbers in brackets indicate the literature references.

2. Method of Evaluation

Each source of data has been subjected to an evaluation based mainly on the general accuracy and reliability of the theoretical or experimental method used, as well as its applicability to the determination of transition probabilities for the spectra covered. For each method there are certain critical factors which affect the accuracy of the data produced; e.g., cascading from higher levels introduces uncertainties in the measurement of lifetimes of excited states. The principal critical factors pertinent to each technique are discussed in one of our earlier data compilations [2].

In some cases an author has neglected to account for one or more critical factors (or has at least failed to mention them). We have nevertheless included the data if they were obtained with a method considered to be generally reliable. For some spectra we were forced to resort to rather crude material, in which case the accuracy ratings have been lowered accordingly.

For the spectra of very highly ionized species we have relied heavily on the fit of data into systematic trends, and have in essence used the consistency of well established regularities as an additional critical factor. In fact, with few exceptions (notably, the work of Weinhold [6] and Sims and Whitten [7] on upper and lower bounds), it is impossible to determine uncertainties in calculated f-values; thus the analysis of systematic trends—which usually contain experimental data—is often the only means of critically evaluating theoretical results.

Some general remarks on the selected sources of data are given below. A more detailed discussion can be found in the short introductions which accompany the tables for individual spectra.

2.1. Review of Data Sources

2.1.1. Experimental

Experimental data for vanadium, chromium, and manganese are essentially limited to the neutral and singly ionized species. Some beam-foil data exist for V III and Mn III; these could not be utilized, however, mainly be-

cause of the unavailability of branching ratios. But experimental results—particularly beam-foil data—have contributed indirectly, i.e., by analysis of systematic trends, to the determination of interpolated f-values for the more highly ionized species.

The overwhelming majority of the available data are relative transition probabilities from either emission, absorption, or anomalous dispersion experiments. On the other hand, the adopted absolute scales have been established from a few experiments of a quite different nature. It is thus advantageous to discuss the absolute and relative scales separately.

(a) Absolute scales. In establishing the absolute scales we have primarily utilized the following sources: (1) the atomic beam absorption experiment of Mie and Richter [8] for V I; (2) the lifetime measurements of Marek [9], done by the delayed coincidence technique with laser excitation, for Cr I and Mn I; (3) the lifetime measurements of Becker et al. [10], done by the level crossing technique, for Cr I; and (4) the total absorption study of Bieniewski [11] for Cr I. On account of the selective excitation mechanisms used in the lifetime experiments of refs. [9] and [10], the results are essentially free of the cascading problems that often affect these measurements. Slightly less accurate sources are the beam-foil experiments of Engman et al. [12] for Cr II and Roberts et al. [13] for V I and II. Since they measured the lifetimes of highly excited atomic levels for which many spontaneous radiative decay modes exist, the observed lifetimes could be converted to transition probabilities only in cases where relative transition probabilities (branching ratios) were available from another source for all downward branches. Otherwise, an observed lifetime provided only an upper limit against which we could check the inverse sum of measured transition probabilities.

(b) Relative f-values. Most of the selected data have been taken from a few experiments that have yielded a large number of relative f-values. In fact, the extensive material for the first spectra of V, Cr, and Mn constitutes approximately two-thirds of all the tabulated data for the more than sixty spectra covered.

In the case of V I, relatively old experimental data had to be used: the results of an absorption experiment of King [14], reported in 1947, which covers 471 lines (of which we presented data for the more prominent lines), and the less extensive results of the anomalous dispersion (hook) measurements of Ostrovskii and Penkin (1958) [15]. Where the two sets of data overlapped (normalized to the same absolute scale), the agreement was consistently good—in all cases within 50%.

For Cr I the major source of data is the anomalous dispersion experiment by Huber and Sandeman [16], who have also carried out absorption measurements for some weaker lines. There is good agreement between their work and the few, but very reliable, absorption measurements of Bieniewski [11] and earlier anomalous dispersion measurements of Penkin [17].

For Mn I we have mainly utilized the extensive emission measurements of Woodgate [18], performed with a vortex-stabilized arc. Good agreement with the much less extensive but very careful absorption measurements of Blackwell and Collins [19] has been found.

We have used the arc emission measurements of Roberts et al. [13] and Musielok and Wujec [20] for V II and Cr II, respectively. For singly ionized manganese, however, only a few data of a reliable nature were available and the few existing sources showed very little overlap, so that almost no consistency checks could be made. Thus the selected data should be considered rather uncertain, and we urge that further experimental work be concentrated on this spectrum to improve the presently unsatisfactory situation.

2.1.2. Theoretical

Since no directly usable experimental data were available beyond the neutral and singly ionized species of V, Cr, and Mn, we had to rely on theoretically derived oscillator strengths for most spectra. The methods used in performing the calculations cover an extended range from rather simplified model potential approaches to quite sophisticated relativistic Hartree-Fock treatments, with varying degrees of configuration interaction and/or intermediate coupling taken into account.

The most comprehensive source of calculated f-values is the publication of Kurucz and Peytremann [21]. Their data have been obtained by a semiempirical Thomas-Fermi-Dirac approach with limited configuration interaction. Although they have published data for the neutral species and for singly to quadruply ionized vanadium through manganese, their results have largely been excluded from this compilation, for reasons explained in section 2.2.

Several authors have published f-values for individual transitions along an entire isoelectronic sequence (or for a relatively large number of ions)—usually for only a few prominent transitions. There are two sources which provide data for several isoelectronic sequences: (1) the many-body perturbation theory Z-expansion calculations of Safronova [22] for the isoelectronic sequences of lithium through fluorine, with relativistic corrections to the energy levels, and (2) the article by Sinanoglu [23], in which the results of his non-closed shell many-electron theory (NCMET) for lower ions have been extrapolated to determine f-values for transitions of highly ionized species of selected heavy elements (one of these being manganese). In addition, several less comprehensive sources of data for specific sequences are mentioned below.

Nonrelativistically derived formulas are provided for transition probabilities of the hydrogen-like species, and, as will be discussed later, relativistic effects are small for most transitions. For the He-like ions, we have extrapolated the variational results of Weiss [24] for the more prominent transitions of low-Z ions of the sequence; the

Z-expansion results of Laughlin [25] have also been tabulated.

For B-like ions, we have used the data of Sinanoglu and Luken [26], which they derived by extrapolation of their NCMET results (incorporating both relativistic and correlation effects) for low-Z ions of the sequence. Results of the very recent many-body perturbation theory Z-expansion calculations of Safronova and Bolotin [27] and Safronova [28] were selected for the N-like and O-like ions respectively. (These results should be more accurate than those reported in ref. [22], in view of the higher level of approximation used.)

Results of the variational superposition-of-configurations (SOC) calculations of Froese-Fischer [29,30] have been chosen for the Al-like ions. The configuration interaction results of Cowan [31] in intermediate coupling were tabulated for Ar-like chromium, and we have used his published data to interpolate f-values for V VI and Mn VIII.

The Hartree-Fock results which have been selected are taken from the work of Cohen et al. [32], Biemont [33], and Ali and Joy [34] for the F-like, Na-like, and P-like ions respectively, as well as the data of Cowan [35], calculated in intermediate coupling, for Cr VI and Mn VII. The results of refs. [32] and [34] are, however, considered to be rather uncertain, as mentioned in the short introductions to the pertinent spectra. The parametric potential calculations of Crance [36] for Ne-like ions have been selected over the self-consistent field results of Kastner et al. [37], since the two sources are in good agreement but the data of Crance are more extensive.

2.1.3. Systematic Trends

For the spectra of numerous higher ions, most, and in some cases all, of the tabulated data have been derived by interpolation of oscillator strengths along isoelectronic sequences of the light elements. This technique, which was developed at NBS several years ago [38], is based on the expansion of the oscillator strength as a power series in the quantity $1/Z$, where Z is the nuclear charge. For infinite Z $(1/Z=0)$, the power series reduces to a single term, which is just the hydrogenic f-value modified by the appropriate angular factors to account for the multiplet structure under consideration. Data which are available from the literature have been evaluated to establish the $1/Z$ dependence of the f-value toward the neutral end of an isoelectronic sequence, and the modified hydrogenic f-value provides the asymptotic limit for high-Z ions. Unknown f-values can thus be predicted by interpolation along a graph of f vs $1/Z$. However, for highly ionized species it becomes difficult to assess the accuracy of such predicted values, since the formalism on which this technique is based is entirely nonrelativistic—and relativistic effects are expected to become increasingly more significant for higher ions of the heavy elements.

Relativistic calculations have thus far been limited to relatively few sequences, so that, for a given transition along an isoelectronic sequence, the minimum value of Z for which the relativistic f-value will deviate significantly from the nonrelativistic value is somewhat uncertain. Existing calculations of f-values for highly ionized species include the relativistic Dirac results of Garstang [39] and Younger and Weiss [40] for hydrogenic ions; the Dirac-Hartree-Fock approaches of Kim and Desclaux [41] for Li-like and Na-like ions, and of Armstrong et al. [42] for Li-like and Be-like ions; and the relativistic random phase approximation calculations of Johnson and Lin [43] for He-like ions. These calculations show that for most transitions, relativistic corrections for highly ionized species of vanadium through manganese usually fall in the 1–10% range, with the exception of $\Delta n=0$ transitions (particularly those for which $\Delta J=\pm 1$), in which relativistic f-values deviate from the corresponding nonrelativistic ones by as much as 30 percent.

Systematic trends have been studied extensively [44] to evaluate existing data and to establish graphs of systematic trends along isoelectronic sequences of He through Mg. These graphs have been updated and revised in connection with the present compilation in order to incorporate more recently published material. In addition, new trends have been established whenever we felt that the volume and reliability of original data warranted it. For ions of the Li sequence, we have also used critically evaluated oscillator strength data [45], which were obtained by means of a generalized analysis of systematic trends [46] based on regularities of f-values both along the isoelectronic sequence and within spectral series, and included further constraints on f-values by forcing adherence to the Wigner-Kirkwood sum rule and the condition of a smooth transition from the line to the continuous spectrum.

2.2. A Critical Review of the Comprehensive Calculations of Kurucz and Peytremann

Kurucz and Peytremann [21] have published log gf-values for numerous transitions of neutral species and for low stages of ionization. They used a semiempirical Thomas-Fermi-Dirac approach with very limited configuration interaction. It is unlikely that this rather simplified theoretical method yields reliable oscillator strengths for all transitions covered. Thus it is important to assess the accuracy of these f-values on a comprehensive scale.

We have compared Kurucz and Peytremann's data for several spectra of iron group elements to experimental results which were estimated to be reliable. We have also made use of Smith's graphical comparison [47] of the difference in log gf between the results of ref. [21] and experimental data, versus both upper energy level and log gf, for Fe I, Ti II, and V II, which is reproduced here as figure 1. Our own comparisons for the neutral species of titanium through manganese are presented in figures 2–5. Clearly, the common characteristic is the enormous degree of scatter betwen the results of ref. [21] and the experimental data. In fact, agreement wtihin 50 percent was found for fewer than two-thirds of the transitions

used in the comparisons, and for a few lines, theory differed from experiment by as much as three to four orders of magnitude.

Kurucz and Peytremann themselves do not rule out the possibility of an error in scale of a factor of two. Moreover, Kurucz has suggested [48] that their theoretical results could be improved in two ways: a) the inclusion of a greater number of configurations in the basis set and b) the availability of better experimental energy level data. The very limited graphical comparison by Parkinson et al. [49] for resonance lines of Sc I (reproduced here as fig. 6), as well as a similar comparison undertaken by us of the data of Blackwell et al. [50] for resonance lines of Fe I (see fig. 7), seems to substantiate the suggestion that the data of Kurucz and Peytremann agree fairly well with experimental results for transitions involving well-known energy levels and moderate configuration interaction. In addition, Smith's comprehensive comparison for Fe I seems to indicate an increase in scatter with upper energy level. The situation for the remaining spectra shows, however, only random scatter, so that no specific conclusion is possible at this time.

The line identifications given by Kurucz and Peytremann sometimes disagree with those of other authors. In addition, there are several cases in which their wavelength list indicates a blend of two lines, so that the experimentally determined f-value, which is attributed to only one or the other of these lines, may be meaningless. We would suggest this as a possible explanation for some of the more serious discrepancies.

In view of the many substantial disagreements of Kurucz and Peytremann's results with experimental data, together with the lack of success in establishing a definitive criterion for evaluating the accuracy of the f-value for any given transition, we have generally excluded this source of data from our compilation. The only exceptions are a few strong lines of the relatively simple spectra of V IV and Cr V, for which fairly reliable results are expected.

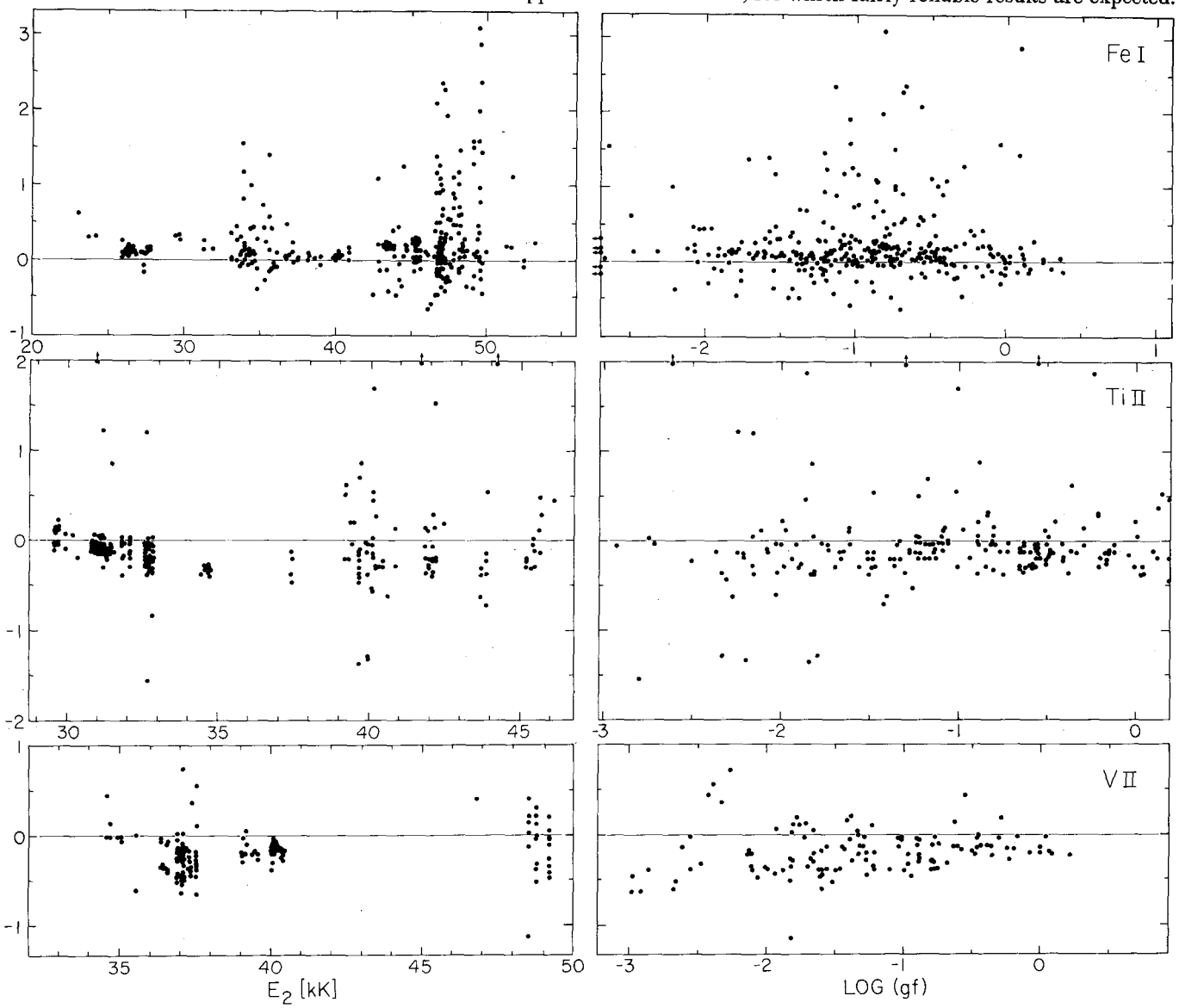

FIGURE 1. Plots reproduced from ref. [47] of log $(gf)_{\text{experiment}}$—log $(gf)_{\text{ref. [21]}}$ vs upper energy level and vs log $(gf)_{\text{experiment}}$ for Fe I, Ti II, and V II. The experimental data are from the following sources: Fe I—Bridges, J. M., and Kornblith, R. L., Astrophys. J. **192**, 793 (1974); Ti II—ref. [4]; and V II—ref. [13].

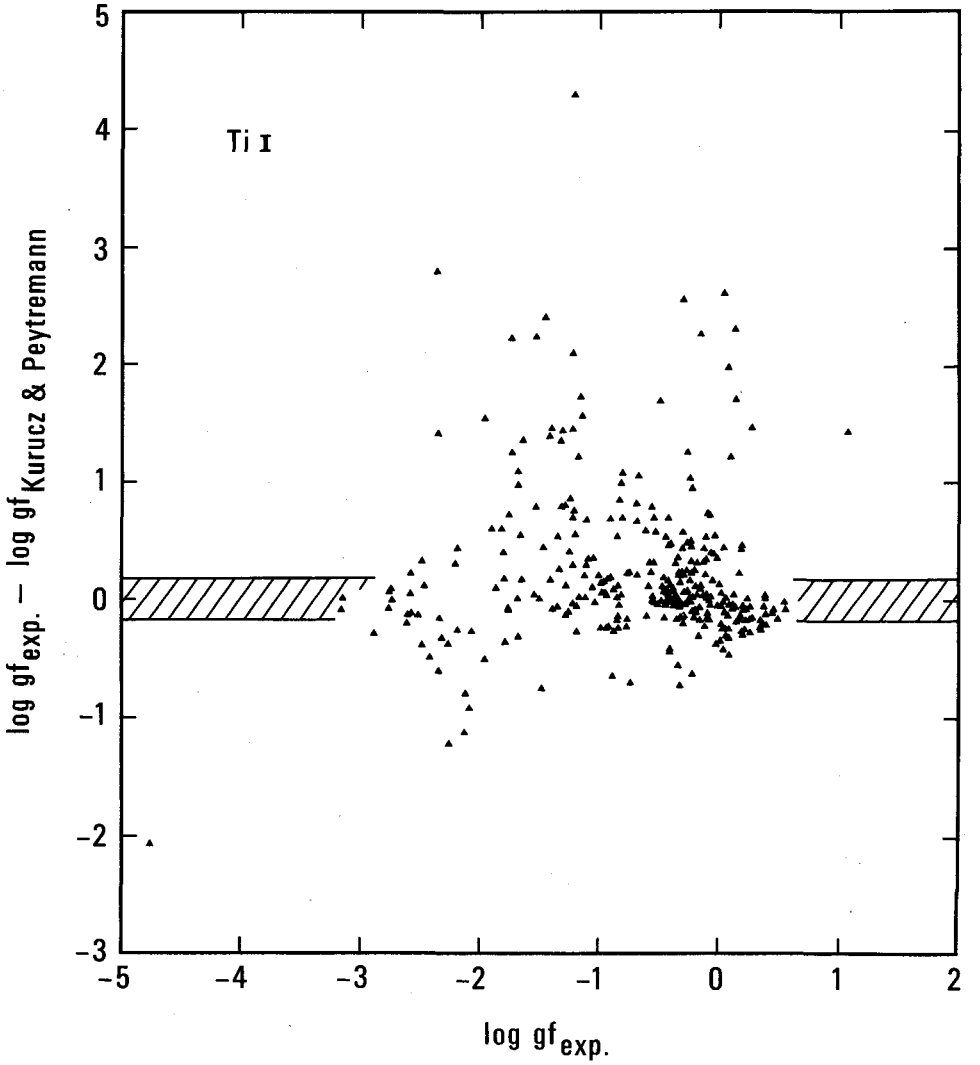

FIGURE 2. Plot of log $(gf)_{\text{experiment}}$—log $(gf)_{\text{ref. [21]}}$ vs log $(gf)_{\text{experiment}}$ for Ti I. The experimental data are from ref. [4]. The cross-hatched area between the solid horizontal lines indicates agreement of experiment and theory within fifty percent.

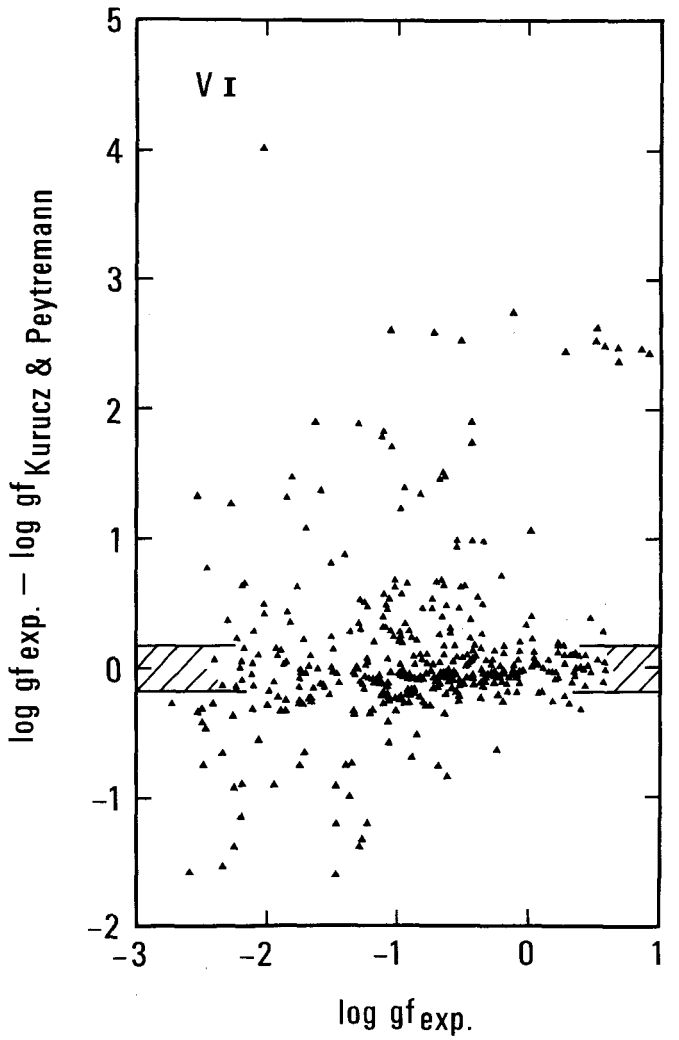

FIGURE 3. Plot of log $(gf)_{\text{experiment}}$ —log $(gf)_{\text{ref. [21]}}$ vs log $(gf)_{\text{experiment}}$ for V I. The experimental data are from the present compilation. The cross-hatched area between the solid horizontal lines indicates agreement of experiment and theory within fifty percent.

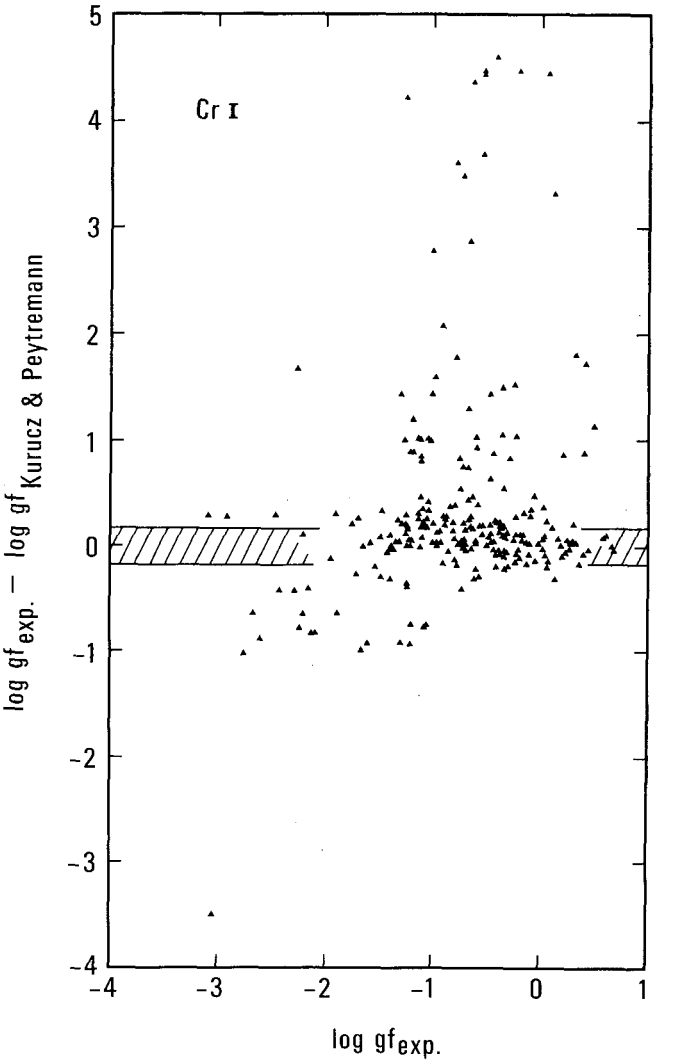

FIGURE 4. Plot of log $(gf)_{\text{experiment}}$ —log $(gf)_{\text{ref. [21]}}$ vs log $(gf)_{\text{experiment}}$ for Cr I. The experimental data are from the present compilation. The cross-hatched area between the solid horizontal lines indicates agreement of experiment and theory within fifty percent.

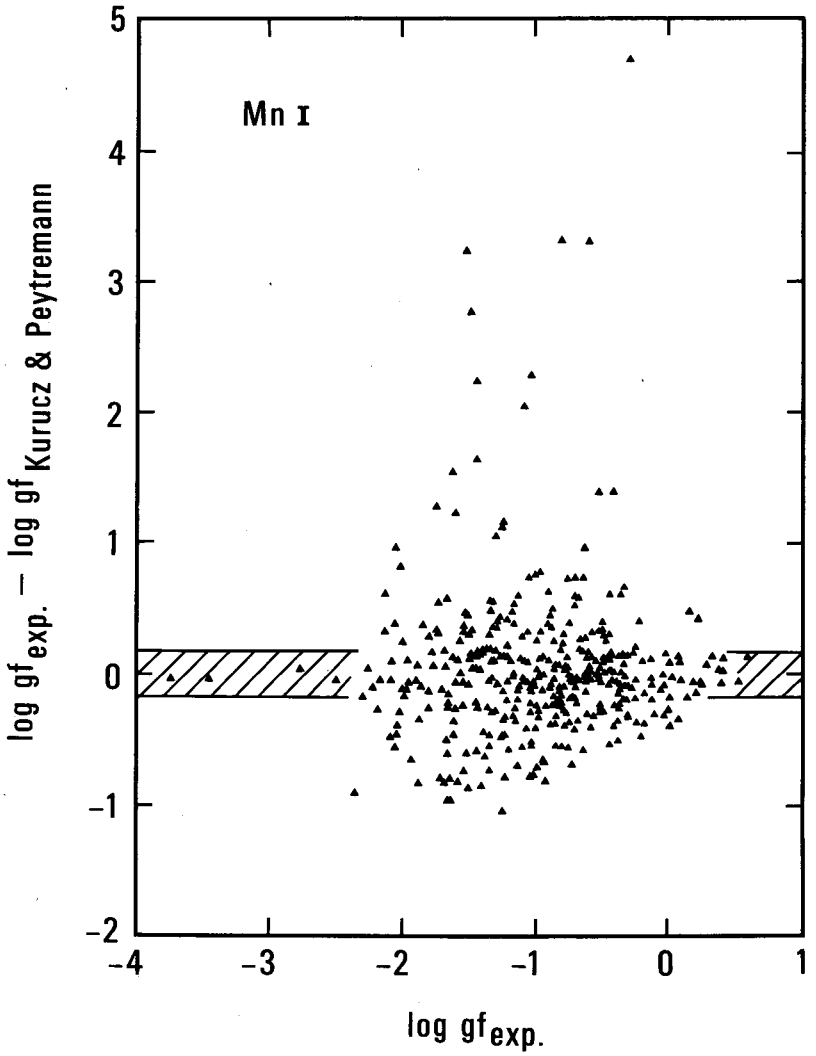

FIGURE 5. Plot of log $(gf)_{\text{experiment}}$—log $(gf)_{\text{ref [21]}}$ vs log $(gf)_{\text{experiment}}$ for Mn I. The experimental data are from the present compilation. The cross-hatched area between the solid horizontal lines indicates agreement of experiment and theory within fifty percent.

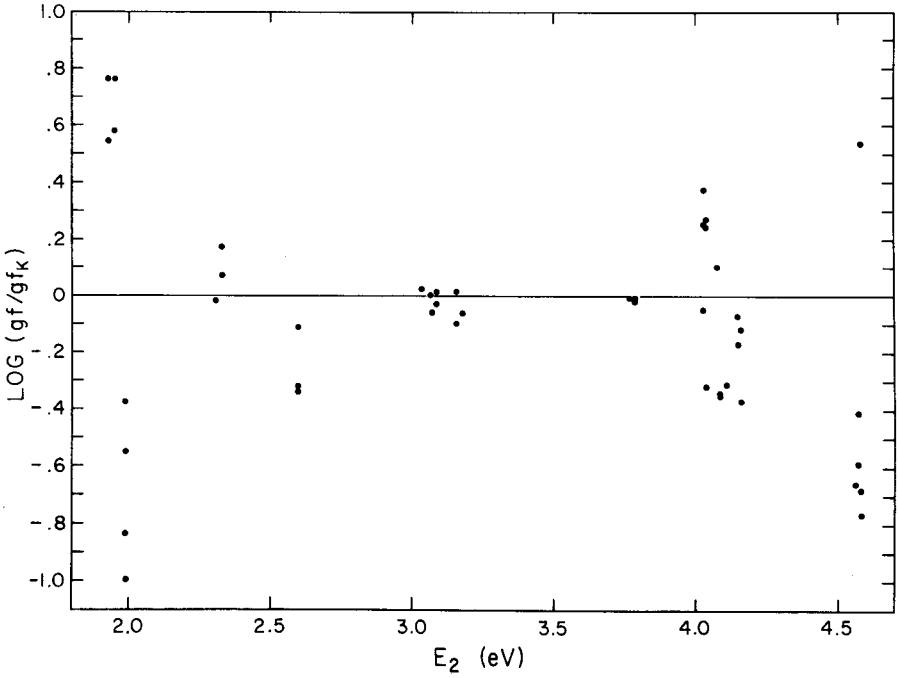

FIGURE 6. Plot reproduced from ref. [49] (with permission of The Royal Society, London) of log $(gf)_{\text{ref. [49]}}$—log $(gf)_{\text{ref. [21]}}$ vs upper energy level for resonance lines of Sc I.

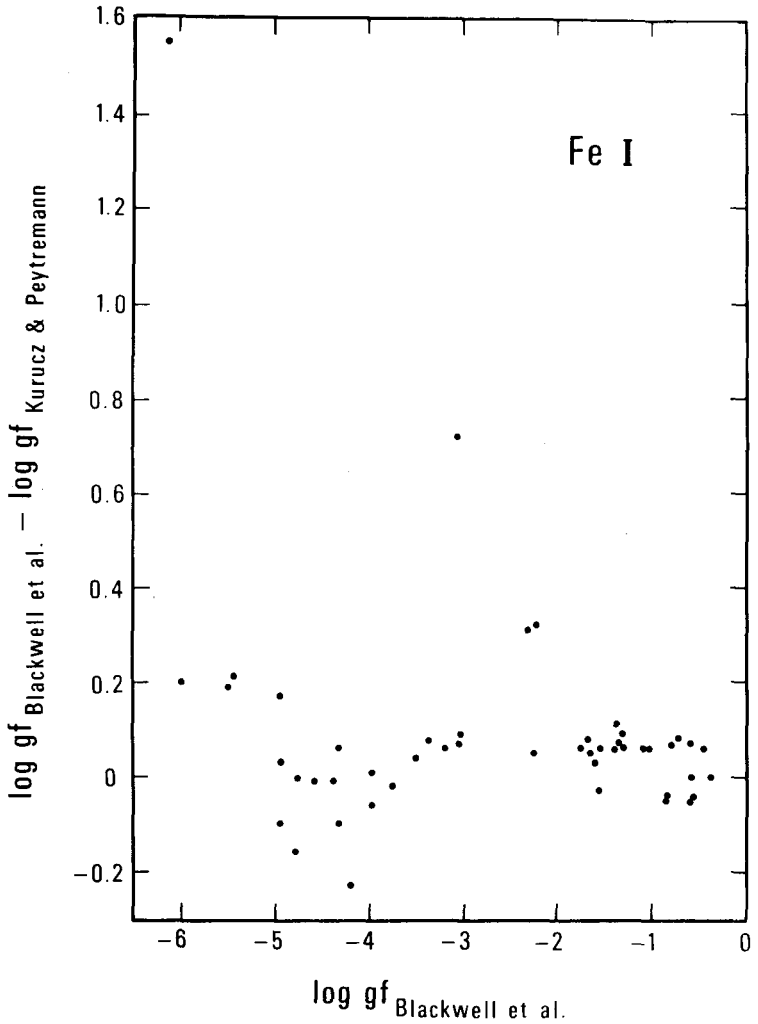

FIGURE 7. Plot of log $(gf)_{\text{ref. [50]}}$—log $(gf)_{\text{ref. [21]}}$ vs log $(gf)_{\text{ref. [50]}}$ for resonance lines of Fe I.

3. General Arrangement of the Tables

The same general format has been maintained throughout the series of NBS compilations [1–4]. For the more complex spectra, we have omitted the transition array column, and the multiplet designation used by Moore [51–53], which labels the terms with lower case letters (*a,b,c, . . ., x,y,z*), has been used to identify the upper and lower states of a transition. In some special cases, we have designated the transition, where appropriate, in a coupling scheme other than Russell-Saunders (*LS*), such as the *jl*-coupling situation encountered in the Ne-like spectra (V XIV, Cr XV and Mn XVI).

The major sources of wavelength and energy level data are the tables of Moore [51–53] and Kelly and Palumbo [54]. For some spectra, particularly for the highly ionized species, little or no data were available from these sources. We thus had to search through the more recent literature on these species to obtain the appropriate data. To this end, the bibliographies on atomic energy levels and spectra [55] were quite helpful. In addition, we made use of the facilities of the NBS Data Center on Atomic Energy Levels in locating the most recent sources of original data. All sources of wavelengths and energy levels other than refs. [51] through [54] which have been used in this compilation are given in table 1.

TABLE 1. Special source material for wavelength and energy level data. Complete citations are given below.

Spectrum	References	Spectrum	References	Spectrum	References
V IV	1	Cr II	24	Mn I	32
V VI	2	Cr V	25	Mn VI	33
V X	3	Cr VI	26,27	Mn VII	26
V XI	3	Cr X	28	Mn VIII	2
V XIII	4	Cr XI	3,28	Mn X	3
V XIV	5,6	Cr XII	3,28	Mn XII	3,28
V XV	7,8	Cr XIV	4,29	Mn XIII	28
V XVI	9	Cr XV	6	Mn XV	4,29
V XVII	10,11,12,13,14,15	Cr XVII	9	Mn XVI	6
V XVIII	11,16,17	Cr XVIII	10,12,13,14,15	Mn XVII	7,8
V XIX	14	Cr XIX	16,18	Mn XVIII	9
V XX	18,19	Cr XXI	18,19	Mn XIX	10,11,12,13,14,15
V XXI	20,21,22	Cr XXII	21,22,30	Mn XX	16,18
V XXII	23	Cr XXIII	31	Mn XXII	18,19
				Mn XXIII	20,21,30

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In the main tables, calculated or extrapolated energy levels are enclosed in square brackets, as are experimentally derived energy levels which are uncertain with respect to the ground state. The same is true of wavelengths that have been calculated from energy level differences rather than obtained from experiment.

We have again classified the uncertainties in the atomic transition probability data with the same notation used in our earlier compilations, i.e.,

A.....for uncertainties within 3 percent,[3]
B.....for uncertainties within 10 percent,
C.....for uncertainties within 25 percent,
D.....for uncertainties within 50 percent,
E.....for uncertainties greater than 50 percent.

[3] No transition probabilities of "A" accuracy are reported in this compilation.

The word *uncertainty* is used here with the connotation "extent of possible error" or "possible deviation from the true value." We have often made a further differentiation in the classification scheme by assigning plus or minus signs to some transitions to indicate that these lines are estimated to be somewhat better or worse than similar lines. These should therefore be the first or last choice among similar transitions.

A summary of the abbreviations and special symbols used in the tables is given in section 4. Also, for convenience, we have included the relations between line and multiplet values in the case of *LS* coupling. In table 2, we provide a table of conversion factors, which we have used throughout this compilation to convert from transition probabilities to oscillator strengths and line strengths, and vice versa.

TABLE 2. Conversion factors

The factor in each box converts by multiplication the quantity above it into the one at its left.

	A_{ki}	f_{ik}	S
A_{ki}	1	$\frac{6.670_2 \times 10^{15}}{\lambda^2}\frac{g_i}{g_k}$	$\frac{2.026_1 \times 10^{18}}{g_k\lambda^3}$
f_{ik}	$\frac{1.4992 \times 10^{-16}\lambda^2 g_k}{g_i}$	1	$\frac{303.7_6}{g_i\lambda}$
S	$4.935_5 \times 10^{-19} g_k\lambda^3$	$3.292_1 \times 10^{-3} g_i\lambda$	1

The line strength is given in atomic units, which are $a_0^2e^2 = 7.188_1 \times 10^{-59}$ m^2C^2 for electric dipole transitions. The transition probability is in units s^{-1}, and the f-value is dimensionless. The wavelength λ is given in angström units, and g_i and g_k are the statistical weights of the lower and upper state, respectively. For the atomic constants entering into the relations, we have used the recommendations of the CODATA Task Group on Fundamental Constants (J. Phys. Chem. Ref. Data **2**, 663 (1973)).

4. Key to Abbreviations and Symbols Used in the Tables [4]

1. Symbols for indication of accuracy:

A.....uncertainties within 3 percent,[3]
B.....uncertainties within 10 percent,
C.....uncertainties within 25 percent,
D.....uncertainties within 50 percent,
E.....uncertainties greater than 50 percent.

2. Abbreviations appearing in the source column of allowed transitions:

ls = *LS* coupling rules applied
ca = Coulomb approximation
n = normalized to a scale different than that of the author (as explained in the introductory remarks to the pertinent spectrum)
interp. = derived by an interpolation technique, rather than taken directly from the literature

3. Special symbols used in the wavelength and energy level columns:

The number in parentheses under the multiplet designation refers to the running number of ref. [52] (Revised Multiplet Table). If letters "uv" are added, we refer to the running number of ref. [53] (Ultraviolet Multiplet Table).

Numbers in italics indicate multiplet values, i.e., weighted averages of line values.

Numbers in square brackets indicate approximate calculated or extrapolated values.

[4] In keeping with the tradition in this field, we have tabulated the spectroscopic quantities in customary units rather than in SI units; e.g., energy levels are expressed in terms of wave numbers, or cm^{-1}.

Useful Relations

(A) Statistical Weights:

The statistical weights are related to the inner quantum number J_L (for one-electron spectra: j_L) of a level (i.e., initial or final state of a *line*) by

$$g_L = 2J_L + 1,$$

and to the quantum numbers of a term (initial or final state of a *multiplet*) by

$$g_M = (2L+1)(2S+1).$$

(The "multiplet" values g_M may also be obtained by summing over all possible "line" values g_L. S is the resultant spin.)

(B) Relations between the strengths of lines and the total multiplet strength:

1. Line strength S:

$$S(i,k) = \sum_{J_i,J_k} S(J_i,J_k)$$

or

$$S(\text{Multiplet}) = \Sigma\, S(\text{line})$$

(k denotes the upper and i the lower term).

2. Absorption oscillator strength f_{ik}:

$$f_{ik}^{\text{multiplet}} = \frac{1}{\bar{\lambda}_{ik} \sum_{J_i} (2J_i+1)} \sum_{J_i,J_k} (2J_i+1) \times\lambda(J_i,J_k) \times f(J_i,J_k).$$

The mean wavelength for the multiplet, $\bar{\lambda}_{ik}$, may be obtained from the *weighted* energy levels. Often the wavelength differences for the lines within a multiplet are small, so that the wavelength factors may be neglected.

3. Transition probability A_{ki}:

$$A_{ki}^{\text{multiplet}} = \frac{1}{(\bar{\lambda}_{ik})^3 \sum_{J_k} (2J_k+1)} \sum_{J_i,J_k} (2J_k+1) \times\lambda(J_i,J_k)^3 \times A(J_i,J_k).$$

Relative strengths $S(J_i,J_k)$ of the components of a multiplet are listed for the case of *LS* coupling in Allen, C. W., *Astrophysical Quantities* 3rd ed. (The Athlone Press, London, 1973); White, H. E., and Eliason, A. Y., Phys. Rev. **44**, 753 (1933); Shore, B. W., and Menzel, D. H., *Principles of Atomic Structure*, p. 447 (John Wiley & Sons, Inc., New York, 1968); Goldberg, L., Astrophys. J. **82**, 1 (1935) and **84**, 11 (1936).

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6. Tables of Spectra

Vanadium

V I

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2\ {}^4F_{3/2}$

Ionization Potential 6.74 eV = 54400 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
3043.12	17	3207.41	14	3543.50	48	3803.47	27
3043.56	17	3212.43	63	3545.34	48	3803.78	58
3044.94	17	3215.38	13	3553.27	48	3803.90	10
3050.40	64	3217.12	14	3555.14	48	3806.80	58
3050.89	16	3218.87	62	3583.70	42	3807.51	27
3052.19	15	3226.11	14	3663.59	85	3808.52	9
3053.65	17	3230.65	13	3667.74	85	3809.60	27
3056.33	17	3233.19	62	3671.21	60	3813.49	9
3060.46	17	3249.57	13	3672.40	86	3815.51	27
3060.93	15	3254.77	13	3673.40	85	3817.84	10
3063.73	16	3263.24	12	3676.68	86	3818.24	9
3066.38	17	3271.64	12	3680.11	85	3819.96	27
3066.51	17	3273.03	61	3683.13	28	3821.49	27
3069.65	15	3277.94	12	3686.26	60	3822.01	9
3075.93	52	3283.31	12	3687.47	85	3822.89	27
3080.15	15	3284.36	61	3688.07	28	3823.21	27
3080.33	52	3291.68	12	3690.28	28	3823.99	41
3082.11	17	3298.14	12	3692.23	28	3826.77	41
3083.54	52	3299.09	50	3695.34	85	3828.56	9
3087.07	52	3308.25	12	3695.87	28	3835.56	41
3088.11	51	3309.18	50	3703.58	28	3836.05	41
3089.13	52	3329.86	50	3704.70	28	3839.00	41
3091.44	15	3356.35	49	3705.04	28	3840.14	57
3091.55	15	3365.55	49	3706.04	79	3840.75	9
3093.24	15	3376.06	49	3708.72	79	3841.89	8
3093.79	52	3377.39	49	3713.96	11	3844.44	7
3094.69	51	3377.63	49	3721.36	11	3847.32	7
3112.93	51	3397.58	49	3777.1	10	3855.37	7
3183.41	14	3400.40	43	3778.68	27	3855.84	9
3183.96	14	3402.57	43	3779.65	59	3859.34	41
3183.98	14	3405.16	43	3784.7	10	3862.22	8
3185.40	14	3406.84	43	3790.32	27	3863.87	57
3198.01	14	3417.1	43	3790.47	59	3864.30	56
3202.38	14	3529.74	48	3791.33	10	3864.86	7
3204.20	13	3533.68	48	3794.96	27	3867.60	7
3205.58	63	3533.76	48	3799.91	27	3871.08	57

List of tabulated lines—Continued

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
3875.08	7	4200.1	24	4469.71	69	5240.88	94
3875.90	7	4200.89	4	4474.05	81	5415.28	93
3876.09	8	4209.86	23	4490.82	68	5487.92	92
3886.59	56	4218.71	23	4491.16	54	5507.75	92
3890.18	8	4219.51	23	4496.06	81	5544.87	35
3892.86	7	4232.46	82	4496.86	68	5545.93	35
3896.16	40	4232.95	82	4501.97	54	5547.08	35
3902.25	7	4234.00	4	4514.19	81	5558.75	65
3909.89	7	4234.52	4	4524.22	74	5561.67	65
3910.79	39	4259.31	4	4525.17	81	5584.49	34
3912.89	39	4268.64	70	4529.59	74	5592.41	34
3920.49	39	4271.55	70	4537.66	66	5604.94	34
3921.91	39	4276.96	70	4540.01	75	5624.61	34
3922.43	39	4284.06	70	4545.39	80	5624.90	34
3925.24	8	4291.82	89	4560.71	80	5626.01	34
3930.02	55	4296.11	89	4571.78	80	5627.63	34
3934.01	39	4297.68	89	4577.17	2	5646.11	34
3936.28	39	4298.03	89	4578.73	80	5657.45	34
3942.01	55	4306.21	3	4579.20	80	5668.37	34
3943.66	39	4307.18	3	4580.39	2	5670.83	33
3992.80	71	4309.80	3	4586.36	2	5698.51	32
3998.73	71	4330.02	3	4594.10	2	5703.56	32
4029.8	5	4332.82	3	4606.15	2	5706.97	32
4032.9	6	4341.01	3	4619.77	2	5725.63	95
4048.6	6	4342.83	78	4624.40	36	5727.02	32
4050.96	90	4350.8	22	4626.48	36	5727.66	32
4051.35	90	4352.87	3	4635.18	2	5731.26	33
4052.4	6	4354.98	78	4640.06	36	5737.04	32
4067.9	6	4355.94	3	4640.74	36	5743.44	32
4070.7	6	4363.53	22	4645.97	2	5748.86	72
4090.58	38	4368.04	3	4646.40	36	5761.41	32
4092.41	47	4379.24	21	4669.27	2	5772.40	72
4092.69	26	4384.2	22	4670.48	36	5776.67	33
4093.50	47	4384.72	21	4706.18	73	5782.60	32
4095.49	38	4387.21	37	4706.57	88	5850.29	72
4099.80	26	4389.97	21	4710.57	88	5980.75	45
4102.16	38	4392.07	22	4746.64	84	5984.60	45
4104.78	83	4393.84	37	4748.53	84	6002.27	45
4105.17	26	4395.23	21	4750.99	84	6002.60	31
4109.79	26	4400.58	21	4751.57	73	6008.65	45
4111.79	26	4405.01	22	4753.96	84	6017.90	45
4113.52	47	4406.15	37	4757.50	84	6039.69	31
4115.19	26	4406.64	21	4766.64	84	6058.11	31
4116.47	26	4407.64	21	4776.36	84	6081.42	31
4116.70	26	4408.20	21	4784.48	1	6087.49	30
4118.64	38	4412.0	22	4786.52	84	6090.18	31
4119.46	38	4416.47	21	4796.93	84	6090.54	30
4120.54	38	4419.94	20	4799.79	1	6097.42	30
4123.57	26	4421.57	21	4807.54	84	6106.97	53
4124.07	47	4423.21	37	4827.46	1	6111.62	31
4128.07	26	4426.01	21	4831.64	1	6119.51	31
4131.1	25	4428.52	20	4832.43	1	6128.30	30
4132.02	26	4429.80	21	4851.48	1	6135.07	53
4134.49	26	4436.14	20	4864.74	1	6135.36	31
4136.39	25	4437.84	20	4864.83	46	6150.13	19
4141.8	25	4441.68	20	4875.46	1	6170.34	19
4142.66	25	4444.21	20	4880.56	46	6189.35	19
4148.86	25	4449.57	54	4881.55	1	6199.20	18
4153.33	25	4452.01	69	4886.82	46	6213.87	19
4159.69	24	4457.48	20	4904.29	46	6216.37	18
4176.79	4	4457.76	76	4904.35	87	6224.51	19
4179.42	24	4459.76	20	4925.66	46	6230.74	18
4182.59	23	4460.29	20	4932.03	46	6233.19	19
4189.84	23	4462.36	69	5193.00	91	6240.14	19
4191.56	23	4468.01	69	5195.39	91	6242.80	18
4198.61	23	4468.76	77	5234.09	94	6243.11	18

List of tabulated lines—Continued

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
6251.83	18	6285.19	18	6357.30	67	6605.98	44
6256.91	18	6292.86	18	6452.35	44	6624.86	44
6258.60	18	6296.52	18	6504.16	44	6753.00	29
6261.24	19	6326.85	67	6531.44	44	6766.49	29
6266.32	19	6339.09	67	6543.51	44	6784.98	29
6274.67	18	6349.48	67	6565.88	44	6812.40	29

For the bulk of the data, we selected the absorption measurements of King [1] and the anomalous dispersion (hook) measurements of Ostrovskii and Penkin [2]. Since these data are on two different relative scales, some absolute f-values were required for the normalization to an absolute scale. A few accurate absolute f-values were measured recently by Mie and Richter [3], who employed the atomic beam absorption technique. Fortunately, their data overlapped with several lines of King [1] as well as Ostrovskii and Penkin [2], so that we were able to convert the two separate relative scales to a common absolute scale. In addition to normalizing the relative data, we have averaged the normalized f-values whenever they provided data for the same lines. We treated both normalized data sources equally, since the techniques are of approximately the same level of refinement and the agreement between them was very good, being almost entirely within ±50 percent.

King has provided data for a few intercombination lines. As a general rule, we have omitted these, as well as other lines having log gf-values less than −3.00, since errors are estimated to be greater than 50 percent for these weak lines. We have also omitted King's data for blended lines, which he indicated as such in his tables.

A source for atomic lifetimes on this spectrum is the beam-foil experiment of Roberts et al. [4]. As a consistency check, we compared the inverse sums of our compiled transition probabilities for all possible downward transitions to these beam-foil lifetimes. As the following table shows, the agreement is quite good and provides additional support for the adopted scale.

Lifetimes (in ns) of various excited states of V I

Upper atomic level	τ_k	$(\sum_i A_{ki})^{-1}$
	Roberts et al. [4]	This compilation
$y\ ^6F^\circ_{7/2}$	11.9	9.0
$y\ ^6D^\circ_{9/2}$	9.3	8.8
$z\ ^4I^\circ_{11/2}$	15.0	<18.9[a]
$z\ ^4I^\circ_{13/2}$	13.7	<15.2[a]
$z\ ^4I^\circ_{15/2}$	11.6	12.5
$x\ ^4H^\circ_{13/2}$	9.5	< 8.7[a]
$w\ ^4H^\circ_{13/2}$	8.7	<12.8[a]

[a] Due to lack of appropriate f-value data, there are more allowed downward transitions from the upper level than have been included in the sum $\sum_i A_{ki}$. These additional contributions could be significant and would thereby decrease the values of $(\sum_i A_{ki})^{-1}$ as tabulated above.

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V I: Allowed transitions

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8\ s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$a\ ^4F$–$z\ ^4D^\circ$ (3)	*4867.0*	*319.3*	*20860*	28	20	0.097	0.025	11	−0.16	D	1*n*,2*n*
		4881.55	553.0	21033	10	8	0.080	0.023	3.7	−0.64	D	1*n*,2*n*
		4875.46	323.4	20828	8	6	0.079	0.021	2.7	−0.77	D	1*n*,2*n*
		4864.74	137.4	20688	6	4	0.080	0.019	1.8	−0.94	D	1*n*,2*n*
		4851.48	0.0	20606	4	2	0.10	0.018	1.1	−1.14	D	1*n*,2*n*
		4827.46	323.4	21033	8	8	0.012	0.0043	0.55	−1.46	D	1*n*,2*n*
		4831.64	137.4	20828	6	6	0.018	0.0062	0.59	−1.43	D	1*n*,2*n*
		4832.43	0.0	20688	4	4	0.023	0.0080	0.51	−1.49	D	1*n*,2*n*
		4784.48	137.4	21033	6	8	6.8(−4)[a]	3.1(−4)	0.029	−2.73	E	1*n*
		4799.79	0.0	20828	4	6	8.5(−4)	4.4(−4)	0.028	−2.75	E	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
2.	$a\,^4F$–$z\,^4G°$ (4)	*4589.0*	*319.3*	*22104*	28	36	0.055	0.022	9.4	—0.21	D	1*n*,2*n*
		4594.10	553.0	22314	10	12	0.061	0.023	3.5	—0.64	D	1*n*,2*n*
		4586.36	323.4	22121	8	10	0.051	0.020	2.4	—0.80	D	1*n*,2*n*
		4580.39	137.4	21964	6	8	0.043	0.018	1.6	—0.97	D	1*n*,2*n*
		4577.17	0.0	21841	4	6	0.045	0.021	1.3	—1.08	D	1*n*,2*n*
		4635.18	553.0	22121	10	10	0.0040	0.0013	0.20	—1.89	D—	1*n*,2*n*
		4619.77	323.4	21964	8	8	0.0053	0.0017	0.21	—1.87	D—	1*n*,2*n*
		4606.15	137.4	21841	6	6	0.0063	0.0020	0.18	—1.92	D—	1*n*,2*n*
		4669.27	553.0	21964	10	8	1.2(—4)	3.1(—5)	0.0048	—3.51	E	1*n*
		4645.97	323.4	21841	8	6	2.3(—4)	5.5(—5)	0.0067	—3.36	E	1*n*
3.	$a\,^4F$–$z\,^4F°$ (5)											
		4352.87	553.0	23520	10	10	0.056	0.016	2.3	—0.80	D	1*n*,2*n*
		4341.01	323.4	23353	8	8	0.050	0.014	1.6	—0.95	D	1*n*,2*n*
		4332.82	137.4	23211	6	6	0.043	0.012	1.0	—1.14	D	1*n*,2*n*
		4330.02	0.0	23088	4	4	0.046	0.013	0.74	—1.28	D	1*n*,2*n*
		4368.04	323.4	23211	8	6	0.010	0.0022	0.25	—1.75	D—	1*n*,2*n*
		4355.94	137.4	23088	6	4	0.0090	0.0017	0.15	—1.99	D—	1*n*
		4309.80	323.4	23520	8	10	0.0078	0.0027	0.31	—1.67	D—	1*n*,2*n*
		4306.21	137.4	23353	6	8	0.011	0.0042	0.36	—1.60	D—	1*n*,2*n*
		4307.18	0.0	23211	4	6	0.011	0.0046	0.26	—1.74	D—	1*n*,2*n*
4.	$a\,^4F$–$z\,^2D°$ (6)											
		4234.00	323.4	23935	8	6	0.0042	8.5(—4)	0.095	—2.17	D—	1*n*
		4259.31	137.4	23609	6	4	0.0055	9.9(—4)	0.083	—2.23	D—	1*n*
		4200.89	137.4	23935	6	6	6.8(—4)	1.8(—4)	0.015	—2.97	E	1*n*
		4234.52	0.0	23609	4	4	0.0060	0.0016	0.089	—2.19	D—	1*n*
		4176.79	0.0	23935	4	6	4.1(—4)	1.6(—4)	0.0088	—3.19	E	1*n*
5.	$a\,^4F$–$z\,^4P°$											
		[4029.8]	323.4	25131	8	6	8.2(—4)	1.5(—4)	0.016	—2.92	E	1*n*
6.	a ^4F–$y\,^6F°$											
		[4070.7]	553.0	25112	10	10	8.5(—4)	2.1(—4)	0.028	—2.68	E	1*n*
		[4052.4]	323.4	24993	8	8	4.1(—4)	1.0(—4)	0.011	—3.10	E	1*n*
		[4067.9]	323.4	24899	8	6	0.0017	3.2(—4)	0.034	—2.59	E	1*n*
		[4048.6]	137.4	24830	6	4	0.0023	3.7(—4)	0.030	—2.65	E	1*n*
		[4032.9]	0.0	24789	4	2	0.0025	3.1(—4)	0.016	—2.91	E	1*n*
7.	$a\,^4F$–$y\,^4F°$ (7)	*3879.7*	*319.3*	*26087*	28	28	0.27	0.062	22	0.24	D	1*n*,2*n*,3
		3902.25	553.0	26172	10	10	0.217	0.0495	6.4	—0.305	C	3
		3875.08	323.4	26122	8	8	0.17	0.038	3.9	—0.52	D	1*n*
		3864.86	137.4	26004	6	6	0.208	0.0466	3.56	—0.55	C	3
		3855.37	0.0	25931	4	4	0.28	0.062	3.1	—0.61	D	1*n*
		3909.89	553.0	26122	10	8	0.037	0.0068	0.88	—1.17	D	2*n*
		3892.86	323.4	26004	8	6	0.065	0.011	1.1	—1.06	D	1*n*,2*n*
		3875.90	137.4	25931	6	4	0.066	0.0099	0.76	—1.23	D	1*n*
		3867.60	323.4	26172	8	10	0.021	0.0058	0.59	—1.33	D	1*n*,2*n*
		3847.32	137.4	26122	6	8	0.037	0.011	0.84	—1.18	D	1*n*
		3844.44	0.0	26004	4	6	0.045	0.015	0.76	—1.22	D	1*n*,2*n*
8.	$a\,^4F$–$z\,^2G°$ (8)											
		3876.09	553.0	26345	10	10	0.071	0.016	2.0	—0.80	D	1*n*
		3890.18	323.4	26022	8	8	0.057	0.013	1.3	—0.98	D	2*n*
		3925.24	553.0	26022	10	8	0.0076	0.0014	0.18	—1.85	D—	1*n*
		3841.89	323.4	26345	8	10	0.0043	0.0012	0.12	—2.02	D—	1*n*
		3862.22	137.4	26022	6	8	0.0087	0.0026	0.20	—1.81	D—	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
9.	$a\,^4F$–$y\,^4D°$ (9)											
		3855.84	553.0	26480	10	8	0.451	0.080	10.2	—0.095	C	3
		3840.75	323.4	26353	8	6	0.46	0.076	7.7	—0.22	D	1*n*
		3828.56	137.4	26249	6	4	0.431	0.063	4.78	—0.422	C	3
		3818.24	0.0	26183	4	2	0.56	0.061	3.07	—0.61	C	3
		3822.01	323.4	26480	8	8	0.064	0.014	1.4	—0.95	D	1*n*
		3813.49	137.4	26353	6	6	0.092	0.020	1.5	—0.92	D	1*n*
		3808.52	0.0	26249	4	4	0.11	0.024	1.2	—1.02	D	1*n*
10.	$a\,^4F$–$y\,^6D°$ (10)											
		3817.84	553.0	26738	10	10	0.0082	0.0018	0.23	—1.74	D—	1*n*
		3803.90	323.4	26605	8	8	0.0033	7.2(—4)	0.072	—2.24	D—	1*n*
		3791.33	137.4	26506	6	6	0.0012	2.6(—4)	0.019	—2.81	E	1*n*
		[3784.7]	323.4	26738	8	10	9.7(—4)	2.6(—4)	0.026	—2.68	E	1*n*
		[3777.1]	137.4	26605	6	8	9.1(—4)	2.6(—4)	0.019	—2.81	E	1*n*
11.	$a\,^4F$–$z\,^2F°$ (11)											
		3713.96	553.0	27471	10	8	0.0024	4.0(—4)	0.049	—2.40	E	1*n*
		3721.36	323.4	27188	8	6	0.0011	1.7(—4)	0.017	—2.87	E	1*n*
12.	$a\,^4F$–$y\,^4G°$ (12)											
		3298.14	553.0	30864	10	12	0.017	0.0034	0.37	—1.47	D	1*n*
		3283.31	323.4	30772	8	10	0.032	0.0065	0.56	—1.28	D	1*n*
		3271.64	137.4	30694	6	8	0.042	0.0090	0.58	—1.27	D	1*n*
		3263.24	0.0	30636	4	6	0.063	0.015	0.64	—1.22	D	1*n*
		3308.25	553.0	30772	10	10	0.0016	2.6(—4)	0.028	—2.59	D—	1*n*
		3291.68	323.4	30694	8	8	0.0035	5.7(—4)	0.049	—2.34	D—	1*n*
		3277.94	137.4	30636	6	6	0.0060	9.6(—4)	0.062	—2.24	D—	1*n*
13.	$a\,^4F$–$x\,^4F°$ (13)											
		3249.57	553.0	31318	10	10	0.0061	9.6(—4)	0.10	—2.02	D—	1*n*
		3230.65	323.4	31268	8	8	0.0054	8.5(—4)	0.072	—2.17	D—	1*n*
		3215.38	137.4	31229	6	6	0.0054	8.4(—4)	0.053	—2.30	D—	1*n*
		3204.20	0.0	31200	4	4	0.0057	8.7(—4)	0.037	—2.46	D—	1*n*
		3254.77	553.0	31268	10	8	0.0013	1.7(—4)	0.018	—2.77	E	1*n*
14.	$a\,^4F$–$x\,^4G°$ (14)	*3185.8*	*319.3*	*31699*	28	36	1.6	0.31	92	0.94	D	1*n*,2*n*
		3185.40	553.0	31937	10	12	1.4	0.26	27	0.41	D	1*n*
		3183.96	323.4	31722	8	10	1.4	0.26	22	0.32	D	1*n*
		3183.41	137.4	31541	6	8	1.3	0.26	16	0.19	D	1*n*
		3183.98	0.0	31398	4	6	1.8	0.41	17	0.21	D	1*n*
		3207.41	553.0	31722	10	10	0.18	0.027	2.9	—0.57	D	1*n*,2*n*
		3202.38	323.4	31541	8	8	0.29	0.044	3.7	—0.45	D	1*n*,2*n*
		3198.01	137.4	31398	6	6	0.31	0.047	3.0	—0.55	D	1*n*,2*n*
		3226.11	553.0	31541	10	8	0.0047	5.9(—4)	0.063	—2.23	D—	1*n*
		3217.12	323.4	31398	8	6	0.0086	0.0010	0.085	—2.10	D—	1*n*
15.	$a\,^4F$–$x\,^4D°$ (15)											
		3091.44	553.0	32891	10	8	0.012	0.0014	0.14	—1.85	D—	1*n*
		3091.55	323.4	32660	8	6	0.0075	8.1(—4)	0.066	—2.19	D—	1*n*
		3093.24	137.4	32456	6	4	0.0033	3.2(—4)	0.020	—2.72	D—	1*n*
		3069.65	323.4	32891	8	8	0.071	0.010	0.81	—1.10	D—	1*n*
		3080.15	0.0	32456	4	4	0.0053	7.6(—4)	0.031	—2.52	D—	1*n*
		3052.19	137.4	32891	6	8	0.021	0.0039	0.24	—1.63	D—	1*n*
		3060.93	0.0	32660	4	6	0.0035	7.3(—4)	0.029	—2.53	D—	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
16.	$a\,^4F$–$z\,^2P°$ (16)											
		3063.73	137.4	32768	6	4	0.033	0.0031	0.19	—1.73	D—	1*n*
		3050.89	0.0	32768	4	4	0.16	0.023	0.92	—1.04	D	1*n*
17.	$a\,^4F$–$w\,^4F°$ (17)											
		3066.38	553.0	33155	10	10	1.6	0.22	22	0.34	D	1*n*,2*n*
		3060.46	323.4	32989	8	8	1.1	0.15	12	0.08	D	1*n*,2*n*
		3056.33	137.4	32847	6	6	1.0	0.14	8.5	—0.08	D	1*n*,2*n*
		3053.65	0.0	32738	4	4	1.1	0.15	6.0	—0.22	D	1*n*,2*n*
		3082.11	553.0	32989	10	8	0.18	0.020	2.0	—0.70	D	1*n*
		3066.51	137.4	32738	6	4	0.28	0.026	1.6	—0.81	D	1*n*
		3044.94	323.4	33155	8	10	0.098	0.017	1.4	—0.87	D	1*n*,2*n*
		3043.12	137.4	32989	6	8	0.17	0.032	1.9	—0.72	D	1*n*,2*n*
		3043.56	0.0	32847	4	6	0.16	0.034	1.4	—0.87	D	2*n*
18.	$a\,^6D$–$z\,^6D°$ (19)											
		6243.11	2425	18438	10	10	0.015	0.0086	1.8	—1.07	D	1*n*
		6251.83	2311	18302	8	8	0.0065	0.0038	0.63	—1.52	D	1*n*
		6256.91	2220	18198	6	6	0.0016	9.3(—4)	0.11	—2.25	D—	1*n*
		6258.60	2112	18086	2	2	0.0039	0.0023	0.095	—2.34	D—	1*n*
		6296.52	2425	18302	10	8	0.0029	0.0014	0.29	—1.85	D—	1*n*
		6292.86	2311	18198	8	6	0.0054	0.0024	0.40	—1.72	D—	1*n*
		6285.19	2220	18126	6	4	0.0076	0.0030	0.37	—1.74	D—	1*n*
		6274.67	2153	18086	4	2	0.011	0.0031	0.26	—1.91	D—	1*n*
		6199.20	2311	18438	8	10	0.0031	0.0022	0.36	—1.75	D—	1*n*
		6216.37	2220	18302	6	8	0.0058	0.0045	0.55	—1.57	D—	1*n*
		6230.74	2153	18198	4	6	0.0074	0.0065	0.53	—1.59	D—	1*n*
		6242.80	2112	18126	2	4	0.0086	0.010	0.41	—1.70	D—	1*n*
19.	$a\,^6D$–$z\,^6F°$ (20)											
		6150.13	2425	18680	10	12	0.0021	0.0014	0.28	—1.85	D—	1*n*
		6170.34	2311	18513	8	10	8.0(—4)	5.7(—4)	0.093	—2.34	D—	1*n*
		6189.35	2220	18372	6	8	2.1(—4)	1.6(—4)	0.020	—3.02	E	1*n*
		6213.87	2425	18513	10	10	0.0014	7.9(—4)	0.16	—2.10	D—	1*n*
		6224.51	2311	18372	8	8	0.0019	0.0011	0.18	—2.06	D—	1*n*
		6233.19	2220	18259	6	6	0.0022	0.0013	0.16	—2.11	D—	1*n*
		6240.14	2153	18174	4	4	9.8(—4)	5.7(—4)	0.047	—2.64	E	1*n*
		6266.32	2220	18174	6	4	0.0019	7.6(—4)	0.094	—2.34	E	1*n*
		6261.24	2153	18120	4	2	0.0019	5.7(—4)	0.047	—2.64	E	1*n*
20.	$a\,^6D$–$z\,^6P°$ (21)	*4450.3*	*2296*	*24760*	30	18	0.33	0.059	26	0.25	D	1*n*,2*n*
		4460.29	2425	24839	10	8	0.26	0.062	9.1	—0.21	D	1*n*
		4459.76	2311	24728	8	6	0.15	0.034	4.0	—0.57	D	1*n*
		4457.48	2220	24648	6	4	0.091	0.018	1.6	—0.97	D	1*n*
		4437.84	2311	24839	8	8	0.078	0.023	2.7	—0.74	D	1*n*,2*n*
		4441.68	2220	24728	6	6	0.11	0.033	2.9	—0.70	D	1*n*,2*n*
		4444.21	2153	24648	4	4	0.13	0.039	2.3	—0.81	D	1*n*,2*n*
		4419.94	2220	24839	6	8	0.014	0.0055	0.48	—1.48	D	1*n*,2*n*
		4428.52	2153	24728	4	6	0.039	0.017	0.99	—1.17	D	1*n*,2*n*
		4436.14	2112	24648	2	4	0.093	0.055	1.6	—0.96	D	1*n*,2*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
21.	$a\,^6D$–$y\,^6F°$ (22)											
		4379.24	2425	25254	10	12	1.2	0.40	58	0.60	D	1*n*,2*n*
		4384.72	2311	25112	8	10	0.97	0.35	40	0.45	D	1*n*
		4389.97	2220	24993	6	8	0.70	0.27	23	0.21	D	1*n*,2*n*
		4395.23	2153	24899	4	6	0.48	0.21	12	—0.08	D	1*n*,2*n*
		4400.58	2112	24830	2	4	0.33	0.19	5.5	—0.42	D	1*n*,2*n*
		4406.64	2425	25112	10	10	0.19	0.056	8.1	—0.25	D	1*n*
		4407.64	2311	24993	8	8	0.38	0.11	13	—0.06	D	1*n*
		4408.20	2220	24899	6	6	0.51	0.15	13	—0.05	D	1*n*
		4429.80	2425	24993	10	8	0.025	0.0058	0.85	—1.24	D	1*n*,2*n*
		4426.01	2311	24899	8	6	0.064	0.014	1.6	—0.95	D	1*n*,2*n*
		4421.57	2220	24830	6	4	0.12	0.023	2.0	—0.86	D	1*n*,2*n*
		4416.47	2153	24789	4	2	0.21	0.031	1.8	—0.91	D	1*n*,2*n*
22.	$a\,^6D$–$z\,^4P°$ (23)											
		4405.01	2220	24915	6	4	0.0030	5.8(—4)	0.050	—2.46	D—	1*n*
		4363.53	2220	25131	6	6	0.0046	0.0013	0.11	—2.11	D—	1*n*
		4392.07	2153	24915	4	4	0.0083	0.0024	0.14	—2.02	D—	1*n*
		[4412.0]	2112	24771	2	2	0.034	0.010	0.29	—1.70	D—	1*n*
		[4350.8]	2153	25131	4	6	0.0019	8.1(—4)	0.046	—2.49	D—	1*n*
		[4384.2]	2112	24915	2	4	0.0029	0.0017	0.049	—2.47	D—	1*n*
23.	$a\,^6D$–$y\,^4F°$ (24)											
		4209.86	2425	26172	10	10	0.017	0.0044	0.61	—1.36	D	1*n*
		4198.61	2311	26122	8	8	0.0031	8.1(—4)	0.090	—2.19	D—	1*n*
		4218.71	2425	26122	10	8	0.0030	6.5(—4)	0.090	—2.19	D—	1*n*
		4219.51	2311	26004	8	6	0.0015	3.1(—4)	0.034	—2.61	E	1*n*
		4189.84	2311	26172	8	10	0.011	0.0036	0.40	—1.54	D—	1*n*
		4182.59	2220	26122	6	8	0.0094	0.0033	0.27	—1.70	D—	1*n*
		4191.56	2153	26004	4	6	0.0056	0.0022	0.12	—2.06	D—	1*n*
24.	$a\,^6D$–$z\,^2G°$ (25)											
		4179.42	2425	26345	10	10	0.015	0.0040	0.55	—1.40	D—	1*n*
		4159.69	2311	26345	8	10	0.0065	0.0021	0.23	—1.77	D—	1*n*
		[4200.1]	2220	26022	6	8	0.0025	8.7(—4)	0.072	—2.28	D—	1*n*
25.	$a\,^6D$–$y\,^4D°$ (26)											
		4136.39	2311	26480	8	8	0.0025	6.3(—4)	0.069	—2.30	E	1*n*
		4142.66	2220	26353	6	6	0.0018	4.7(—4)	0.038	—2.55	E	1*n*
		4148.86	2153	26249	4	4	0.0029	7.5(—4)	0.041	—2.52	E	1*n*
		4153.33	2112	26183	2	2	0.0054	0.0014	0.038	—2.55	E	1*n*
		[4131.1]	2153	26353	4	6	0.0013	4.8(—4)	0.026	—2.72	E	1*n*
		[4141.8]	2112	26249	2	4	0.0012	6.3(—4)	0.017	—2.90	E	1*n*
26.	$a\,^6D$–$y\,^6D°$ (27)											
		4111.79	2425	26738	10	10	0.91	0.23	31	0.36	D	1*n*,2*n*
		4115.19	2311	26605	8	8	0.59	0.15	16	0.08	D	2*n*
		4116.47	2220	26506	6	6	0.24	0.062	5.0	—0.43	D	1*n*,2*n*
		4116.70	2153	26438	4	4	0.015	0.0037	0.20	—1.83	E	1*n*
		4134.49	2425	26605	10	8	0.27	0.056	7.6	—0.25	D	1*n*,2*n*
		4132.02	2311	26506	8	6	0.52	0.10	11	—0.10	D	1*n*,2*n*
		4128.07	2220	26438	6	4	0.70	0.12	9.8	—0.14	D	1*n*,2*n*
		4123.57	2153	26397	4	2	0.94	0.12	6.5	—0.32	D	1*n*,2*n*
		4092.69	2311	26738	8	10	0.21	0.066	7.1	—0.28	D	1*n*,2*n*
		4099.80	2220	26605	6	8	0.39	0.13	11	—0.11	D	1*n*,2*n*
		4105.17	2153	26506	4	6	0.42	0.16	8.6	—0.19	D	1*n*
		4109.79	2112	26438	2	4	0.47	0.24	6.5	—0.32	D	1*n*,2*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
27.	$a\,^6D$–$x\,^6D^\circ$ (28)											
		3794.96	2425	28768	10	10	0.21	0.046	5.7	—0.34	D	2*n*
		3803.47	2311	28596	8	8	0.12	0.026	2.6	—0.68	D	1*n*,2*n*
		3809.60	2220	28462	6	6	0.041	0.0090	0.68	—1.27	D	1*n*
		3815.51	2112	28314	2	2	0.055	0.012	0.30	—1.62	D	1*n*
		3819.96	2425	28596	10	8	0.046	0.0080	1.0	—1.10	D	1*n*
		3822.89	2311	28462	8	6	0.091	0.015	1.5	—0.92	D	1*n*
		3823.21	2220	28369	6	4	0.12	0.018	1.4	—0.97	D	1*n*
		3821.49	2153	28314	4	2	0.18	0.020	1.0	—1.10	D	1*n*
		3778.68	2311	28768	8	10	0.041	0.011	1.1	—1.06	D	1*n*,2*n*
		3790.32	2220	28596	6	8	0.073	0.021	1.6	—0.90	D	1*n*,2*n*
		3799.91	2153	28462	4	6	0.10	0.033	1.7	—0.88	D	1*n*,2*n*
		3807.51	2112	28369	2	4	0.090	0.039	0.98	—1.11	D	1*n*
28.	$a\,^6D$–$y\,^6P^\circ$ (29)											
		3703.58	2425	29418	10	8	0.79	0.13	16	0.11	D	1*n*
		3704.70	2311	29296	8	6	0.58	0.089	8.7	—0.15	D	1*n*
		3705.04	2220	29203	6	4	0.31	0.043	3.1	—0.59	D	1*n*
		3688.07	2311	29418	8	8	0.28	0.058	5.6	—0.33	D	1*n*,2*n*
		3692.23	2220	29296	6	6	0.46	0.091	6.6	—0.26	D	1*n*,2*n*
		3695.87	2153	29203	4	4	0.54	0.11	5.4	—0.36	D	1*n*,2*n*
		3683.13	2153	29296	4	6	0.16	0.048	2.3	—0.72	D	1*n*,2*n*
		3690.28	2112	29203	2	4	0.37	0.15	3.6	—0.52	D	1*n*,2*n*
29.	$a\,^4D$–$z\,^4F^\circ$ (31)											
		6753.00	8716	23520	8	10	0.0028	0.0024	0.43	—1.72	D—	1*n*
		6766.49	8579	23353	6	8	0.0022	0.0020	0.27	—1.92	D—	1*n*
		6784.98	8476	23211	4	6	0.0015	0.0016	0.14	—2.19	D—	1*n*
		6812.40	8413	23088	2	4	0.0014	0.0020	0.090	—2.40	D—	1*n*
30.	$a\,^4D$–$y\,^6F^\circ$ (33)											
		6097.42	8716	25112	8	10	3.3(—4)	2.3(—4)	0.037	—2,74	E	1*n*
		6090.54	8579	24993	6	8	5.0(—4)	3.7(—4)	0.045	—2.65	E	1*n*
		6087.49	8476	24899	4	6	4.1(—4)	3.4(—4)	0.027	—2.87	E	1*n*
		6128.30	8476	24789	4	2	0.0039	0.0011	0.089	—2.36	E	1*n*
31.	$a\,^4D$–$z\,^4P^\circ$ (34)	*6095.1*	*8597*	*24999*	20	12	0.17	0.057	23	0.06	D	1*n*
		6090.18	8716	25131	8	6	0.13	0.055	8.8	—0.36	D	1*n*
		6119.51	8579	24915	6	4	0.11	0.040	4.8	—0.62	D	1*n*
		6135.36	8476	24771	4	2	0.078	0.022	1.8	—1.06	D	1*n*
		6039.69	8579	25131	6	6	0.035	0.019	2.3	—0.94	D	1*n*
		6081.42	8476	24915	4	4	0.056	0.031	2.5	—0.91	D	1*n*
		6111.62	8413	24771	2	2	0.089	0.050	2.0	—1.00	D	1*n*
		6002.60	8476	25131	4	6	0.0039	0.0032	0.25	—1.89	D—	1*n*
		6058.11	8413	24915	2	4	0.010	0.011	0.44	—1.66	D—	1*n*
32.	$a\,^4D$–$y\,^4F^\circ$ (35)	*5716.0*	*8597*	*26087*	20	28	0.24	0.17	63	0.52	D	1*n*
		5727.02	8716	26172	8	10	0.18	0.11	17	—0.06	D	1*n*
		5698.51	8579	26122	6	8	0.28	0.18	20	0.03	D	1*n*
		5703.56	8476	26004	4	6	0.19	0.14	11	—0.25	D	1*n*
		5706.97	8413	25931	2	4	0.19	0.19	7.1	—0.42	D	1*n*
		5743.44	8716	26122	8	8	0.024	0.012	1.8	—1.02	D	1*n*
		5737.04	8579	26004	6	6	0.055	0.027	3.1	—0.79	D	1*n*
		5727.66	8476	25931	4	4	0.063	0.031	2.3	—0.91	D	1*n*
		5782.60	8716	26004	8	6	0.0021	7.9(—4)	0.12	—2.20	E	1*n*
		5761.41	8579	25931	6	4	0.0042	0.0014	0.16	—2.08	E	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
33.	$a\,^4D$–$z\,^2G°$ (36)											
		5670.83	8716	26345	8	10	0.068	0.041	6.1	—0.48	D	1*n*
		5731.26	8579	26022	6	8	0.038	0.025	2.8	—0.82	D	1*n*
		5776.67	8716	26022	8	8	0.0064	0.0032	0.49	—1.59	D—	1*n*
34.	$a\,^4D$–$y\,^4D°$ (37)	*5626.2*	*8597*	*26366*	20	20	0.11	0.054	20	0.03	D	1*n*
		5627.63	8716	26480	8	8	0.11	0.052	7.7	—0.38	D	1*n*
		5624.61	8579	26353	6	6	0.065	0.031	3.4	—0.73	D	1*n*
		5624.90	8476	26249	4	4	0.042	0.020	1.5	—1.10	D	1*n*
		5626.01	8413	26183	2	2	0.048	0.023	0.85	—1.34	D	1*n*
		5668.37	8716	26353	8	6	0.024	0.0085	1.3	—1.17	D	1*n*
		5657.45	8579	26249	6	4	0.047	0.015	1.7	—1.05	D	1*n*
		5646.11	8476	26183	4	2	0.059	0.014	1.0	—1.25	D	1*n*
		5584.49	8579	26480	6	8	0.0093	0.0058	0.64	—1.46	D	1*n*
		5592.41	8476	26353	4	6	0.012	0.0086	0.63	—1.46	D	1*n*
		5604.94	8413	26249	2	4	0.025	0.024	0.89	—1.32	D	1*n*
35.	$a\,^4D$–$y\,^6D°$ (38)											
		5547.08	8716	26738	8	10	0.0090	0.0052	0.76	—1.38	D	1*n*
		5545.93	8579	26605	6	8	0.0031	0.0019	0.21	—1.94	D—	1*n*
		5544.87	8476	26506	4	6	0.0012	8.3(—4)	0.061	—2.48	D—	1*n*
36.	$a\,^4D$–$y\,^4P°$ (39)											
		4670.48	8716	30121	8	6	0.12	0.030	3.7	—0.62	D	1*n*
		4646.40	8579	30095	6	4	0.088	0.019	1.7	—0.94	D	1*n*
		4640.06	8476	30022	4	2	0.068	0.011	0.67	—1.36	D	1*n*
		4640.74	8579	30121	6	6	0.016	0.0053	0.49	—1.50	D	1*n*
		4624.40	8476	30095	4	4	0.041	0.013	0.79	—1.28	D	1*n*
		4626.48	8413	30022	2	2	0.078	0.025	0.76	—1.30	D	1*n*
37.	$a\,^4D$–$x\,^4F°$ (40)											
		4423.21	8716	31318	8	10	0.035	0.013	1.5	—0.98	D	1*n*
		4406.15	8579	31268	6	8	0.039	0.015	1.3	—1.05	D	1*n*
		4393.84	8476	31229	4	6	0.018	0.0079	0.46	—1.50	D—	1*n*
		4387.21	8413	31200	2	4	0.016	0.0092	0.27	—1.74	D—	1*n*
38.	$a\,^4D$–$w\,^4F°$ (41)											
		4090.58	8716	33155	8	10	0.77	0.24	26	0.28	D	2*n*
		4095.49	8579	32989	6	8	0.54	0.18	15	0.03	D	1*n*,2*n*
		4102.16	8476	32847	4	6	0.50	0.19	10	—0.12	D	1*n*,2*n*
		4118.64	8716	32989	8	8	0.094	0.024	2.6	—0.72	D	1*n*
		4119.46	8579	32847	6	6	0.14	0.035	2.8	—0.68	D	1*n*
		4120.54	8476	32738	4	4	0.14	0.036	2.0	—0.84	D	1*n*
39.	$a\,^4D$–$w\,^4D°$ (42)											
		3934.01	8716	34128	8	8	0.56	0.13	13	0.02	D	1*n*
		3922.43	8579	34066	6	6	0.23	0.052	4.0	—0.51	D	1*n*
		3920.49	8476	33976	4	4	0.074	0.017	0.88	—1.17	D	1*n*
		3943.66	8716	34066	8	6	0.069	0.012	1.2	—1.02	D	1*n*
		3936.28	8579	33976	6	4	0.084	0.013	1.0	—1.11	D	1*n*
		3921.91	8476	33967	4	2	0.23	0.027	1.4	—0.97	D	1*n*
		3912.89	8579	34128	6	8	0.028	0.0087	0.67	—1.28	D	1*n*
		3910.79	8413	33976	2	4	0.087	0.040	1.0	—1.10	D	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
40.	$a\,^4D$–$v\,^4F^\circ$ (43)											
		3896.16	8716	34375	8	8	0.048	0.011	1.1	—1.06	D	1*n*
41.	$a\,^4D$–$v\,^4D^\circ$ (44)											
		3839.00	8579	34620	6	6	0.18	0.039	3.0	—0.63	D	1*n*
		3836.05	8476	34537	4	4	0.10	0.022	1.1	—1.06	D	1*n*
		3835.56	8413	34477	2	2	0.15	0.032	0.81	—1.19	D	1*n*
		3859.34	8716	34620	8	6	0.078	0.013	1.3	—0.98	D	1*n*
		3823.99	8476	34620	4	6	0.076	0.025	1.3	—1.00	D	1*n*
		3826.77	8413	34537	2	4	0.071	0.031	0.78	—1.21	D	1*n*
42.	$a\,^4D$–$x\,^4P^\circ$ (45)											
		3583.70	8716	36612	8	6	0.048	0.0070	0.66	—1.25	D	1*n*
43.	$a\,^4D$–$t\,^4D^\circ$ (46)											
		3400.40	8716	38116	8	8	0.22	0.038	3.4	—0.52	D	1*n*
		3402.57	8579	37960	6	6	0.16	0.028	1.9	—0.77	D	1*n*
		3405.16	8476	37835	4	4	0.12	0.021	0.94	—1.08	D	1*n*
		3406.84	8413	37757	2	2	0.16	0.028	0.63	—1.25	D	1*n*
		[3417.1]	8579	37835	6	4	0.12	0.014	0.94	—1.08	D	1*n*
44.	$a\,^4P$–$z\,^4P^\circ$ (48)	*6541.4*	*9716*	*24999*	12	12	0.020	0.013	3.3	—0.81	D	1*n*
		6531.44	9825	25131	6	6	0.012	0.0079	1.0	—1.32	D	1*n*
		6543.51	9637	24915	4	4	0.0044	0.0028	0.24	—1.95	D—	1*n*
		6565.88	9545	24771	2	2	0.0048	0.0031	0.13	—2.21	D—	1*n*
		6624.86	9825	24915	6	4	0.0082	0.0036	0.47	—1.67	D—	1*n*
		6605.98	9637	24771	4	2	0.014	0.0046	0.40	—1.74	D—	1*n*
		6452.35	9637	25131	4	6	0.0074	0.0069	0.59	—1.56	D—	1*n*
		6504.16	9545	24915	2	4	0.0087	0.011	0.47	—1.66	D—	1*n*
45.	$a\,^4P$–$y\,^4D^\circ$ (49)											
		6002.27	9825	26480	6	8	0.0024	0.0017	0.20	—1.99	D—	1*n*
		5980.75	9637	26353	4	6	0.0025	0.0020	0.16	—2.10	D—	1*n*
		5984.60	9545	26249	2	4	0.0019	0.0020	0.079	—2.40	D—	1*n*
		6017.90	9637	26249	4	4	0.0018	0.0010	0.079	—2.40	D—	1*n*
		6008.65	9545	26183	2	2	0.0028	0.0015	0.059	—2.52	D—	1*n*
46.	$a\,^4P$–$y\,^4P^\circ$ (50)											
		4925.66	9825	30121	6	6	0.063	0.023	2.2	—0.86	D	1*n*
		4886.82	9637	30095	4	4	0.015	0.0055	0.35	—1.66	D	1*n*
		4932.03	9825	30095	6	4	0.041	0.0099	0.96	—1.23	D	1*n*
		4904.29	9637	30022	4	2	0.067	0.012	0.77	—1.32	D	1*n*
		4880.56	9637	30121	4	6	0.028	0.015	0.96	—1.22	D	1*n*
		4864.83	9545	30095	2	4	0.035	0.025	0.80	—1.30	D	1*n*
47.	$a\,^4P$–$w\,^4D^\circ$ (52)											
		4113.52	9825	34128	6	8	0.15	0.050	4.1	—0.52	D	1*n*
		4092.41	9637	34066	4	6	0.12	0.047	2.5	—0.73	D	1*n*
		4124.07	9825	34066	6	6	0.055	0.014	1.1	—1.08	D	1*n*
		4093.50	9545	33967	2	2	0.17	0.043	1.2	—1.07	D	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
48.	$a\,^4P$–$t\,^4D°$ (53)											
		3533.68	9825	38116	6	8	0.44	0.11	7.7	—0.18	D	1*n*
		3529.74	9637	37960	4	6	0.36	0.10	4.6	—0.40	D	1*n*
		3533.76	9545	37835	2	4	0.32	0.12	2.8	—0.62	D	1*n*
		3553.27	9825	37960	6	6	0.19	0.036	2.5	—0.67	D	1*n*
		3545.34	9637	37835	4	4	0.32	0.061	2.8	—0.61	D	1*n*
		3543.50	9545	37757	2	2	0.58	0.11	2.6	—0.66	D	1*n*
		3555.14	9637	37757	4	2	0.22	0.021	0.98	—1.08	D	1*n*
49.	$a\,^4P$–$w\,^4P°$ (54)											
		3377.63	9825	39423	6	6	0.53	0.090	6.0	—0.27	D	1*n*
		3376.06	9637	39249	4	4	0.28	0.048	2.1	—0.72	D	1*n*
		3397.58	9825	39249	6	4	0.21	0.024	1.6	—0.84	D	1*n*
		3377.39	9637	39237	4	2	0.80	0.068	3.0	—0.57	D	1*n*
		3356.35	9637	39423	4	6	0.27	0.069	3.0	—0.56	D	1*n*
		3365.55	9545	39249	2	4	0.41	0.14	3.1	—0.55	D	1*n*
50.	$a\,^4P$–$x\,^4S°$ (55)	*3317.9*	*9716*	*39847*	12	4	1.1	0.061	8.0	—0.14	D	1*n*
		3329.86	9825	39847	6	4	0.69	0.076	5.0	—0.34	D	1*n*
		3309.18	9637	39847	4	4	0.28	0.046	2.0	—0.74	D	1*n*
		3299.09	9545	39847	2	4	0.13	0.044	0.96	—1.06	D	1*n*
51.	$a\,^4P$–$v\,^4P°$ (56)											
		3112.93	9637	41752	4	2	0.43	0.031	1.3	—0.91	D	1*n*
		3088.11	9637	42010	4	6	0.43	0.092	3.7	—0.43	D	1*n*
		3094.69	9545	41848	2	4	0.38	0.11	2.2	—0.66	D	1*n*
52.	$a\,^4P$–$r\,^4D°$ (57)											
		3083.54	9825	42246	6	8	0.22	0.041	2.5	—0.61	D	1*n*
		3075.93	9637	42138	4	6	0.24	0.052	2.1	—0.68	D	1*n*
		3080.33	9545	41999	2	4	0.23	0.066	1.3	—0.88	D	1*n*
		3093.79	9825	42138	6	6	0.36	0.052	3.2	—0.51	D	1*n*
		3089.13	9637	41999	4	4	0.45	0.065	2.6	—0.59	D	1*n*
		3087.07	9545	41928	2	2	0.77	0.11	2.2	—0.66	D	1*n*
53.	$a\,^2G$–$z\,^2F°$ (60)											
		6106.97	11101	27471	10	8	0.0034	0.0015	0.30	—1.82	D—	1*n*
		6135.07	10893	27188	8	6	0.0043	0.0018	0.29	—1.84	D—	1*n*
54.	$a\,^2G$–$y\,^2G°$ (62)											
		4501.97	11101	33307	10	10	0.049	0.015	2.2	—0.82	D	1*n*
		4449.57	10893	33360	8	8	0.033	0.0098	1.1	—1.11	D	1*n*
		4491.16	11101	33360	10	8	0.013	0.0031	0.46	—1.51	D—	1*n*
55.	$a\,^2G$–$x\,^2G°$ (63)											
		3930.02	11101	36539	10	10	0.29	0.066	8.5	—0.18	D	1*n*
		3942.01	11101	36461	10	8	0.091	0.017	2.2	—0.77	D	1*n*
56.	$a\,^2G$–$w\,^4G°$ (64)											
		3886.59	11101	36823	10	8	0.14	0.026	3.3	—0.59	D	1*n*
		3864.30	10893	36763	8	6	0.17	0.028	2.8	—0.65	D	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
57.	$a\,^2G$–$x\,^2F°$ (66)	*3867.7*	*11009*	*36857*	18	14	0.35	0.061	14	0.04	D	1*n*
		3871.08	11101	36926	10	8	0.24	0.044	5.6	—0.36	D	1*n*
		3863.87	10893	36766	8	6	0.27	0.046	4.7	—0.43	D	1*n*
		3840.14	10893	36926	8	8	0.18	0.040	4.0	—0.49	D	1*n*
58.	$a\,^2G$–$v\,^2G°$ (68)											
		3806.80	11101	37362	10	10	0.22	0.047	5.9	—0.33	D	1*n*
		3803.78	10893	37175	8	8	0.12	0.027	2.7	—0.67	D	1*n*
59.	$a\,^2G$–$w\,^2F°$ (69)											
		3790.47	11101	37475	10	8	0.20	0.034	4.2	—0.47	D	1*n*
		3779.65	10893	37343	8	6	0.10	0.016	1.6	—0.89	D	1*n*
60.	$a\,^2G$–$x\,^2H°$ (70)											
		3686.26	11101	38221	10	12	0.20	0.049	5.9	—0.31	D	1*n*
		3671.21	10893	38124	8	10	0.18	0.046	4.4	—0.43	D	1*n*
61.	$a\,^2G$–$t\,^2G°$ (71)											
		3284.36	11101	41539	10	10	0.24	0.039	4.2	—0.41	D	1*n*
		3273.03	10893	41437	8	8	0.24	0.038	3.3	—0.52	D	1*n*
62.	$a\,^2G$–$u\,^2F°$ (72)											
		3233.19	11101	42021	10	8	0.28	0.035	3.7	—0.46	D	1*n*
		3218.87	10893	41950	8	6	0.31	0.036	3.1	—0.54	D	1*n*
63.	$a\,^2G$–$u\,^2H°$ (73)											
		3212.43	11101	42221	10	12	1.2	0.22	23	0.34	D	1*n*
		3205.58	10893	42079	8	10	1.1	0.22	19	0.25	D	1*n*
64.	$a\,^2G$–$t\,^2F°$ (74)											
		3050.40	11101	43874	10	8	0.47	0.052	5.2	—0.28	D	1*n*
65.	$a\,^2P$–$z\,^2S°$ (77)	*5559.9*	*13805*	*31786*	6	2	0.14	0.021	2.3	—0.90	D	1*n*
		5558.75	13802	31786	4	2	0.082	0.019	1.4	—1.12	D	1*n*
		5561.67	13811	31786	2	2	0.054	0.025	0.92	—1.30	D	1*n*
66.	$a\,^2D$–$y\,^2P°$ (82)											
		4537.66	14549	36580	6	4	0.14	0.029	2.6	—0.76	D	1*n*
67.	$a\,^4H$–$y\,^4G°$ (84)											
		6326.85	15063	30864	14	12	0.019	0.0097	2.8	—0.87	D	1*n*
		6339.09	15001	30772	12	10	0.024	0.012	3.0	—0.84	D	1*n*
		6349.48	14949	30694	10	8	0.023	0.011	2.3	—0.96	D	1*n*
		6357.30	14910	30636	8	6	0.029	0.013	2.2	—0.98	D	1*n*
68.	$a\,^4H$–$y\,^2H°$ (86)											
		4496.86	14949	37181	10	10	0.069	0.021	3.1	—0.68	D	1*n*
		4490.82	14949	37211	10	12	0.10	0.037	5.5	—0.43	D	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
69.	$a\,^4H$–$z\,^4I°$ (87)											
		4452.01	15063	37518	14	16	0.80	0.27	55	0.58	D	1*n*
		4462.36	15001	37404	12	14	0.66	0.23	41	0.44	D	1*n*
		4469.71	14949	37316	10	12	0.53	0.19	28	0.28	D	1*n*
		4468.01	14910	37285	8	10	0.20	0.074	8.7	—0.23	D	1*n*
70.	$a\,^4H$–$x\,^4H°$ (88)											
		4268.64	15063	38483	14	14	1.0	0.28	55	0.59	D	1*n*
		4271.55	15001	38405	12	12	0.84	0.23	39	0.44	D	1*n*
		4276.96	14949	38324	10	10	0.84	0.23	32	0.36	D	1*n*
		4284.06	14910	38246	8	8	1.0	0.28	32	0.35	D	1*n*
71.	$a\,^4H$–$u\,^4G°$ (89)											
		3998.73	15063	40064	14	12	0.92	0.19	35	0.42	D	1*n*
		3992.80	15001	40039	12	10	1.1	0.21	33	0.40	D	1*n*
72.	$b\,^4P$–$x\,^4D°$ (92)											
		5772.40	15572	32891	6	8	0.060	0.040	4.6	—0.62	D	1*n*
		5748.86	15270	32660	4	6	0.042	0.031	2.3	—0.91	D	1*n*
		5850.29	15572	32660	6	6	0.035	0.018	2.1	—0.97	D	1*n*
73.	$b\,^4P$–$x\,^4P°$ (94)											
		4751.57	15572	36612	6	6	0.097	0.033	3.1	—0.70	D	1*n*
		4706.18	15572	36815	6	4	0.21	0.047	4.4	—0.55	D	1*n*
74.	$a\,^2H$–$v\,^2G°$ (99)											
		4524.22	15265	37362	12	10	0.26	0.066	12	—0.10	D	1*n*
		4529.59	15104	37175	10	8	0.21	0.052	7.7	—0.28	D	1*n*
75.	$a\,^2H$–$z\,^4I°$ (100)											
		4540.01	15265	37285	12	10	0.074	0.019	3.4	—0.64	D	1*n*
76.	$a\,^2H$–$z\,^2I°$ (101)											
		4457.76	15104	37530	10	12	0.24	0.086	13	—0.07	D	1*n*
77.	$a\,^2H$–$w\,^2F°$ (102)											
		4468.76	15104	37475	10	8	0.096	0.023	3.4	—0.64	D	1*n*
78.	$a\,^2H$–$x\,^2H°$ (103)											
		4354.98	15265	38221	12	12	0.11	0.032	5.5	—0.42	D	1*n*
		4342.83	15104	38124	10	10	0.13	0.036	5.1	—0.44	D	1*n*
79.	$a\,^2H$–$u\,^2H°$ (104)											
		3708.72	15265	42221	12	12	0.39	0.080	12	—0.02	D	1*n*
		3706.04	15104	42079	10	10	0.46	0.094	11	—0.03	D	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
80.	$b\ ^4F$–$v\ ^4G°$ (109)											
		4545.39	15771	37765	10	12	0.67	0.25	37	0.40	D	1*n*
		4560.71	15724	37644	8	10	0.62	0.24	29	0.28	D	1*n*
		4571.78	15689	37556	6	8	0.53	0.22	20	0.12	D	1*n*
		4578.73	15665	37499	4	6	0.59	0.28	17	0.05	D	1*n*
		4579.20	15724	37556	8	8	0.13	0.040	4.8	−0.49	D	1*n*
81.	$b\ ^4F$–$t\ ^4D°$ (110)											
		4474.05	15771	38116	10	8	0.41	0.098	14	−0.01	D	1*n*
		4496.06	15724	37960	8	6	0.35	0.079	9.4	−0.20	D	1*n*
		4514.19	15689	37835	6	4	0.29	0.060	5.4	−0.44	D	1*n*
		4525.17	15665	37757	4	2	0.36	0.055	3.3	−0.66	D	1*n*
82.	$b\ ^4F$–$u\ ^4F°$ (111)											
		4232.46	15771	39391	10	10	0.86	0.23	32	0.36	D	1*n*
		4232.95	15724	39342	8	8	0.67	0.18	20	0.16	D	1*n*
83.	$b\ ^4F$–$s\ ^4D°$ (112)											
		4104.78	15771	40126	10	8	1.9	0.38	51	0.58	D	1*n*
84.	$z\ ^6G°$–$e\ ^6F$ (113)											
		4807.54	17136	37931	14	12	0.51	0.15	33	0.32	D	1*n*
		4796.93	16917	37758	12	10	0.42	0.12	23	0.16	D	1*n*
		4786.52	16729	37615	10	8	0.40	0.11	17	0.04	D	1*n*
		4776.36	16573	37503	8	6	0.43	0.11	14	−0.06	D	1*n*
		4766.64	16450	37423	6	4	0.48	0.11	10	−0.18	D	1*n*
		4757.50	16361	37375	4	2	0.65	0.11	6.9	−0.36	D	1*n*
		4753.96	16729	37758	10	10	0.13	0.045	7.0	−0.35	D	1*n*
		4750.99	16573	37615	8	8	0.15	0.050	6.3	−0.40	D	1*n*
		4748.53	16450	37503	6	6	0.10	0.035	3.3	−0.68	D	1*n*
		4746.64	16361	37423	4	4	0.17	0.057	3.6	−0.64	D	1*n*
85.	$z\ ^6G°$–$e\ ^6H$ (114)											
		3695.34	17136	44190	14	16	2.5	0.59	100	0.92	D	1*n*
		3687.47	16917	44028	12	14	2.6	0.61	89	0.86	D	1*n*
		3680.11	16729	43894	10	12	1.9	0.47	57	0.67	D	1*n*
		3673.40	16573	43788	8	10	2.4	0.60	58	0.68	D	1*n*
		3667.74	16450	43707	6	8	2.4	0.64	46	0.58	D	1*n*
		3663.59	16361	43649	4	6	2.7	0.82	40	0.52	D	1*n*
86.	$z\ ^6G°$–$f\ ^6G$ (115)											
		3676.68	17136	44327	14	14	1.1	0.23	39	0.51	D	1*n*
		3672.40	16917	44140	12	12	0.79	0.16	23	0.28	D	1*n*
87.	$a\ ^4G$–$y\ ^4H°$ (118)											
		4904.35	17242	37626	12	14	0.086	0.036	7.0	−0.36	D	1*n*
88.	$a\ ^4G$–$x\ ^4H°$ (119)											
		4706.57	17242	38483	12	14	0.15	0.057	11	−0.16	D	1*n*
		4710.57	17182	38405	10	12	0.17	0.066	10	−0.18	D	1*n*

V I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
89.	$a\,^4G$–$w\,^4H°$ (120)											
		4291.82	17242	40536	12	14	0.78	0.25	42	0.48	D	1*n*
		4296.11	17182	40452	10	12	0.69	0.23	33	0.36	D	1*n*
		4297.68	17117	40379	8	10	0.61	0.21	24	0.23	D	1*n*
		4298.03	17055	40315	6	8	0.70	0.26	22	0.19	D	1*n*
90.	$a\,^4G$–$t\,^4G°$ (121)											
		4051.35	17242	41918	12	12	1.2	0.29	46	0.54	D	1*n*
		4050.96	17182	41861	10	10	1.2	0.30	40	0.48	D	1*n*
91.	$z\,^6F°$–$e\,^6F$ (125)											
		5193.00	18680	37931	12	12	0.35	0.14	29	0.23	D	1*n*
		5195.39	18372	37615	8	8	0.21	0.083	11	—0.18	D	1*n*
92.	$b\,^2H$–$v\,^2G°$ (129)											
		5487.92	19145	37362	12	10	0.25	0.093	20	0.05	D	1*n*
		5507.75	19023	37175	10	8	0.30	0.11	20	0.04	D	1*n*
93.	$b\,^2H$–$z\,^2I°$ (130)											
		5415.28	19145	37606	12	14	0.27	0.14	30	0.23	D	1*n*
94.	$b\,^2H$–$x\,^2H°$ (131)											
		5240.88	19145	38221	12	12	0.39	0.16	33	0.28	D	1*n*
		5234.09	19023	38124	10	10	0.41	0.17	29	0.23	D	1*n*
95.	$a\,^2F$–$x\,^2G°$ (135)											
		5725.63	19078	36539	8	10	0.18	0.11	17	—0.06	D	1*n*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V II

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4\ {}^5D_0$

Ionization Potential 14.65 eV = 118200 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
2464.09	18	2879.16	9	3214.75	16	3732.76	23
2493.58	5	2880.03	9	3230.92	38	3743.61	26
2503.02	17	2882.49	9	3231.95	42	3745.81	23
2506.22	17	2888.24	34	3234.50	42	3750.88	26
2514.63	17	2889.61	9	3239.83	42	3760.24	26
2515.72	17	2891.64	9	3259.68	38	3770.97	26
2522.39	17	2893.31	9	3271.12	15	3831.02	11
2545.46	4	2896.20	8	3276.12	15	3850.41	21
2672.01	3	2903.07	8	3287.71	15	3852.10	11
2677.80	3	2906.45	8	3289.39	15	3866.74	21
2678.57	3	2907.46	7	3298.74	15	3878.72	32
2679.33	3	2908.81	9	3300.91	41	3884.85	32
2685.69	3	2910.01	8	3315.18	44	3896.16	20
2687.96	3	2910.38	8	3321.54	44	3899.14	32
2688.72	3	2911.05	7	3361.51	43	3903.27	21
2690.79	3	2917.37	8	3392.66	43	3914.33	32
2694.74	2	2919.99	8	3461.58	14	3916.42	20
2700.94	1	2924.02	7	3479.84	14	3926.32	49
2702.19	2	2924.63	7	3485.92	14	3926.50	21
2705.22	2	2930.13	33	3489.95	46	3929.73	20
2706.17	1	2930.80	7	3493.16	14	3951.97	20
2706.70	2	2934.39	7	3499.82	13	3968.11	19
2707.86	2	2944.57	7	3504.43	14	3973.64	19
2711.74	2	2950.34	7	3509.02	45	3977.73	20
2713.05	2	2952.07	7	3513.88	45	3989.80	31
2714.21	2	2957.52	7	3516.00	14	3997.13	19
2723.22	1	3048.89	37	3517.30	14	4002.94	19
2726.54	25	3093.11	6	3520.02	13	4005.71	31
2727.93	25	3100.94	36	3524.71	13	4008.17	31
2728.64	1	3102.30	6	3527.87	45	4023.39	31
2733.91	1	3108.70	36	3530.77	13	4035.63	31
2739.72	1	3110.71	6	3531.48	12	4036.78	19
2741.56	1	3118.38	6	3538.24	12	4039.57	31
2742.43	1	3121.14	6	3541.34	48	4056.27	22
2742.67	10	3125.28	6	3545.19	13	4178.39	29
2743.77	10	3126.22	6	3556.80	13	4183.44	35
2762.71	24	3130.26	6	3560.59	12	4202.35	29
2768.57	24	3133.33	6	3563.71	12	4204.20	29
2774.28	24	3145.97	6	3568.18	12	4220.05	29
2799.45	28	3164.82	16	3589.75	12	4224.51	29
2802.80	28	3168.13	16	3592.01	12	4225.23	35
2803.47	28	3187.72	16	3593.32	12	4404.68	30
2836.53	27	3188.52	16	3622.29	47	4424.62	30
2841.04	27	3190.69	16	3715.48	23	4528.51	40
2869.96	9	3193.97	39	3718.16	26	4564.59	40
2875.69	9	3208.35	16	3722.16	23	4600.19	40
2877.69	34			3727.35	26		

For this ion, we have exclusively utilized the work of Roberts, Andersen, and Sorensen [1], who determined absolute oscillator strengths by combining arc emission measurements and beam-foil lifetime measurements. In cases of blended lines, Roberts et al. have provided *f*-value data from *LS* coupling calculations. Since the application of *LS* coupling is rather doubtful for such a complex spectrum, we have omitted all such lines from our tabulation.

Reference

[1] Roberts, J. R., Andersen, T., and Sorensen, G., Astrophys. J. **181**, 587 (1973).

V II: Allowed transitions

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$a\,^5D$–$z\,^5F^\circ$ (uv 1)											
		2700.94	339.2	37352	9	11	0.29	0.039	3.2	—0.45	C	1
		2706.17	208.9	37151	7	9	0.29	0.040	2.5	—0.55	C	1
		2728.64	36.1	36674	3	5	0.20	0.037	0.98	—0.96	C	1
		2739.72	0.0	36489	1	3	0.12	0.040	0.36	—1.40	C—	1
		2723.22	208.9	36919	7	7	0.015	0.0016	0.10	—1.94	D	1
		2733.91	106.6	36674	5	5	0.025	0.0028	0.12	—1.86	D	1
		2742.43	36.1	36489	3	3	0.035	0.0039	0.11	—1.93	D	1
		2741.56	208.9	36674	7	5	0.0027	2.2(—4)[a]	0.014	—2.82	E	1
2.	$a\,^5D$–$z\,^3D^\circ$ (uv 2)											
		2711.74	339.2	37205	9	7	0.061	0.0052	0.42	—1.33	D	1
		2714.21	208.9	37041	7	5	0.061	0.0048	0.30	—1.47	D	1
		2713.05	106.6	36955	5	3	0.050	0.0033	0.15	—1.78	D	1
		2702.19	208.9	37205	7	7	0.20	0.022	1.4	—0.81	D	1
		2706.70	106.6	37041	5	5	0.13	0.015	0.66	—1.13	D	1
		2707.86	36.1	36955	3	3	0.10	0.011	0.30	—1.48	D	1
		2694.74	106.6	37205	5	7	0.0025	3.8(—4)	0.017	—2.72	E	1
		2705.22	0.0	36955	1	3	0.037	0.012	0.11	—1.91	D	1
3.	$a\,^5D$–$z\,^5D^\circ$ (uv 3)											
		2687.96	339.2	37531	9	9	0.60	0.065	5.2	—0.23	D	1
		2679.33	208.9	37521	7	7	0.26	0.029	1.8	—0.70	D	1
		2685.69	36.1	37259	3	3	0.051	0.0055	0.15	—1.78	D—	1
		2688.72	339.2	37521	9	7	0.12	0.010	0.83	—1.03	D	1
		2690.79	106.6	37259	5	3	0.43	0.028	1.3	—0.85	D	1
		2678.57	208.9	37531	7	9	0.10	0.014	0.88	—1.00	D	1
		2672.01	106.6	37521	5	7	0.18	0.027	1.2	—0.87	D	1
		2677.80	36.1	37369	3	5	0.29	0.052	1.4	—0.81	D	1
4.	$a\,^5D$–$z\,^3G^\circ$ (uv 4)											
		2545.46	339.2	39613	9	11	0.0042	5.0(—4)	0.037	—2.35	E	1
5.	$a\,^5D$–$z\,^3F^\circ$ (uv 5)											
		2493.58	339.2	40430	9	9	0.0057	5.3(—4)	0.039	—2.32	E	1
6.	$a\,^5F$–$z\,^5G^\circ$ (1)											
		3093.11	3163	35483	11	13	1.8	0.31	35	0.53	D	1
		3102.30	2968	35193	9	11	1.6	0.29	26	0.41	D	1
		3110.71	2809	34947	7	9	1.5	0.29	20	0.30	D	1
		3118.38	2687	34746	5	7	1.5	0.30	16	0.18	D	1
		3125.28	2605	34593	3	5	1.6	0.39	12	0.07	D	1
		3121.14	3163	35193	11	11	0.22	0.032	3.6	—0.45	D—	1
		3126.22	2968	34947	9	9	0.41	0.060	5.5	—0.27	D—	1
		3130.26	2809	34746	7	7	0.50	0.073	5.3	—0.29	D—	1
		3133.33	2687	34593	5	5	0.48	0.071	3.7	—0.45	D—	1
		3145.97	2968	34796	9	7	0.039	0.0045	0.42	—1.39	E	1

V II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
7.	$a\,^5F$–$z\,^5F^\circ$ (uv 10)											
		2924.02	3163	37352	11	11	1.2	0.15	16	0.22	C	1
		2924.63	2968	37151	9	9	0.91	0.12	10	0.02	C	1
		2930.80	2809	36919	7	7	0.47	0.061	4.1	—0.37	C—	1
		2950.34	2605	36489	3	3	0.34	0.045	1.3	—0.87	C—	1
		2944.57	2968	36919	9	7	0.65	0.065	5.7	—0.23	C—	1
		2952.07	2809	36674	7	5	0.58	0.054	3.7	—0.42	C—	1
		2957.52	2687	36489	5	3	0.44	0.035	1.7	—0.76	C—	1
		2907.46	2968	37352	9	11	0.19	0.030	2.6	—0.57	C—	1
		2911.05	2809	37151	7	9	0.30	0.050	3.3	—0.46	C—	1
		2934.39	2605	36674	3	5	0.15	0.033	0.94	—1.01	D	1
8.	$a\,^5F$–$z\,^3D^\circ$ (uv 11)											
		2919.99	2968	37205	9	7	0.053	0.0053	0.46	—1.32	D	1
		2917.37	2687	36955	5	3	0.14	0.011	0.53	—1.26	D	1
		2906.45	2809	37205	7	7	0.53	0.067	4.5	—0.33	D	1
		2910.01	2687	37041	5	5	0.72	0.091	4.4	—0.34	D	1
		2910.38	2605	36955	3	3	0.87	0.11	3.2	—0.48	D	1
		2896.20	2687	37205	5	7	0.12	0.022	1.0	—0.96	D	1
		2903.07	2605	37041	3	5	0.21	0.045	1.3	—0.87	D	1
9.	$a\,^5F$–$z\,^5D^\circ$ (uv 12)											
		2908.81	3163	37531	11	9	1.1	0.11	12	0.10	D	1
		2893.31	2968	37521	9	7	0.70	0.069	5.9	—0.21	D	1
		2891.64	2687	37259	5	3	0.92	0.069	3.3	—0.46	D	1
		2889.61	2605	37201	3	1	1.4	0.057	1.6	—0.77	D	1
		2880.03	2809	37521	7	7	0.15	0.019	1.3	—0.87	D—	1
		2882.49	2687	37369	5	5	0.27	0.034	1.6	—0.77	D—	1
		2879.16	2809	37531	7	9	0.026	0.0041	0.27	—1.54	E	1
		2869.96	2687	37521	5	7	0.017	0.0030	0.14	—1.83	E	1
		2875.69	2605	37369	3	5	0.020	0.0042	0.12	—1.90	E	1
10.	$a\,^5F$–$z\,^3G^\circ$ (uv 13)											
		2742.67	3163	39613	11	11	0.049	0.0055	0.54	—1.22	C—	1
		2743.77	2968	39404	9	9	0.014	0.0016	0.13	—1.85	D	1
11.	$a\,^3F$–$z\,^5G^\circ$ (3)											
		3831.02	9098	35193	9	11	0.0012	3.1(—4)	0.036	—2.55	E	1
		3852.10	8640	34593	5	5	0.0034	7.6(—4)	0.048	—2.42	E	1
12.	$a\,^3F$–$z\,^5F^\circ$ (4)											
		3538.24	9098	37352	9	11	0.0042	9.7(—4)	0.10	—2.06	E	1
		3531.48	8842	37151	7	9	0.0017	4.0(—4)	0.033	—2.55	E	1
		3563.71	9098	37151	9	9	0.0032	6.1(—4)	0.064	—2.26	E	1
		3560.59	8842	36919	7	7	0.011	0.0022	0.18	—1.82	D	1
		3568.18	8640	36674	5	5	0.036	0.0069	0.41	—1.46	D	1
		3593.32	9098	36919	9	7	0.089	0.013	1.4	—0.92	D	1
		3592.01	8842	36674	7	5	0.23	0.032	2.6	—0.65	D	1
		3589.75	8640	36489	5	3	0.37	0.043	2.5	—0.67	D	1

V II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
13.	$a\,^3F$–$z\,^3D°$ (5)	*3545.6*	*8904*	*37100*	21	15	0.21	0.028	6.9	—0.23	D	1
		3556.80	9098	37205	9	7	0.20	0.029	3.1	—0.58	D	1
		3545.19	8842	37041	7	5	0.18	0.024	1.9	—0.78	D	1
		3530.77	8640	36955	5	3	0.19	0.021	1.2	—0.97	D	1
		3524.71	8842	37205	7	7	0.024	0.0044	0.36	—1.51	D—	1
		3520.02	8640	37041	5	5	0.028	0.0053	0.30	—1.58	D—	1
		3499.82	8640	37205	5	7	0.0018	4.6(—4)	0.026	—2.64	E	1
14.	$a\,^3F$–$z\,^5D°$ (6)											
		3516.00	9098	37531	9	9	7.5(—4)	1.4(—4)	0.015	—2.90	E	1
		3485.92	8842	37521	7	7	0.017	0.0031	0.25	—1.67	D	1
		3479.84	8640	37369	5	5	0.0090	0.0016	0.093	—2.09	E	1
		3517.30	9098	37521	9	7	0.14	0.021	2.2	—0.73	D	1
		3504.43	8842	37369	7	5	0.069	0.0090	0.73	—1.20	D	1
		3493.16	8640	37259	5	3	0.030	0.0032	0.19	—1.79	D	1
		3461.58	8640	37521	5	7	0.0033	8.3(—4)	0.048	—2.38	E	1
15.	$a\,^3F$–$z\,^3G°$ (7)											
		3276.12	9098	39613	9	11	1.1	0.21	21	0.28	C	1
		3271.12	8842	39404	7	9	1.1	0.23	17	0.20	C	1
		3287.71	8640	39234	5	7	1.2	0.26	14	0.12	C	1
		3298.74	9098	39404	9	9	0.055	0.0090	0.88	—1.09	D	1
		3289.39	8842	39234	7	7	0.086	0.014	1.1	—1.01	D	1
16.	$a\,^3F$–$z\,^3F°$ (8)	*3189.3*	*8904*	*40250*	21	21	0.95	0.15	32	0.48	D	1
		3190.69	9098	40430	9	9	0.88	0.13	13	0.08	D	1
		3188.52	8842	40196	7	7	0.80	0.12	8.9	—0.07	D	1
		3187.72	8640	40002	5	5	0.85	0.13	6.8	—0.19	D	1
		3214.75	9098	40196	9	7	0.12	0.015	1.4	—0.88	D—	1
		3208.35	8842	40002	7	5	0.17	0.019	1.4	—0.88	D—	1
		3164.82	8842	40430	7	9	0.029	0.0056	0.41	—1.41	E	1
		3168.13	8640	40196	5	7	0.046	0.0098	0.51	—1.31	E	1
17.	$a\,^3F$–$y\,^3G°$ (uv 21)											
		2514.63	9098	48853	9	11	0.24	0.028	2.1	—0.60	C	1
		2506.22	8842	48731	7	9	0.23	0.028	1.6	—0.71	C	1
		2503.02	8640	48580	5	7	0.23	0.030	1.2	—0.82	C	1
		2522.39	9098	48731	9	9	0.022	0.0021	0.16	—1.72	D	1
		2515.72	8842	48580	7	7	0.029	0.0027	0.16	—1.72	D	1
18.	$a\,^3F$–$y\,^3F°$ (uv 22)											
		2464.09	8640	49211	5	7	0.0099	0.0013	0.051	—2.20	E	1
19.	$a\,^3P$–$z\,^5F°$ (9)											
		3997.13	11908	36919	5	7	0.014	0.0048	0.32	—1.62	D	1
		3973.64	11515	36674	3	5	0.027	0.011	0.42	—1.49	D	1
		3968.11	11296	36489	1	3	0.029	0.020	0.27	—1.69	D	1
		4036.78	11908	36674	5	5	0.0088	0.0021	0.14	—1.97	D—	1
		4002.94	11515	36489	3	3	0.021	0.0052	0.20	—1.81	D—	1

V II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
20.	$a\,^3P$–$z\,^3D°$ (10)											
		3951.97	11908	37205	5	7	0.034	0.011	0.71	—1.26	D	1
		3916.42	11515	37041	3	5	0.023	0.0088	0.34	—1.58	D	1
		3896.16	11296	36955	1	3	0.023	0.016	0.20	—1.80	D	1
		3977.73	11908	37041	5	5	0.0070	0.0017	0.11	—2.08	D—	1
		3929.73	11515	36955	3	3	0.034	0.0078	0.30	—1.63	D	1
21.	$a\,^3P$–$z\,^5D°$ (11)											
		3903.27	11908	37521	5	7	0.039	0.013	0.81	—1.20	D	1
		3866.74	11515	37369	3	5	0.0089	0.0033	0.13	—2.00	D—	1
		3850.41	11296	37259	1	3	0.0037	0.0025	0.031	—2.61	E	1
		3926.50	11908	37369	5	5	0.0030	6.9(—4)	0.045	—2.46	E	1
22.	$a\,^3H$–$z\,^5F°$ (14)											
		4056.27	12706	37352	13	11	5.2(—4)	1.1(—4)	0.019	—2.85	E	1
23.	$a\,^3H$–$z\,^3G°$ (15)											
		3715.48	12706	39613	13	11	0.16	0.028	4.4	—0.44	C	1
		3732.76	12622	39404	11	9	0.16	0.028	3.8	—0.51	C	1
		3745.81	12545	39234	9	7	0.17	0.028	3.1	—0.60	C	1
		3722.16	12545	39404	9	9	0.0066	0.0014	0.15	—1.91	D	1
24.	$a\,^3H$–$y\,^3G°$ (uv 46)											
		2768.57	12622	48731	11	9	0.82	0.077	7.8	—0.07	C	1
		2774.28	12545	48580	9	7	0.88	0.079	6.5	—0.15	C	1
		2762.71	12545	48731	9	9	0.032	0,0037	0.30	—1.48	C—	1
25.	$a\,^3H$–$y\,^3F°$ (uv 47)											
		2727.93	12622	49269	11	9	0.011	0.0010	0.10	—1.94	D	1
		2726.54	12545	49211	9	7	0.053	0.0046	0.37	—1.38	C—	1
26.	$b\,^3F$–$z\,^3F°$ (21)											
		3727.35	13609	40430	9	9	0.22	0.046	5.1	—0.38	C	1
		3750.88	13543	40196	7	7	0.20	0.042	3.6	—0.53	C	1
		3770.97	13491	40002	5	5	0.22	0.047	2.9	—0.63	C	1
		3760.24	13609	40196	9	7	0.035	0.0057	0.63	—1.29	C—	1
		3718.16	13543	40430	7	9	0.014	0.0037	0.31	—1.59	C—	1
		3743.61	13491	40196	5	7	0.020	0.0058	0.36	—1.54	C—	1
27.	$b\,^3F$–$y\,^3G°$ (uv 61)											
		2836.53	13609	48853	9	11	0.25	0.037	3.1	—0.48	C	1
		2841.04	13543	48731	7	9	0.27	0.042	2.8	—0.53	C	1
28.	$b\,^3F$–$y\,^3F°$ (uv 62)											
		2803.47	13609	49269	9	9	0.58	0.069	5.7	—0.21	C	1
		2802.80	13543	49211	7	7	0.46	0.054	3.5	—0.42	C	1
		2799.45	13491	49202	5	5	0.60	0.071	3.3	—0.45	C	1

V II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
29.	$a\,^5P$–$z\,^5D°$ (25)											
		4202.35	13742	37531	7	9	0.0049	0.0017	0.16	—1.93	D	1
		4178.39	13595	37521	5	7	0.011	0.0040	0.27	—1.70	D	1
		4204.20	13742	37521	7	7	0.0012	3.1(—4)	0.030	—2.67	E	1
		4224.51	13595	37259	5	3	0.0014	2.2(—4)	0.015	—2.96	E	1
		4220.05	13512	37201	3	1	0.0040	3.6(—4)	0.015	—2.97	E	1
30.	$a\,^3G$–$z\,^5F°$ (30)											
		4404.68	14656	37352	11	11	0.0015	4.5(—4)	0.071	—2.31	E	1
		4424.62	14556	37151	9	9	0.0012	3.5(—4)	0.046	—2.50	E	1
31.	$a\,^3G$–$z\,^3G°$ (32)											
		4005.71	14656	39613	11	11	0.066	0.016	2.3	—0.76	C	1
		4023.39	14556	39404	9	9	0.060	0.015	1.7	—0.88	C	1
		4035.63	14462	39234	7	7	0.064	0.016	1.5	—0.96	C	1
		4039.57	14656	39404	11	9	0.0035	7.1(—4)	0.10	—2.11	E	1
		3989.80	14556	39613	9	11	0.0029	8.4(—4)	0.10	—2.12	E	1
		4008.17	14462	39404	7	9	0.0035	0.0011	0.10	—2.12	E	1
32.	$a\,^3G$–$z\,^3F°$ (33)											
		3878.72	14656	40430	11	9	0.082	0.015	2.1	—0.78	C	1
		3899.14	14556	40196	9	7	0.074	0.013	1.5	—0.93	C	1
		3914.33	14462	40002	7	5	0.083	0.014	1.2	—1.02	C	1
		3884.85	14462	40196	7	7	0.014	0.0033	0.29	—1.64	D	1
33.	$a\,^3G$–$y\,^3G°$ (uv 81)											
		2930.13	14462	48580	7	7	0.27	0.034	2.3	—0.62	C	1
34.	$a\,^3G$–$y\,^3F°$ (uv 82)											
		2888.24	14656	49269	11	9	0.54	0.055	5.7	—0.22	C	1
		2877.69	14462	49202	7	5	0.67	0.060	3.9	—0.38	C	1
35.	$b\,^3G$–$z\,^3F°$ (37)											
		4183.44	16533	40430	11	9	0.018	0.0040	0.60	—1.36	C—	1
		4225.23	16341	40002	7	5	0.017	0.0032	0.31	—1.65	D	1
36.	$a\,^3G$–$y\,^3G°$ (39)											
		3100.94	16341	48580	7	7	1.0	0.15	11	0.02	C	1
		3108.70	16422	48580	9	7	0.016	0.0018	0.16	—1.80	D	1
37.	$a\,^3G$–$y\,^3F°$ (40)											
		3048.89	16422	49211	9	7	0.54	0.058	5.3	—0.28	C	1
38.	$a\,^1G$–$y\,^3G°$ (48)											
		3230.92	17911	48853	9	11	0.025	0.0049	0.46	—1.36	C—	1
		3259.68	17911	48580	9	7	0.014	0.0018	0.17	—1.80	D	1
39.	$a\,^1G$–$y\,^3F°$ (49)											
		3193.97	17911	49211	9	7	0.026	0.0031	0.29	—1.56	C—	1

V II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8 s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
40.	$a\,^3D$–$z\,^3F^\circ$ (56)											
		4528.51	18354	40430	7	9	0.018	0.0070	0.73	—1.31	C—	1
		4564.59	18294	40196	5	7	0.016	0.0071	0.53	—1.45	C—	1
		4600.19	18269	40002	3	5	0.0087	0.0046	0.21	—1.86	D	1
41.	$a\,^3D$–$y\,^3G^\circ$ (60)											
		3300.91	18294	48580	5	7	0.023	0.0053	0.29	—1.58	C—	1
42.	$a\,^3D$–$y\,^3F^\circ$ (61)											
		3231.95	18269	49202	3	5	0.23	0.061	1.9	—0.74	C	1
		3239.83	18354	49211	7	7	0.017	0.0027	0.20	—1.72	D	1
		3234.50	18294	49202	5	5	0.052	0.0081	0.43	—1.39	D	1
43.	$b\,^1G$–$y\,^3G^\circ$ (70)											
		3361.51	19113	48853	9	11	0.034	0.0070	0.70	—1.20	C—	1
		3392.66	19113	48580	9	7	0.022	0.0029	0.29	—1.58	D	1
44.	$b\,^1G$–$y\,^3F^\circ$ (71)											
		3315.18	19113	49269	9	9	0.056	0.0092	0.91	—1.08	C	1
		3321.54	19113	49211	9	7	0.15	0.020	1.9	—0.75	C	1
45.	$b\,^3H$–$y\,^3G^\circ$ (117)											
		3509.02	20363	48853	13	11	0.024	0.0037	0.55	—1.32	C—	1
		3513.88	20280	48731	11	9	0.024	0.0036	0.46	—1.40	C—	1
		3527.87	20242	48580	9	7	0.012	0.0018	0.19	—1.79	D	1
46.	$b\,^3D$–$y\,^3F^\circ$ (131)											
		3489.95	20623	49269	7	9	0.011	0.0026	0.21	—1.74	D	1
47.	$a\,^1D$–$y\,^3G^\circ$ (144)											
		3622.29	20981	48580	5	7	0.013	0.0035	0.21	—1.76	D	1
48.	$a\,^1D$–$y\,^3F^\circ$ (145)											
		3541.34	20981	49211	5	7	0.041	0.011	0.63	—1.27	C—	1
49.	$a\,^1H$–$y\,^3G^\circ$ (165)											
		3926.32	23391	48853	11	11	0.024	0.0056	0.80	—1.21	C—	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V IV

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3\ {}^3F_2$

Ionization Potential 46.707 eV = 376730 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
675.47	3	1308.1	20	2011.2	10	2600.0	41
677.35	3	1355.1	26	2014.2	10	2620.3	44
678.74	3	1395.0	18	2079.3	9	2624.2	43
679.65	3	1414.4	22	2086.1	32	2636.4	43
680.63	3	1419.6	22	2088.7	9	2645.5	44
681.15	3	1423.7	28	2120.1	30	2655.4	45
682.46	2	1426.7	22	2129.9	15	2656.9	45
682.92	2	1451.0	24	2141.2	31	3077.5	48
684.37	2	1454.0	24	2146.8	34	3110.4	47
684.45	2	1520.1	23	2149.9	31	3113.0	47
693.13	1	1522.5	23	2150.2	34,35	3241.5	57
699.50	5	1601.9	27	2155.3	33	3284.6	60
722.91	7	1611.9	25	2162.5	14	3294.3	49
723.05	7	1806.2	17	2170.4	33	3328.5	59
723.54	7	1809.9	12	2268.3	13	3334.8	50
723.65	7	1810.6	12	2416.6	38	3490.9	58
724.07	7	1813.1	12	2421.3	38	3496.4	58
749.64	6	1817.7	12	2431.9	38	3514.3	58
750.11	4	1825.8	12	2433.5	36	4906.3	54
750.81	6	1861.6	16	2446.1	38	4985.7	56
751.91	6	1939.1	11	2446.8	37	5130.8	53
752.04	6	1951.4	11	2449.4	36	5146.5	53
884.15	8	1963.1	11	2450.9	37	5176.0	53
1226.5	19	1971.5	11	2480.7	46	5262.2	52
1247.1	21	1990.7	10	2556.9	40	5352.3	52
1273.0	29	1997.7	10	2570.7	42	5353.1	52
1304.2	20	1999.3	10	2584.6	39	5509.2	51
1305.4	20	2002.5	10	2598.3	41	5940.1	55

Oscillator strengths for several hundred transitions in V IV have been calculated by Kurucz and Peytremann [1] using a scaled Thomas-Fermi method including limited configuration interaction. Of these lines, we have listed only the prominent ones for reasons discussed in detail in the general introduction.

It is expected that for the stronger lines of the relatively simple, essentially two-electron spectrum of V IV, Kurucz and Peytremann's data should be fairly reliable. This conjecture seems to be supported by the good consistency between similarly calculated values and lifetime measurements for the isoelectronic ion Ti III [2].

The criterion for selecting data from Kurucz and Peytremann's material for this spectrum was to include all observed lines with an intensity within a factor of 20 of the strongest line. The wavelength list of Iglesias was applied [3].

References

[1] Kurucz, R. L., and Peytremann, E., Smithsonian Astrophysical Observatory Special Report 362 (1975).
[2] Wiese, W. L., and Fuhr, J. R., J. Phys. Chem. Ref. Data **4**, 263 (1975).
[3] Iglesias, L., J. Res. Nat. Bur. Stand. Sect. A **72**, 295 (1968).

V IV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3d^2$–$3d4p$	^3F–$^1D°$											
			693.13	0	144273	5	5	0.80	0.0058	0.066	—1.54	D	1
2.		^3F–$^3D°$ (uv 1)											
			684.37	734.7	146855	9	7	7.7	0.042	0.86	—0.42	D	1
			684.45	325.4	146429	7	5	7.7	0.038	0.61	—0.57	D	1
			684.37	0	146118	5	3	20	0.085	0.96	—0.37	D	1
			682.46	325.4	146855	7	7	6.5	0.045	0.71	—0.50	D	1
			682.92	0	146429	5	5	6.9	0.048	0.54	—0.62	D	1
3.		^3F–$^3F°$ (uv 2)											
			677.35	734.7	148369	9	9	6.7	0.046	0.93	—0.38	D	1
			678.74	325.4	147657	7	7	1.1	0.0077	0.12	—1.27	D—	1
			679.65	0	147135	5	5	0.91	0.0063	0.071	—1.50	D—	1
			680.63	734.7	147657	9	7	12	0.062	1.3	—0.25	D	1
			681.15	325.4	147135	7	5	11	0.056	0.87	—0.41	D	1
			675.47	325.4	148369	7	9	0.45	0.0039	0.061	—1.56	D—	1
4.		^1D–$^1D°$ (uv 3)	750.11	10959.3	144273	5	5	10	0.087	1.1	—0.36	D	1
5.		^1D–$^1F°$	699.50	10959.3	153919	5	7	0.87	0.0089	0.10	—1.35	D	1
6.		^3P–$^3D°$											
			749.64	13458.3	146855	5	7	1.6	0.019	0.24	—1.02	D	1
			750.81	13239.2	146429	3	5	1.7	0.024	0.18	—1.14	D	1
			751.91	13122.8	146118	1	3	2.0	0.051	0.13	—1.29	D	1
			752.04	13458.3	146429	5	5	0.21	0.0017	0.022	—2.06	D	1
7.		^3P–$^3P°$											
			724.07	13458.3	151567	5	5	11	0.089	1.1	—0.35	D	1
			723.65	13239.2	151427	3	3	3.9	0.030	0.22	—1.04	D	1
			723.54	13239.2	151449	3	1	15	0.038	0.27	—0.94	D	1
			722.91	13239.2	151567	3	5	3.1	0.040	0.29	—0.92	D	1
			723.05	13122.8	151427	1	3	4.3	0.10	0.24	—1.00	D	1
8.		^1S–$^1P°$	884.15	42462.1	155566	1	3	4.7	0.17	0.48	—0.78	D	1
9.	$3d4s$–$3d4p$	^3D–$^1D°$											
			2079.3	96196.1	144273	3	5	0.28	0.030	0.61	—1.05	D	1
			2088.7	96412.1	144273	5	5	0.31	0.020	0.69	—1.00	D	1
10.		^3D–$^3D°$ (uv 5)											
			1997.7	96798.0	146855	7	7	4.7	0.28	13	0.29	D	1
			1999.3	96412.1	146429	5	5	3.6	0.21	7.1	0.03	D	1
			2002.5	96196.1	146118	3	3	3.6	0.22	4.3	—0.19	D	1
			2014.2	96798.0	146429	7	5	0.97	0.042	2.0	—0.53	D	1
			2011.2	96412.1	146118	5	3	1.7	0.060	2.0	—0.52	D	1
			1990.7	96196.1	146429	3	5	0.33	0.033	0.64	—1.01	D—	1
11.		^3D–$^3F°$ (uv 6)											
			1939.1	96798.0	148369	7	9	5.8	0.42	19	0.47	D	1
			1951.4	96412.1	147657	5	7	5.0	0.40	13	0.30	D	1
			1963.1	96196.1	147135	3	5	4.8	0.46	8.9	0.14	D	1
			1971.5	96412.1	147135	5	5	0.27	0.016	0.52	—1.10	D—	1

V IV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
12.		^3D–$^3P^\circ$ (uv 7)											
			1825.8	96798.0	151567	7	5	5.3	0.19	7.9	0.12	D	1
			1817.7	96412.1	151427	5	3	9.5	0.28	8.5	0.15	D	1
			1809.9	96196.1	151449	3	1	7.2	0.12	2.1	−0.45	D—	1
			1813.1	96412.1	151567	5	5	1.5	0.073	2.2	−0.44	D—	1
			1810.6	96196.1	151427	3	3	2.3	0.11	2.0	−0.47	D—	1
13.		^1D–$^1D^\circ$ (uv 8)	2268.3	100201	144273	5	5	3.2	0.25	9.2	0.09	D	1
14.		^1D–$^3D^\circ$											
			2162.5	100201	146429	5	5	0.32	0.022	0.80	−0.95	D	1
15.		^1D–$^3F^\circ$											
			2129.9	100201	147135	5	5	0.16	0.011	0.39	−1.26	D	1
16.		^1D–$^1F^\circ$ (uv 9)	1861.6	100201	153919	5	7	6.6	0.48	15	0.38	D	1
17.		^1D–$^1P^\circ$ (uv 10)	1806.2	100201	155566	5	3	7.3	0.21	6.4	0.030	D	1
18.	$3d4p$–$3d4d$	$^1D^\circ$–^1F	1395.0	144273	215958	5	7	14	0.59	14	0.47	D	1
19.		$^1D^\circ$–^1D	1226.5	144273	225804	5	5	15	0.35	7.0	0.24	D	1
20.		$^3D^\circ$–^3F											
			1308.1	146855	223305	7	9	7.9	0.26	7.8	0.26	D	1
			1305.4	146429	223033	5	7	7.0	0.25	5.4	0.10	D	1
			1304.2	146118	222795	3	5	15	0.62	8.0	0.27	D	1
21.		$^3D^\circ$–^3P											
			1247.1	146429	226617	5	3	4.7	0.066	1.4	−0.48	D	1
22.		$^3F^\circ$–^3G											
			1426.7	148369	218464	9	11	22	0.82	35	0.87	D	1
			1419.6	147657	218100	7	9	13	0.50	16	0.54	D	1
			1414.4	147135	217836	5	7	12	0.51	12	0.41	D	1
23.		$^3P^\circ$–^3D											
			1520.1	151567	217350	5	7	7.2	0.35	8.7	0.24	D	1
			1522.5	151427	217108	3	5	5.5	0.32	4.8	−0.02	D—	1
24.		$^3P^\circ$–^3S											
			1454.0	151567	220344	5	3	11	0.21	5.0	0.02	D	1
			1451.0	151427	220344	3	3	7.0	0.22	3.2	−0.18	D	1
25.		$^1F^\circ$–^1F	1611.9	153919	215958	7	7	5.2	0.20	7.5	0.15	D	1
26.		$^1F^\circ$–^1G	1355.1	153919	227713	7	9	25	0.88	28	0.79	D	1
27.		$^1P^\circ$–^1P	1601.9	155566	217991	3	3	12	0.46	7.3	0.14	D	1
28.		$^1P^\circ$–^1D	1423.7	155566	225804	3	5	7.1	0.36	5.0	0.03	D	1
29.		$^1P^\circ$–^1S	1273.0	155566	234122	3	1	27	0.22	2.8	−0.18	D	1
30.	$3d4d$–$3d4f$	^1F–$^1G^\circ$	2120.1	215958	263111	7	9	8.1	0.70	34	0.69	D	1
31.		^3D–$^3F^\circ$											
			2149.9	217108	263608	5	7	5.1	0.49	17	0.39	D	1
			2141.2	216905	263593	3	5	7.0	0.80	17	0.38	D	1
32.		^3D–$^3D^\circ$											
			2086.1	217350	265272	7	7	2.8	0.18	8.8	0.11	D	1

V IV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
33.		^3G–$^3H^\circ$											
			2155.3	218464	264846	11	13	12	0.95	74	1.02	D	1
			2170.4	218100	264162	9	11	3.2	0.28	18	0.40	D	1
34.		^3G–$^3G^\circ$											
			2150.2	218100	264592	9	11	7.7	0.65	42	0.77	D	1
			2146.8	217836	264402	7	9	6.6	0.58	29	0.61	D	1
35.		^1P–$^1D^\circ$	2150.2	217991	264483	3	5	6.3	0.73	15	0.34	D	1
36.		^3F–$^3F^\circ$											
			2433.5	223033	264113	7	9	1.6	0.18	10	0.11	D	1
			2449.4	222795	263608	5	7	3.2	0.40	16	0.30	D	1
37.		^3F–$^3H^\circ$											
			2446.8	223305	264162	9	11	5.3	0.58	42	0.72	D	1
			2450.9	223033	263822	7	9	2.4	0.28	16	0.29	D	1
38.		^3F–$^3G^\circ$											
			2421.3	223305	264592	9	11	1.6	0.18	13	0.20	D	1
			2416.6	223033	264402	7	9	1.8	0.20	11	0.14	D	1
			2431.9	222795	263902	5	7	3.2	0.40	16	0.30	D	1
			2446.1	223033	263902	7	7	2.0	0.18	10	0.10	D	1
39.		^1D–$^1D^\circ$	2584.6	225804	264483	5	5	2.6	0.26	11	0.11	D	1
40.		^1D–$^1F^\circ$	2556.9	225804	264902	5	7	3.3	0.45	19	0.35	D	1
41.		^3P–$^3D^\circ$											
			2598.3	226796	265272	5	7	2.9	0.41	17	0.31	D	1
			2600.0	226617	265067	3	5	3.4	0.57	15	0.23	D	1
42.		^1G–$^1H^\circ$	2570.7	227713	266600	9	11	8.0	0.92	69	0.92	D	1
43.	$3d4d$–$3d5p$	^3D–$^3D^\circ$											
			2624.2	217350	255446	7	7	1.1	0.12	7.0	—0.09	D	1
			2636.4	216905	254824	3	3	1.0	0.11	2.7	—0.50	D	1
44.		^3G–$^3F^\circ$											
			2645.5	218464	256252	11	9	2.8	0.24	23	0.42	D	1
			2620.3	218100	256252	9	9	0.13	0.013	1.0	—0.93	D—	1
45.		^3G–$^3F^\circ$											
			2655.4	218100	255748	9	7	2.7	0.22	17	0.30	D	1
			2656.9	217836	255463	7	5	2.5	0.19	12	0.13	D	1
46.		^1P–$^1P^\circ$	2480.7	217991	258289	3	3	1.7	0.16	3.8	—0.33	D	1
47.		^3F–$^3D^\circ$											
			3110.4	223305	255446	9	7	1.6	0.18	17	0.21	D	1
			3113.0	223033	255147	7	5	1.4	0.15	11	0.02	D—	1
48.		^1D–$^1P^\circ$	3077.5	225804	258289	5	3	0.91	0.078	3.9	—0.41	D	1
49.		^3P–$^3P^\circ$											
			3294.3	226796	257143	5	5	0.93	0.15	8.2	—0.12	D	1
50.		^1G–$^1F^\circ$	3334.8	227713	257691	9	7	2.1	0.27	27	0.39	D	1
51.	$3d5s$–$3d5p$	^3D–$^1D^\circ$											
			5509.2	236322	254469	5	5	0.20	0.091	8.3	—0.34	D	1

V VI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
52.		^3D–$^3D^\circ$											
			5352.3	236767	255446	7	7	0.84	0.36	44	0.40	D	1
			5353.1	236149	254824	3	3	0.74	0.32	17	—0.02	D—	1
			5262.2	236149	255147	3	5	0.47	0.33	17	—0.01	D—	1
53.		^3D–$^3F^\circ$											
			5130.8	236767	256252	7	9	1.2	0.60	70	0.62	D	1
			5146.5	236322	255748	5	7	0.92	0.51	44	0.41	D	1
			5176.0	236149	255463	3	5	0.61	0.41	21	0.09	D—	1
54.		^3D–$^3P^\circ$											
			4906.3	236767	257143	7	5	1.1	0.29	32	0.30	D	1
55.		^1D–$^1D^\circ$	5940.1	237639	254469	5	5	0.59	0.31	30	0.19	D	1
56.		^1D–$^1F^\circ$	4985.7	237639	257691	5	7	1.3	0.66	54	0.52	D	1
57.	$3d5p$–$3d5d$	$^6D^\circ$–^3F											
			3241.5	255446	286287	7	9	3.7	0.75	56	0.72	D	1
58.		$^3F^\circ$–^3G											
			3514.3	256252	284699	9	11	4.7	1.1	110	0.98	D	1
			3496.4	255748	284340	7	9	4.4	1.0	83	0.86	D	1
			3490.9	255463	284101	5	7	3.2	0.81	47	0.61	D	1
59.		$^3F^\circ$–^3F											
			3328.5	256252	286287	9	9	1.7	0.29	28	0.41	D	1
60.		$^1F^\circ$–^1G	3284.6	257691	288128	7	9	5.3	1.1	84	0.89	D	1

V VI

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6\ ^1S_0$

Ionization Potential 128.12 eV = 1033400 cm^{-1}

Allowed Transitions

Oscillator strengths for two transitions were obtained by interpolating the results of Cowan's configuration interaction calculation [1] (which was done in intermediate coupling) from neighboring ions of the Ar isoelectronic sequence.

Reference

[1] Cowan, R. D., J. Phys. (Paris), Colloq. C4 **31**, 191 (1970).

V VI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3p^6$–$3p^5 3d$	^1S–$^3D^\circ$											
			[291.14]	0	343476	1	3	0.79	0.0030	0.0029	—2.52	E	*interp.*
2.		^1S–$^1P^\circ$	224.50	0	445430	1	3	2200	4.9	3.6	0.69	E	*interp.*

V VIII

Ground State $1s^2 2s^2 2p^6 3s^2 3p^4\ {}^3P_2$

Ionization Potential 173.7 eV = 1401000 cm^{-1}

Allowed Transitions

The single multiplet oscillator strength presented was derived by graphical interpolation from the systematic trend along the sulfur isoelectronic sequence. The lines within the multiplet are analyzed according to *LS* coupling.

V VIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2 3p^4$–$3s3p^5$	${}^3P$–${}^3P^\circ$	*460.7*	*2840*	[*219900*]	9	9	25	0.079	1.1	—0.15	E	*interp.*
			459.82	0	217480	5	5	19	0.061	0.46	—0.52	E	*ls*
			462.11	6000	222350	3	3	6.3	0.020	0.092	—1.22	E	*ls*
			449.74	0	222350	5	3	11	0.020	0.15	—0.99	E	*ls*
			[457.0]	6000	[224800]	3	1	25	0.027	0.12	—1.10	E	*ls*
			472.91	6000	217480	3	5	5.7	0.032	0.15	—1.02	E	*ls*
			465.55	7550	222350	1	3	8.0	0.078	0.12	—1.11	E	*ls*

V IX

Ground State $1s^2 2s^2 2p^6 3s^2 3p^3\ {}^4S^\circ_{3/2}$

Ionization Potential [204] eV = [1645000] cm^{-1}

Allowed Transitions

The multiplet oscillator strength for the first multiplet was derived by graphical interpolation from the systematic trend along the phosphorus isoelectronic sequence.

The data for the second multiplet are the result of calculations by Ali and Joy, done in a single configuration Hartree-Fock approximation [1]. Thus, configuration interaction was not taken into account, which may be important for this transition. However, a comparison of the transition integral calculated by Ali with the nuclear charge expansion method (unpublished result), which includes limited configuration interaction, shows good agreement. We calculated our *f*-values from the "free" form of Ali's transition integral instead of using his published *gf*-value directly, in order to take advantage of better energy level data now available.

We estimate that all listed data are outside the ±50% accuracy range, but the first multiplet may not be uncertain by more than a factor of two.

Reference

[1] Ali, M. A., and Joy, H. W., J. Phys. B **3**, 1552 (1970).

V IX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2 3p^3$–$3s3p^4$	${}^4S^\circ$–${}^4P$	*461.38*	0	*216740*	4	12	19	0.18	1.1	—0.14	E	*interp.*
			467.19	0	214050	4	6	18	0.089	0.55	—0.45	E	*ls*
			456.96	0	218840	4	4	20	0.061	0.37	—0.61	E	*ls*
			453.33	0	220590	4	2	20	0.030	0.18	—0.92	E	*ls*
2.	$3p^3$–$3p^2({}^3P)3d$	${}^4S^\circ$–${}^4P$	*244.53*	0	*408950*	4	12	650	1.7	5.6	0.84	E	1
			244.89	0	408350	4	6	640	0.87	2.8	0.54	E	*ls*
			244.46	0	409060	4	4	660	0.59	1.9	0.37	E	*ls*
			243.58	0	410540	4	2	650	0.29	0.93	0.064	E	*ls*

V X

Ground State $1s^2 2s^2 2p^6 3s^2 3p^2\ {}^3P_0$

Ionization Potential [230.0] eV = [1855100] cm^{-1}

Allowed Transitions

The multiplet oscillator strengths were derived by graphical interpolation from systematic trends along the silicon isoelectronic sequence. The lines within the multiplets are analyzed according to *LS* coupling.

V x: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2 3p^2$–$3s 3p^3$	${}^3P$–${}^3D^\circ$	*466.35*	*6660*	*221090*	9	15	8.8	0.048	0.66	—0.36	D	*interp.*
			470.25	9480	222130	5	7	8.6	0.040	0.31	—0.70	D	*ls*
			461.04	4190	221090	3	5	7.0	0.037	0.17	—0.95	D	*ls*
			457.29	0	218680	1	3	5.2	0.048	0.073	—1.31	D	*ls*
			[472.57]	9480	221090	5	5	2.1	0.0071	0.055	—1.45	D	*ls*
			[466.22]	4190	218680	3	3	3.7	0.012	0.055	—1.45	D	*ls*
			[478.01]	9480	218680	5	3	0.23	4.7(—4)[a]	0.0037	—2.63	D	*ls*
2.		${}^3P$–${}^3P^\circ$				9	9		0.068		—0.21	D	*interp.*
3.		${}^1D$–${}^1D^\circ$	405.15			5	5	34	0.083	0.55	—0.38	D	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XI

Ground State $1s^2 2s^2 2p^6 3s^2 3p\ {}^2P^\circ_{1/2}$

Ionization Potential 255.04 eV = 2057100 cm^{-1}

Allowed Transitions

The oscillator strengths for the first two multiplets are taken from the superposition-of-configurations calculations of Froese Fischer [1,2]. The calculation of Ref. [2] is an improvement over that of Ref. [1] in that more configurations are included. While the full effect of electron correlation has not been included in these calculations, comparisons with experiment for a few lower ions of the Al sequence suggest that the results should be accurate to within 50 percent.

Data for the third multiplet were obtained by interpolation from graphs of systematic trends along the Al isoelectronic sequence.

References

[1] Froese Fischer, C., J. Quant. Spectrosc. Radiat. Transfer **8**, 755 (1968).

[2] Froese Fischer, C., *Fourth International Conference on Atomic Physics, Abstracts of Contributed Papers*, Kowalski, J., and Weber, H. G., eds., Heidelberg (1974).

V XI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^{8}s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p$–$3s3p^2$	^{2}P°–^{2}D	*440.65*	*6690*	*233630*	6	10	11	0.051	0.44	—0.51	D	1
			446.32	10040	234090	4	6	9.9	0.044	0.26	—0.75	D	*ls*
			429.29	0	232940	2	4	9.6	0.053	0.15	—0.97	D	*ls*
			[448.63]	10040	232940	4	4	1.6	0.0049	0.029	—1.71	E	*ls*
2.	$3p$–$3d$	^{2}P°–^{2}D	*269.61*	*6690*	*377590*	6	10	320	0.58	3.1	0.54	D	2
			271.75	10040	378030	4	6	320	0.53	1.9	0.33	D	*ls*
			265.31	0	376920	2	4	271	0.57	1.0	0.059	D	*ls*
			[272.57]	10040	376920	4	4	53	0.059	0.21	—0.63	E	*ls*
3.	$3p$–$4s$	^{2}P°–^{2}S	*107.18*	*6690*	939670	6	2	1200	0.071	0.15	—0.37	D	*interp.*
			107.57	10040	939670	4	2	810	0.071	0.10	—0.55	D—	*ls*
			106.42	0	939670	2	2	420	0.071	0.050	—0.85	D—	*ls*

V XII

Ground State $1s^22s^22p^63s^2\ ^1S_0$

Ionization Potential 308.25 eV = 2486300 cm^{-1}

Allowed Transitions

Oscillator strengths for this ion of the Mg isoelectronic sequence were derived by interpolation from graphs of systematic trends along isoelectronic sequences. The low accuracies reflect the general scarcity of data for high ions. Furthermore, for some transitions a level crossing occurs at Cl VI, which greatly complicates extrapolation of lower Z data. It is expected that data marked "E" are accurate to within a factor of two.

Victor, Stewart, and Laughlin [1] have recently presented data for a large number of transitions in the ions Mg I to Cl VI, which may be useful in the construction of additional systematic trends for transitions not presented here. Caution must be exercised when constructing such trends, however, for the reasons mentioned above.

Reference

[1] Victor, G. A., Stewart, R. F., and Laughlin, C., Astrophys. J. **31**, 237 (1976).

V XII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki} (10^{8}s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2$–$3s3p$	^{1}S–^{1}P°	355.11	0	281600	1	3	120	0.66	0.77	—0.18	C+	*interp.*
2.	$3s3p$–$3p^2$	^{3}P°–^{3}P	*384.72*	[*195080*]	[*455010*]	9	9	160	0.35	4.0	0.50	D	*interp.*
			383.63	[198610]	[459280]	5	5	120	0.27	1.7	0.13	D	*ls*
			385.54	[191450]	[450830]	3	3	39	0.087	0.33	—0.59	D	*ls*
			396.61	[198610]	[450830]	5	3	61	0.086	0.56	—0.37	D	*ls*
			392.60	[191450]	[446160]	3	1	150	0.11	0.44	—0.47	D	*ls*
			373.20	[191450]	[459280]	3	5	44	0.15	0.56	—0.34	D	*ls*
			380.87	[188350]	[450830]	1	3	54	0.35	0.44	—0.45	D	*ls*
3.		^{1}P°–^{1}D	[577.93]?	281600	[454630]	3	5	12	0.10	0.57	—0.52	D	*interp.*
4.		^{1}P°–^{1}S	411.12	281600	524840	3	1	140	0.12	0.49	—0.44	D	*interp.*
5.	$3s3p$–$3s3d$	^{3}P°–^{3}D				9	15		0.40		0.56	D	*interp.*
6.		^{1}P°–^{1}D	609.24	281600	445740	3	5	84	0.78	4.7	0.37	E	*interp.*

V XII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
7.	3s3p–3s4s	^{1}P°–^{1}S				3	1		0.085		—0.59	E	*interp.*
8.		^{3}P°–^{3}S	*98.288*	[*195080*]	[1212500]	9	3	1400	0.070	0.20	—0.20	E	*interp.*
			98.630	[198610]	[1212500]	5	3	770	0.068	0.11	—0.47	E	*ls*
			97.938	[191450]	[1212500]	3	3	480	0.069	0.067	—0.68	E	*ls*
			97.642	[188350]	[1212500]	1	3	160	0.068	0.022	—1.16	E	*ls*

V XIII

Ground State $1s^22s^22p^63s\ ^2S_{1/2}$

Ionization Potential 336.267 eV = 2712150 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
52.590	6	74.250	11	135.4	18	324.58	7
52.870	3	74.313	11	136.2	18	401.0	26
52.908	6	74.360	11	145.0	23	401.3	26
52.928	3	78.132	8	145.1	23	401.4	26
58.139	9	78.773	8	145.2	23	422.81	1
58.505	9	78.807	8	169.23	16	443.48	1
58.514	9	93.025	4	169.81	16	854.7	19
60.596	14	93.994	4	179.5	20	883.4	19
60.640	14	99.523	12	180.8	20	888.1	19
60.642	14	99.625	12	180.9	20	1082	15
61.705	5	99.650	12	218.5	17	1136	15
62.132	5	117.90	10	220.7	17	1783	25
70.262	13	118.08	10	259.1	22	1838	25
70.323	13	118.50	10	259.5	22	1848	25
70.328	13	125.9	21	260.4	22	2202	24
71.799	2	126.6	21	313.38	7	2303	24
72.025	2			323.23	7		

The data are taken primarily from the Hartree-Fock calculations of Biemont [1]. Data for several multiplets not given by Biemont were derived by interpolation from graphs of systematic trends along the Na isoelectronic sequence. For the first two multiplets we have employed the relativistic Hartree-Fock calculations of Kim and Desclaux [2]. Line strengths within multiplets are given according to *LS* coupling.

References

[1] Biemont, E., J. Quant. Spectrosc. Radiat. Transfer **15**, 531 (1975).

[2] Kim, Y.-K., and Desclaux, J. P., private communication.

V XIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	3*s*–3*p*	^{2}S–^{2}P°	*429.48*	0	*232840*	2	6	54	0.451	1.28	—0.045	C	2
			422.81	0	236510	2	4	57	0.306	0.85	—0.213	C	2
			443.48	0	225490	2	2	49.2	0.145	0.423	—0.54	C	2
2.	3*s*–4*p*	^{2}S–^{2}P°	*71.875*	0	*1391300*	2	6	800	0.186	0.088	—0.429	C	2
			71.799	0	1392800	2	4	790	0.122	0.058	—0.61	C	2
			72.025	0	1388400	2	2	820	0.064	0.030	—0.89	C	2
3.	3*s*–5*p*	^{2}S–^{2}P°	*52.890*	0	*1890700*	2	6	490	0.062	0.022	—0.91	C	1
			52.870	0	1891400	2	4	510	0.043	0.015	—1.06	C	*ls*
			52.928	0	1889400	2	2	500	0.021	0.0073	—1.38	C	*ls*
4.	3*p*–4*s*	^{2}P°–^{2}S	*93.672*	*232840*	1300400	6	2	1600	0.068	0.13	—0.39	C	1
			93.994	236510	1300400	4	2	1100	0.070	0.087	—0.55	C	*ls*
			93.025	225490	1300400	2	2	540	0.070	0.043	—0.85	C	*ls*
5.	3*p*–5*s*	^{2}P°–^{2}S	*61.990*	*232840*	1846000	6	2	690	0.0132	0.0162	—1.101	C	1
			62.132	236510	1846000	4	2	456	0.0132	0.0108	—1.277	C	*ls*
			61.705	225490	1846000	2	2	230	0.013	0.0054	—1.58	C	*ls*
6.	3*p*–6*s*	^{2}P°–^{2}S	*52.794*	*232840*	2127000	6	2	370	0.0051	0.0053	—1.51	C	*interp.*
			[52.908]	236510	2127000	4	2	240	0.0050	0.0035	—1.07	C	*ls*
			52.590	225490	2127000	2	2	130	0.0052	0.0018	—1.98	C	*ls*
7.	3*p*–3*d*	^{2}P°–^{2}D	*319.97*	*232840*	*545370*	6	10	136	0.347	2.19	0.318	C	1
			323.23	236510	545890	4	6	131	0.308	1.31	0.090	C	*ls*
			313.38	225490	544590	2	4	120	0.35	0.73	—0.15	C	*ls*
			324.58	236510	544590	4	4	21.6	0.0342	0.146	—0.86	C—	*ls*
8.	3*p*–4*d*	^{2}P°–^{2}D	*78.557*	*232840*	*1505800*	6	10	1710	0.264	0.410	0.200	C	1
			78.773	236510	1506000	4	6	1700	0.237	0.246	—0.023	C	*ls*
			78.132	225490	1505400	2	4	1450	0.266	0.137	—0.274	C	*ls*
			78.807	236510	1505400	4	4	283	0.0263	0.0273	—0.98	C—	*ls*
9.	3*p*–5*d*	^{2}P°–^{2}D	*58.382*	*232840*	*1945700*	6	10	1000	0.089	0.10	—0.27	C	1
			58.505	236510	1945800	4	6	1000	0.078	0.060	—0.51	C	*ls*
			58.139	225490	1945500	2	4	850	0.086	0.033	—0.76	C	*ls*
			[58.514]	236510	1945500	4	4	170	0.0087	0.0067	—1.46	C—	*ls*
10.	3*d*–4*p*	^{2}D–^{2}P°	*118.21*	*545370*	*1391300*	10	6	372	0.0468	0.182	—0.330	C	1
			118.08	545890	1392800	6	4	335	0.0467	0.109	—0.55	C	*ls*
			118.50	544590	1388400	4	2	370	0.039	0.061	—0.81	C	*ls*
			[117.90]	544590	1392800	4	4	37.4	0.0078	0.0121	—1.51	C—	*ls*
11.	3*d*–5*p*	^{2}D–^{2}P°	*74.331*	*545370*	*1890700*	10	6	140	0.0072	0.018	—1.14	C	1
			74.313	545890	1891400	6	4	140	0.0075	0.011	—1.35	C	*ls*
			[74.360]	544590	1889400	4	2	150	0.0061	0.0060	—1.61	C	*ls*
			[74.250]	544590	1891400	4	4	15	0.0012	0.0012	—2.31	C—	*ls*
12.	3*d*–4*f*	^{2}D–^{2}F°	*99.579*	*545370*	*1549600*	10	14	4400	0.92	3.0	0.96	C	*interp.*
			99.625	545890	1549700	6	8	4400	0.86	1.7	0.71	C	*ls*
			99.523	544590	1549400	4	6	4100	0.92	1.2	0.56	C	*ls*
			[99.650]	545890	1549400	6	6	290	0.044	0.086	—0.58	C—	*ls*
13.	3*d*–5*f*	^{2}D–^{2}F°	*70.297*	*545370*	*1967900*	10	14	1640	0.170	0.393	0.230	C	*interp.*
			70.323	545890	1967900	6	8	1640	0.162	0.225	—0.012	C	*ls*
			70.262	544590	1967800	4	6	1530	0.170	0.157	—0.168	C	*ls*
			[70.328]	545890	1967800	6	6	109	0.0081	0.0112	—1.315	C—	*ls*

V XIII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
14.	3*d*–6*f*	^{2}D–^{2}F°	*60.620*	*545370*	*2195000*	10	14	830	0.064	0.13	—0.19	C	1
			60.640	545890	2195000	6	8	840	0.062	0.074	—0.43	C	*ls*
			60.596	544590	2194900	4	6	790	0.065	0.052	—0.58	C	*ls*
			[60.642]	545890	2194900	6	6	56	0.0031	0.0037	—1.73	C—	*ls*
15.	4*s*–4*p*	^{2}S–^{2}P°	*1100*	1300400	*1391300*	2	6	12	0.66	4.8	0.12	C	1
			[1082]	1300400	1392800	2	4	13	0.45	3.2	—0.05	C	*ls*
			[1136]	1300400	1388400	2	2	11	0.21	1.6	—0.37	C	*ls*
16.	4*s*–5*p*	^{2}S–^{2}P°	*169.4*	1300400	*1890700*	2	6	160	0.206	0.230	—0.385	C	1
			169.23	1300400	1891400	2	4	160	0.137	0.153	—0.56	C	*ls*
			169.81	1300400	1889400	2	2	160	0.069	0.077	—0.86	C	*ls*
17.	4*p*–5*s*	^{2}P°–^{2}S	*219.9*	*1391300*	1846000	6	2	484	0.117	0.51	—0.154	C	1
			[220.7]	1392800	1846000	4	2	320	0.12	0.34	—0.33	C	*ls*
			[218.5]	1388400	1846000	2	2	170	0.12	0.17	—0.63	C	*ls*
18.	4*p*–6*s*	^{2}P°–^{2}S	*135.9*	*1391300*	2127000	6	2	2450	0.226	0.61	0.132	C	*interp.*
			[136.2]	1392800	2127000	4	2	1600	0.23	0.41	—0.04	C	*ls*
			[135.4]	1388400	2127000	2	2	820	0.22	0.20	—0.35	C	*ls*
19.	4*p*–4*d*	^{2}P°–^{2}D	*873.4*	*1391300*	*1505800*	6	10	29	0.55	9.5	0.52	C	1
			[883.4]	1392800	1506000	4	6	28	0.49	5.7	0.29	C	*ls*
			[854.7]	1388400	1505400	2	4	26	0.57	3.2	0.06	C	*ls*
			[888.1]	1392800	1505400	4	4	4.6	0.054	0.63	—0.67	C—	*ls*
20.	4*p*–5*d*	^{2}P°–^{2}D	[*180.4*]	*1391300*	*1945700*	6	10	271	0.220	0.78	0.121	C	1
			[180.8]	1392800	1945800	4	6	270	0.20	0.47	—0.10	C	*ls*
			[179.5]	1388400	1945500	2	4	230	0.22	0.26	—0.36	C	*ls*
			[180.9]	1392800	1945500	4	4	44	0.022	0.052	—1.06	C—	*ls*
21.	4*p*–6*d*	^{2}P°–^{2}D	*126.3*	*1391300*	*2182900*	6	10	180	0.072	0.18	—0.36	D	*interp.*
			[126.6]	1392800	2182900	4	6	180	0.066	0.11	—0.58	D	*ls*
			[125.9]	1388400	2182800	2	4	150	0.072	0.060	—0.84	D	*ls*
			[126.6]	1392800	2182800	4	4	30	0.0072	0.012	—1.54	D—	*ls*
22.	4*d*–5*p*	^{2}D–^{2}P°	*259.8*	*1505800*	*1890700*	10	6	171	0.104	0.89	0.017	C	1
			[259.5]	1506000	1891400	6	4	150	0.10	0.53	—0.21	C	*ls*
			[260.4]	1505400	1889400	4	2	170	0.087	0.30	—0.46	C	*ls*
			[259.1]	1505400	1891400	4	4	17	0.017	0.059	—1.16	C—	*ls*
23.	4*d*–6*f*	^{2}D–^{2}F°	*145.1*	*1505800*	*2195000*	10	14	403	0.178	0.85	0.250	C	1
			[145.1]	1506000	2195000	6	8	410	0.17	0.49	0.01	C	*ls*
			[145.0]	1505400	2194900	4	6	380	0.18	0.34	—0.15	C	*ls*
			[145.2]	1506000	2194900	6	6	26	0.0084	0.024	—1.30	C—	*ls*
24.	5*s*–5*p*	^{2}S–^{2}P°	*2236*	1846000	*1890700*	2	6	3.6	0.82	12	0.21	C	1
			[2202]	1846000	1891400	2	4	3.8	0.55	8.0	0.04	C	*ls*
			[2303]	1846000	1889400	2	2	3.3	0.26	4.0	—0.28	C	*ls*
25.	5*p*–5*d*	^{2}P°–^{2}D	*1818*	*1890700*	*1945700*	6	10	8.8	0.73	26	0.64	C	1
			[1838]	1891400	1945800	4	6	8.7	0.66	16	0.42	C	*ls*
			[1783]	1889400	1945500	2	4	7.8	0.74	8.7	0.17	C	*ls*
			[1848]	1891400	1945500	4	4	1.4	0.070	1.7	—0.55	C—	*ls*
26.	5*d*–6*f*	^{2}D–^{2}F°	*401.1*	*1945700*	*2195000*	10	14	180	0.62	8.2	0.79	C	1
			[401.3]	1945800	2195000	6	8	180	0.59	4.7	0.55	C	*ls*
			[401.0]	1945500	2194900	4	6	170	0.62	3.3	0.40	C	*ls*
			[401.4]	1945800	2194900	6	6	12	0.029	0.23	—0.76	C—	*ls*

V XIV

Ground State $1s^2 2s^2 2p^6\ {}^1S_0$

Ionization Potential 895.58 eV = 7223500 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
15.609	14	23.794	1	420.7	20	484.0	26
15.748	13	243.8	23	421.1	21	485.7	19
16.939	12	281.1	28	432.3	27	494.6	18
17.094	11	329.9	22	433.8	21	541.1	18
17.575	4	331.7	21	435.4	26	567.9	26
17.754	3	350.0	22	437.3	19	575.7	20
20.716	10	374.7	19	447.8	19	723.6	18
21.018	9	383.1	21	453.9	19,20	766.9	24
23.490	2	403.4	21	470.6	25		

Two theoretical studies are available for this ion of the Ne sequence, the parametric-potential method of Crance [1] and the self-consistent field calculations by Kastner et al. [2]. Both authors obtain very similar results for the oscillator strengths, with agreement of 25 percent or better in every case.

Since the two sources use rather equivalent approaches, but Crance's calculations are more complete, we have applied his work exclusively for this compilation. Some transitions are represented in *jl*-coupling notation, as given by Crance.

Both calculations have been done in a single-configuration approximation only, but this should not lead to significant uncertainties for this highly ionized species. However, the weaker lines are expected to be affected by uncertainties in the calculated intermediate coupling coefficients more than the stronger lines, and the accuracy ratings have been correspondingly lowered. Also, a configuration-interaction calculation for Fe XVII by Loulergue [3] indicates that some of Crance's data would be too low by as much as a factor of two. Systematic trends along the sequence have not yet been definitively established, since sufficient data are only available for the first few ions.

References

[1] Crance, M., At. Data **5**, 185 (1973).
[2] Kastner, S. O., Omidvar, K., and Underwood, J. H., Astrophys. **148**, 269 (1967).
[3] Loulergue, M., Astron. Astrophys. **15**, 216 (1971).

V XIV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2p^6$–$2p^5 3s$	${}^1S$–${}^3P^o$											
			23.794	0	4202700	1	3	2500	0.064	0.0050	—1.19	D—	1
2.		${}^1S$–${}^1P^o$	23.490	0	4257100	1	3	2700	0.068	0.0053	—1.17	D—	1
3.	$2p^6$–$2p^5 4s$	${}^1S$–[1½]°	17.754	0	5632500	1	3	1200	0.017	9.9(—4)[a]	—1.77	D—	1
4.		${}^1S$–[½]°	17.575	0	5689900	1	3	790	0.011	6.4(—4)	—1.96	D—	1
5.	$2p^6$–$2p^5 5s$	${}^1S$–[1½]°				1	3		0.0068		—2.17	E	1
6.		${}^1S$–[½]°				1	3		0.0038		—2.42	E	1
7.	$2p^6$–$2p^5 6s$	${}^1S$–[1½]°				1	3		0.0035		—2.46	E	1
8.		${}^1S$–[½]°				1	3		0.0019		—2.72	E	1
9.	$2p^6$–$2p^5 3d$	${}^1S$–${}^3D^o$											
			21.018	0	4757800	1	3	2.1(+4)	0.42	0.029	—0.38	D	1
10.		${}^1S$–${}^1P^o$	20.716	0	4827200	1	3	1.2(+5)	2.37	0.16	0.37	D	1
11.	$2p^6$–$2p^5 4d$	${}^1S$–${}^3D^o$											
			17.094	0	5850000	1	3	2.3(+4)	0.30	0.017	—0.52	D	1
12.		${}^1S$–${}^1P^o$	16.939	0	5903500	1	3	3.3(+4)	0.43	0.024	—0.37	D	1

V XIV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
13.	$2p^6$–$2p^5 5d$	^1S–$^3D^\circ$											
			15.748	0	6350000	1	3	1.3(+4)	0.14	0.0073	—0.85	D	1
14.		^1S–$^1P^\circ$	15.609	0	6406600	1	3	1.6(+4)	0.17	0.0087	—0.77	D	1
15.	$2p^6$–$2p^5 6d$	^1S–$^3P^\circ$											
						1	3		0.0010		—3.00	E	1
16.		^1S–$^3D^\circ$											
						1	3		0.064		—1.19	E	1
17.		^1S–$^1P^\circ$				1	3		0.095		—1.02	E	1
18.	$2p^5 3s$–$2p^5 3p$	$^3P^\circ$–^3S	*528.3*	[*4198200*]	[4387500]	9	3	26	0.036	0.57	—0.48	D	1
			[494.6]	[4185300]	[4387500]	5	3	29	0.064	0.52	—0.50	D	1
			[541.1]	4202700	[4387500]	3	3	1.8	0.0079	0.042	—1.63	E	1
			[723.6]	[4249300]	[4387500]	1	3	0.21	0.0049	0.012	—2.31	E	1
19.		$^3P^\circ$–^3D											
			[437.3]	[4185300]	[4414000]	5	7	50	0.20	1.4	0.00	D	1
			[485.7]	4202700	[4408600]	3	5	20	0.12	0.57	—0.45	D	1
			[453.9]	[4249300]	[4469600]	1	3	19	0.18	0.26	—0.75	D	1
			[447.8]	[4185300]	[4408600]	5	5	21	0.063	0.47	—0.50	D	1
			[374.7]	4202700	[4469600]	3	3	0.19	4.0(—4)	0.0015	—2.92	E	1
20.		$^3P^\circ$–^1P											
			[420.7]	[4185300]	[4423000]	5	3	3.2	0.0051	0.035	—1.59	E	1
			[453.9]	4202700	[4423000]	3	3	42	0.13	0.58	—0.41	D	1
			[575.7]	[4249300]	[4423000]	1	3	0.16	0.0024	0.0045	—2.62	E	1
21.		$^3P^\circ$–^3P											
			[403.4]	[4185300]	[4433200]	5	5	32	0.078	0.52	—0.41	D	1
			[331.7]	[4185300]	[4486800]	5	3	5.3	0.0052	0.029	—1.58	E	1
			[383.1]	4202700	[4463700]	3	1	50	0.037	0.14	—0.96	D	1
			[433.8]	4202700	[4433200]	3	5	23	0.11	0.46	—0.49	E	1
			[421.1]	[4249300]	[4486800]	1	3	28	0.22	0.31	—0.65	E	1
22.		$^3P^\circ$–^1D											
			[329.9]	[4185300]	[4488400]	5	5	0.95	0.0016	0.0084	—2.11	E	1
			[350.0]	4202700	[4488400]	3	5	1.2	0.0037	0.013	—1.96	E	1
23.		$^3P^\circ$–^1S											
			[243.8]	4202700	[4612900]	3	1	94	0.028	0.067	—1.08	E	1
24.		$^1P^\circ$–^3S											
			[766.9]	4257100	[4387500]	3	3	0.20	0.0018	0.013	—2.28	E	1
25.		$^1P^\circ$–^3D											
			[470.6]	4257100	[4469600]	3	3	22	0.073	0.34	—0.66	D	1
26.		$^1P^\circ$–^3P											
			[567.9]	4257100	[4433200]	3	5	0.44	0.0035	0.020	—1.97	E	1
			[435.4]	4257100	[4486800]	3	3	20	0.057	0.24	—0.77	D	1
			[484.0]	4257100	[4463700]	3	1	12	0.014	0.067	—1.38	E	1
27.		$^1P^\circ$–^1D	[432.3]	4257100	[4488400]	3	5	48	0.22	0.96	—0.17	D	1
28.		$^1P^\circ$–^1S	[281.1]	4257100	[4612900]	3	1	120	0.047	0.13	—0.85	D	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XV

Ground State $1s^2 2s^2 2p^5\ ^2P^o_{3/2}$

Ionization Potential 974.02 eV = 7856200 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
18.990	16	19.671	9	20.038	9	21.909	3
19.208	16	19.725	11	20.078	8	21.945	2
19.203	16	19.757	10	20.121	8	22.081	3
19.298	15	19.782	8	21.019	5	22.083	2
19.366	15	19.80	9	21.285	5	22.192	2,3
19.443	12	19.846	8	21.555	4	22.232	2
19.518	15	19.888	8	21.568	4	22.371	2
19.589	14	19.903	9	21.800	3	113.87	1
19.645	10	19.988	10	21.832	4	121.97	1
19.666	12						

The multiplet strength for the first multiplet is taken from Safronova's many-body perturbation theory calculation [1]. At lower Z, this calculation is in excellent agreement with the non-closed shell many-electron theory of Sinanoglu [2]. As an expansion in Z^{-1}, Safronova's results should improve with increasing Z, and should be fairly accurate for V XV. The data resulting from the expansion in Z^{-1} of the line strength by Cohen and Dalgarno [3] were found to lie above both Safronova's and Sinanoglu's values by about 20%.

The oscillator strengths of Cohen, Feldman, and Kastner [4], obtained with the Hartree-Fock method, should be used with caution, as similar calculations for Sc XIII, another ion of the F isoelectronic sequence, have shown discrepancies of more than a factor of 5 for some transitions when compared to more accurate material [5].

Additional data for this ion are available from the work of Ali [6,7], who has calculated multiplet strengths for the fairly strong $3s$–$3p$ and $3p$–$3d$ transitions, again using an expansion in Z^{-1}. We did not tabulate this material, however, since the relevant wavelengths and energy levels are not known.

References

[1] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 231 (1975).

[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

[3] Cohen, M., and Dalgarno, A., Proc. R. Soc. London, Ser. A **280**, 258 (1964).

[4] Cohen, L., Feldman, U., and Kastner, S. O., J. Opt. Soc. Am. **58**, 331 (1968).

[5] Wiese, W. L., and Fuhr, J. R., J. Phys. Chem. Ref. Data **4**, 263 (1975).

[6] Ali, M. A., Int. J. Quantum Chem., Symp. **3**, 359 (1970).

[7] Ali, M. A., J. Quant. Spectrosc. Radiat. Transfer **11**, 503 (1971).

V XV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p^5$–$2s2p^6$	$^2P^o$–^2S	*116.45*	*19440*	878190	6	2	770	0.052	0.12	—0.50	D	1
			113.87	0	878190	4	2	550	0.053	0.080	—0.67	D	*ls*
			121.97	58320	878190	2	2	220	0.050	0.040	—1.00	D	*ls*
2.	$2p^5$–$2p^4(^3P)3s$	$^2P^o$–^4P											
			22.192	0	4506100	4	6	150	0.0017	5.0(—4)[a]	—2.17	E	4
			[22.371]	58320	4528400	2	4	230	0.0034	5.0(—4)	—2.17	E	4
			[22.083]	0	4528400	4	4	4700	0.034	0.0099	—0.87	E	4
			22.232	58320	4556800	2	2	360	0.0027	4.0(—4)	—2.27	E	4
			[21.945]	0	4556800	4	2	200	7.2(—4)	2.1(—4)	—2.54	E	4
3.		$^2P^o$–^2P	*21.966*	*19440*	*4571900*	6	6	5700	0.041	0.018	—0.60	E	4
			21.909	0	4564300	4	4	4900	0.035	0.010	—0.85	E	4
			[22.081]	58320	4587200	2	2	6200	0.045	0.0065	—1.05	E	4
			21.800	0	4587200	4	2	450	0.0016	4.6(—4)	—2.19	E	4
			22.192	58320	4564300	2	4	470	0.0069	0.0010	—1.86	E	4

V xv: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
4.	$2p^5$–$2p^4(^1D)3s$	$^2P°$–^2D	*21.65*	*19440*	*4637600*	6	10	3600	0.042	0.018	—0.60	E	4
			21.568	0	4636500	4	6	3400	0.036	0.010	—0.84	E	4
			21.832	58320	4639200	2	4	4100	0.058	0.0083	—0.94	E	4
			[21.555]	0	4639200	4	4	8.2	5.7(—5)	1.6(—5)	—3.64	E	4
5.	$2p^5$–$2p^4(^1S)3s$	$^2P°$–^2S	*21.105*	*19440*	4757600	6	2	3900	0.0086	0.0036	—1.29	E	4
			21.019	0	4757600	4	2	1500	0.0051	0.0014	—1.69	E	4
			21.285	58320	4757600	2	2	2400	0.016	0.0022	—1.49	E	4
6.	$2p^5$–$2p^4(^3P)3d$	$^2P°$–^4D											
						4	6		2.1(—4)		—3.08	E	4
						2	4		0.077		—0.81	E	4
						4	4		0.15		—0.22	E	4
						2	2		0.055		—0.96	E	4
						4	2		0.018		—1.14	E	4
7.		$^2P°$–^4F											
						4	6		0.034		—0.87	E	4
						2	4		0.069		—0.86	E	4
						4	4		0.067		—0.57	E	4
8.		$^2P°$–^4P											
			19.782	0	5055100	4	6	1100	0.0097	0.0025	—1.41	E	4
			20.078	58320	5038900	2	4	1200	0.015	0.0020	—1.52	E	4
			[19.846]	0	5038900	4	4	2500	0.015	0.0039	—1.22	E	4
			[20.121]	58320	5028200	2	2	43	2.6(—4)	3.4(—5)	—3.28	E	4
			19.888	0	5028200	4	2	1500	0.0044	0.0012	—1.75	E	4
9.		$^2P°$–^2P	*19.790*	*19440*	*5072600*	6	6	5.2(+4)	0.31	0.12	0.27	E	4
			[19.671]	0	5083600	4	4	4.1(+4)	0.24	0.062	—0.02	E	4
			20.038	58320	5050500	2	2	1.8(+4)	0.11	0.015	—0.66	E	4
			19.80	0	5050500	4	2	1.6(+4)	0.047	0.012	—0.73	E	4
			19.903	58320	5083600	2	4	1.8(+4)	0.21	0.028	—0.38	E	4
10.		$^2P°$–^2D	*19.765*	*19440*	*5078800*	6	10	8.4(+4)	0.82	0.32	0.69	E	4
			19.645	0	5090400	4	6	5.2(+4)	0.45	0.12	0.26	E	4
			19.988	58320	5061500	2	4	1.0(+5)	1.2	0.16	0.38	E	4
			19.757	0	5061500	4	4	2.6(+4)	0.15	0.039	—0.22	E	4
11.		$^2P°$–^2F											
			19.725	0	5069700	4	6	3300	0.029	0.0075	—0.94	E	4
12.	$2p^5$–$2p^4(^1D)3d$	$^2P°$–^2S	*19.517*	*19440*	5143200	6	2	9.0(+4)	0.17	0.066	0.01	E	4
			19.443	0	5143200	4	2	4.9(+4)	0.14	0.036	—0.25	E	4
			[19.666]	58320	5143200	2	2	4.0(+4)	0.23	0.030	—0.34	E	4
13.		$^2P°$–^2F											
						4	6		0.12		—0.32	E	4
14.		$^2P°$–^2P											
						4	4		0.21		—0.08	E	4
						2	2		0.31		—0.21	E	4
						4	2		0.095		—0.42	E	4
			19.589	58320	[5163200]	2	4	870	0.010	0.0013	—1.70	E	4

V XV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
15.		$^2P°$–^2D	*19.412*	*19440*	*5171000*	6	10	5.8(+4)	0.55	0.21	0.52	E	4
			19.366	0	5163700	4	6	9.8(+4)	0.83	0.21	0.52	E	4
			19.518	58320	5181900	2	4	130	0.0015	1.9(—4)	—2.52	E	4
			19.298	0	5181900	4	4	160	9.2(—4)	2.3(—4)	—2.43	E	4
16.	$2p^5$–$2p^4(^1S)3d$	$^2P°$–^2D	*19.083*	*19440*	*5259600*	6	10	7300	0.066	0.025	—0.40	E	4
			19.028	0	5255400	4	6	8500	0.069	0.017	—0.56	E	4
			19.203	58320	5266000	2	4	3.1(+4)	0.34	0.0043	—0.17	E	4
			[18.990]	0	5266000	4	4	3000	0.016	0.0040	—1.19	E	4

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XVI

Ground State $1s^2 2s^2 2p^4\ ^3P_2$

Ionization Potential [1058.0] eV = [8533600] cm^{-1}

Allowed Transitions

The transition probabilities for lines of the first seven multiplets are from the Z-expansion calculations of Safronova [1]. Relativistic effects are included, and the results are in good agreement with the many-electron theory of Sinanoglu [2] for nearby ions of the same isoelectronic sequence, e.g., Mn XVIII.

References

[1] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 223 (1975).
[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

V XVI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p^4$–$2s2p^5$	^3P–$^3P°$	*131.69*	*21920*	*781290*	9	9	350	0.092	0.36	—0.08	D	1
			131.22	0	762080	5	5	270	0.070	0.15	—0.46	D	1
			133.29	49060	799300	3	3	89	0.024	0.031	—1.15	D	1
			125.11	0	799300	5	3	150	0.021	0.043	—0.98	D	1
			129.16	49060	823290	3	1	400	0.033	0.043	—1.00	D	1
			140.25	49060	762080	3	5	78	0.038	0.053	—0.94	D	1
			133.48	50120	799300	1	3	100	0.080	0.035	—1.10	D	1
2.		^3P–$^1P°$											
			[96]			5	3	140	0.012	0.018	—1.24	D	1
			[100]			3	3	34	0.0051	0.0050	—1.82	D	1
3.		^1D–$^3P°$											
			[146]			5	3	25	0.0048	0.012	—1.62	D	1
4.		^1D–$^1P°$	108.15			5	3	1000	0.11	0.19	—0.28	D	1
5.		^1S–$^1P°$	123.72			1	3	69	0.048	0.019	—1.32	D	1
6.	$2s2p^5$–$2p^6$	$^1P°$–^1S	[136]			3	1	1100	0.10	0.14	—0.52	D	1
7.		$^3P°$–^1S											
			[103]			3	1	36	0.0019	0.0019	—2.24	D	1
8.	$2p^3(^4S°)3s$–$2p^3(^4S°)3p$	$^3S°$–^3P				3	9		0.38		0.06	D	*interp.*
9.		$^5S°$–^5P				5	15		0.19		—0.02	D	*interp.*

V XVII

Ground State $1s^2 2s^2 2p^3\ {}^4S^\circ_{3/2}$

Ionization Potential [1165.0] eV = [9396600] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
102.84	3	125.27	6	136.45	2	152.57	4
108.95	3	126.82	5	137	2	155	8
111.27	3	129.22	7	142	8	158.13	4
113.39	6	130.98	7	146.73	1	159	4
117.23	6	131.69	5	150.03	1	159.30	1
120.33	7	132	2	151	9	167.37	9
120.82	6	134.01	2	151.69	9	182	9

Transition probabilities for lines of the first nine multiplets are the results of the many-body perturbation theory calculations by Safronova and Bolotin [1]. These results are in good agreement with extrapolations from lower charged ions, based mainly on the non-closed shell many-electron theory of Sinanoglu [2].

Oscillator strengths for the last five multiplets were obtained by graphical interpolation of systematic trends along the nitrogen isoelectronic sequence.

References

[1] Safronova, U. I., and Bolotin, A. B., Czech. J. Phys., Sect. B **26**, 945 (1976).
[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

V XVII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p^3$–$2s2p^4$	${}^4S^\circ$–${}^4P$	*153.93*	0	*649640*	4	12	110	0.12	0.24	—0.32	C+	1
			159.30	0	627750	4	6	98	0.056	0.12	—0.65	C+	1
			150.03	0	666530	4	4	120	0.040	0.080	—0.79	C+	1
			146.73	0	681520	4	2	130	0.021	0.041	—1.08	C+	1
2.		${}^2D^\circ$–${}^2D$	*137*			10	10	240	0.067	0.30	—0.18	C	1
			136.45			6	6	230	0.064	0.17	—0.41	C+	1
			134.01			4	4	280	0.075	0.13	—0.52	C+	1
			[137]			6	4	3.8	7.1(—4)[a]	0.0019	—2.37	D	1
			[132]			4	6	0.21	8.2(—5)	1.4(—4)	—3.48	D	1
3.		${}^2D^\circ$–${}^2P$	*110*			10	6	690	0.075	0.27	—0.13	C+	1
			111.27			6	4	730	0.090	0.20	—0.27	C+	1
			102.84			4	2	310	0.025	0.033	—1.01	C	1
			108.95			4	4	130	0.023	0.033	—1.03	C	1
4.		${}^2P^\circ$–${}^2D$	*158*			6	10	39	0.024	0.076	—0.84	C	1
			158.13			4	6	47	0.026	0.055	—0.98	C+	1
			152.57			2	4	25	0.017	0.018	—1.46	C+	1
			[159]			4	4	3.2	0.0012	0.0025	—2.31	D	1
5.		${}^2P^\circ$–${}^2S$	*129*			6	2	300	0.025	0.064	—0.82	C	1
			131.69			4	2	54	0.0070	0.012	—1.55	D	1
			126.82			2	2	260	0.063	0.052	—0.90	C+	1
6.		${}^2P^\circ$–${}^2P$	*123*			6	6	290	0.066	0.16	—0.40	C+	1
			125.27			4	4	86	0.020	0.033	—1.09	C+	1
			113.39			2	2	43	0.0083	0.0062	—1.78	C+	1
			117.23			4	2	610	0.063	0.097	—0.60	C+	1
			120.82			2	4	55	0.024	0.019	—1.32	C+	1

V XVII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
7.	$2s2p^4$–$2p^5$	^2D–$^2P^o$	*130*			10	6	370	0.056	0.24	—0.25	C+	1
			130.98			6	4	320	0.055	0.14	—0.48	C+	1
			120.33			4	2	360	0.039	0.062	—0.81	C+	1
			129.22			4	4	92	0.023	0.039	—1.04	C+	1
8.		^2S–$^2P^o$	*160*			2	6	37	0.043	0.045	—1.07	C	1
			[155]			2	4	60	0.043	0.044	—1.06	C+	1
			[142]			2	2	4.9	0.0015	0.0014	—2.53	D	1
9.		^2P–$^2P^o$	*170*			6	6	260	0.11	0.38	—0.17	C+	1
			167.37			4	4	230	0.097	0.21	—0.41	C+	1
			151.69			2	2	230	0.079	0.079	—0.80	C+	1
			[151]			4	2	200	0.034	0.068	—0.86	C+	1
			[182]			2	4	17	0.017	0.020	—1.4	C	1
10.	$2p^2(^3P)3s$–$2p^2(^3P)3p$	^4P–$^4D^o$				12	20		0.15		0.26	E	*interp.*
11.		^4P–$^4P^o$				12	12		0.11		0.12	E	*interp.*
12.		^2P–$^2D^o$				6	10		0.17		0.01	E	*interp.*
13.	$2p^2(^1D)3s$–$2p^2(^1D)3p$	^2D–$^2F^o$				10	14		0.11		0.04	E	*interp.*
14.	$2p^2(^1D)3p$–$2p^2(^1D)3d$	$^2F^o$–^2G				14	18		0.16		0.35	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XVIII

Ground State $1s^2 2s^2 2p^2\ ^3P_0$

Ionization Potential [1259] eV = [10155000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
16.467	10	117.15	5	141.73	2	170.67	1
16.816	11	120.60	3	143.39	2	176.39	1
17.717	8	133.77	4	143.84	2	176.41	1
18.06	9	134.1	6	148.11	2	179.97	1
111.44	3	136.00	2	149.81	2	186.35	1
116.35	3			165.35	1		

The data have been obtained by the generation and analysis of systematic trends along the carbon isoelectronic sequence and the subsequent determination of interpolated oscillator strengths. For many transitions our final recommended data agree well with the interpolated values given by Smith and Wiese [1]. However, in some cases the dependence of the oscillator strength on the inverse nuclear charge, $1/Z$, has been reinterpreted as a result of the availability of new f-value data (or, in some cases, of wavelength data which enabled us to convert previously published line strengths to oscillator strengths).

To single out some of the principal contributing sources, the nuclear charge expansion method has been used by Safronova [2], Laughlin and Dalgarno [3], and Cohen and Dalgarno [4] to calculate line strengths for the entire isoelectronic sequence, so that f-values could be derived whenever wavelength data existed. In addition, the extrapolated values given by Sinanoglu [5] for the higher ions of the sequence, which were based on data calculated according to his many-electron theory for the lower ions, were helpful in establishing some systematic trends, as were the self-consistent field (SCF) calculations in intermediate coupling by Fawcett et al. [6] for Fe XXI.

It should be noted that uncertainties in the interpolated data are expected to be fairly large, mainly since relativistic effects should become significant at about this point and have either not at all, or only roughly, been accounted for in the existing calculated data.

References

[1] Smith, M. W., and Wiese, W. L., Astrophys. J. Suppl. Ser. **23**, No. 196, 103 (1971).

[2] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 231 (1975).

[3] Laughlin, C., and Dalgarno, A., J. Chem. Phys. **60**, 1688 (1974).

[4] Cohen, M., and Dalgarno, A., Proc. R. Soc. London, Ser. A **280**, 258 (1964).

[5] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

[6] Fawcett, B. C., Cowan, R. D., and Hayes, R. W., Astrophys. J. **187**, 377 (1974).

V XVIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^22p^2$–$2s2p^3$	^3P–$^3D°$	*173.99*	*50480*	*625220*	9	15	63	0.048	0.25	—0.36	C	*interp.*
			176.41	68150	635010	5	7	63	0.041	0.12	—0.68	C—	*ls*
			170.67	37860	623790	3	5	51	0.037	0.063	—0.95	C—	*ls*
			165.35	0	604780	1	3	42	0.051	0.028	—1.29	C—	*ls*
			[179.97]	68150	623790	5	5	15	0.0071	0.021	—1.45	D	*ls*
			[176.39]	37860	604780	3	3	26	0.012	0.021	—1.44	C—	*ls*
			[186.35]	68150	604780	5	3	1.5	4.6(—4)[a]	0.0014	—2.64	D	*ls*
2.		^3P–$^3P°$	*145.12*	*50480*	*739570*	9	9	150	0.048	0.21	—0.36	C	*interp.*
			148.11	68150	743430	5	5	110	0.036	0.088	—0.74	C—	*ls*
			143.39	37860	735290	3	3	41	0.013	0.018	—1.42	C—	*ls*
			149.81	68150	735290	5	3	58	0.012	0.029	—1.23	C—	*ls*
			143.84	37860	733080	3	1	160	0.016	0.023	—1.31	C—	*ls*
			141.73	37860	743430	3	5	41	0.021	0.029	—1.21	C—	*ls*
			136.00	0	735290	1	3	62	0.051	0.023	—1.29	C—	*ls*
3.		^3P–$^3S°$	*118.08*	*50480*	*897340*	9	3	790	0.055	0.19	—0.31	C	*interp.*
			120.60	68150	897340	5	3	420	0.055	0.11	—0.56	C—	*ls*
			116.35	37860	897340	3	3	270	0.055	0.063	—0.78	D	*ls*
			111.44	0	897340	1	3	100	0.057	0.021	—1.24	D	*ls*
4.		^1D–$^1D°$	133.77	[163000]	[911000]	5	5	260	0.070	0.15	—0.46	C	*interp.*
5.		^1D–$^1P°$	117.15	[163000]	[1017000]	5	3	520	0.064	0.12	—0.49	C	*interp.*
6.		^1S–$^1P°$	134.1	[271000]	[1017000]	1	3	150	0.12	0.053	—0.92	C	*interp.*
7.	$2p^2$–$2p3s$	^3P–$^3P°$				9	9		0.045		—0.39	C	*interp.*
8.		^1D–$^1P°$	17.717	[163000]	[5807000]	5	3	1.5(+4)	0.041	0.012	—0.69	C	*interp.*
9.		^1S–$^1P°$	[18.06]	[271000]	[5807000]	1	3	3000	0.044	0.0026	—1.36	C	*interp.*
10.	$2p^2$–$2p3d$	^1D–$^1F°$	16.467	[163000]	[6236000]	5	7	1.7(+5)	0.95	0.26	0.68	C	*interp.*
11.		^1S–$^1P°$	16.816	[271000]	[6218000]	1	3	9.5(+4)	1.21	0.067	0.083	C	*interp.*
12.	$2p^2$–$2p4s$	^3P–$^3P°$				9	9		0.010		—1.05	D	*interp.*
13.	$2s2p^3$–$2p^4$	$^3D°$–^3P				15	9		0.054		—0.09	D—	*interp.*
14.		$^3P°$–^3P				9	9		0.034		—0.51	D	*interp.*
15.	$2p3s$–$2p3p$	$^3P°$–^3D				9	15		0.10		—0.05	D	*interp.*
16.		$^3P°$–^3S				9	3		0.024		—0.67	D	*interp.*
17.		$^3P°$–^3P				9	9		0.083		—0.13	D	*interp.*
18.		$^1P°$–^1P				3	3		0.056		—0.77	D	*interp.*
19.		$^1P°$–^1D				3	5		0.16		—0.32	D	*interp.*
20.	$2p3p$–$2p3d$	^1P–$^1D°$				3	5		0.11		—0.48	D	*interp.*
21.		^1P–$^1P°$				3	3		0.036		—0.97	D	*interp.*

V XVIII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
22.		^3D–$^3P^\circ$				15	9		0.0017		—1.59	D	*interp.*
23.		^3D–$^3F^\circ$				15	21		0.042		—0.20	D—	*interp.*
24.		^3D–$^3D^\circ$				15	15		0.037		—0.26	D	*interp.*
25.		^3S–$^3P^\circ$				3	9		0.088		—0.58	D	*interp.*
26.		^3P–$^3D^\circ$				9	15		0.061		—0.26	D	*interp.*
27.		^3P–$^3P^\circ$				9	9		0.040		—0.44	D	*interp.*
28.		^1D–$^1D^\circ$				5	5		0.0038		—1.72	D	*interp.*
29.		^1D–$^1F^\circ$				5	7		0.12		—0.22	D	*interp.*
30.		^1D–$^1P^\circ$				5	3		7.2(—4)		—2.44	D	*interp.*
31.		^1S–$^1P^\circ$				1	3		0.077		—1.11	D	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XIX

Ground State $1s^2 2s^2 2p\ ^2P^\circ_{1/2}$

Ionization Potential [1353] eV = [1091300] cm^{-1}

Allowed Transitions

The oscillator strength data were derived by interpolation from graphs of systematic trends along the boron isoelectronic sequence. Although in most cases these trends are fairly well established for low Z, V XIX lies at a point in the sequence where significant relativistic changes on line strengths and energy levels are expected to occur. Mainly for this reason, it is estimated that the values presented are uncertain within a factor of two.

V XIX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p$–$2s 2p^2$	$^2P^\circ$–^2D				6	10		0.046		—0.56	E	interp.
2.		$^2P^\circ$–^2S				6	2		0.027		—0.79	E	*interp.*
3.		$^2P^\circ$–^2P	*132.94*	*45750*	*797990*	6	6	420	0.11	0.29	—0.18	E	*interp.*
			136.25	68630	802570	4	4	320	0.089	0.16	—0.45	E	*ls*
			126.77	0	788830	2	2	320	0.077	0.064	—0.81	E	*ls*
			138.84	68630	788830	4	2	120	0.018	0.032	—1.15	E	*ls*
			124.60	0	802570	2	4	84	0.039	0.032	—1.11	E	*ls*
4.	$2s 2p^2$–$2p^3$	^4P–$^4S^\circ$				12	4		0.043		—0.29	E	*interp.*
5.		^2D–$^2D^\circ$				10	10		0.050		—0.30	E	*interp.*
6.		^2D–$^2P^\circ$				10	6		0.028		—0.55	E	*interp.*
7.		^2P–$^2D^\circ$				6	10		0.055		—0.48	E	*interp.*
8.		^2P–$^2P^\circ$				6	6		0.058		—0.46	E	*interp.*
9.	$2p$–$3s$	$^2P^\circ$–^2S				6	2		0.020		—0.92	E	*interp.*
10.	$2p$–$3d$	$^2P^\circ$–^2D				6	10		0.65		0.59	E	*interp.*
11.	$3s$–$3p$	^2S–$^2P^\circ$				2	6		0.17		—0.47	E	*interp.*
12.	$3p$–$3d$	$^2P^\circ$–^2D				6	10		0.055		—0.48	E	*interp.*

V XX

Ground State $1s^2 2s^2\ {}^1S_0$

Ionization Potential [1482] eV = [11953000] cm^{-1}

Allowed Transitions

Oscillator strengths were derived mainly by interpolation from graphs of systematic trends along the Be isoelectronic sequence. For the $2s^2\ {}^1S$–$2s3p\ {}^1P^\circ$ transition we have used the results of the relativistic random phase approximation calculations of Lin and Johnson [1].

The data marked "E" are estimated to be accurate to within a factor of two.

Reference

[1] Lin, C. D., and Johnson, W. R., Phys. Rev. **15**, 1046 (1977).

V XX: Allowed transitions

No.	Transition array	Multiplet	λ (Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2$–$2s2p$	${}^1S$–${}^1P^\circ$	[159.36]	0	[627510]	1	3	150	0.17	0.089	—0.77	C	*interp.*
2.	$2s^2$–$2s3p$	${}^1S$–${}^1P^\circ$	14.38	0	6954000	1	3	6.9(+4)[a]	0.64	0.030	—0.19	C	1
3.	$2s^2$–$2s4p$	${}^1S$–${}^1P^\circ$				1	3		0.16		—0.80	E	*interp.*
4.	$2s2p$–$2p^2$	${}^3P^\circ$–${}^3P$				9	9		0.070		—0.20	D	*interp.*
5.		${}^1P^\circ$–${}^1D$				3	5		0.070		—0.68	D	*interp.*
6.		${}^1P^\circ$–${}^1S$				3	1		0.040		—0.92	D	*interp.*
7.	$2s2p$–$2s3s$	${}^3P^\circ$–${}^3S$				9	3		0.030		—0.57	E	*interp.*
8.		${}^1P^\circ$–${}^1S$				3	1		0.0070		—1.68	E	*interp.*
9.	$2s2p$–$2s3d$	${}^3P^\circ$–${}^3D$				9	15		0.74		0.82	D	*interp.*
10.		${}^1P^\circ$–${}^1D$	15.434	[627510]	[7106700]	3	5	9.1(+4)	0.54	0.082	0.21	D	*interp.*
11.	$2s3s$–$2s3p$	${}^3S$–${}^3P^\circ$				3	9		0.19		—0.24	E	*interp.*
12.		${}^1S$–${}^1P^\circ$				1	3		0.060		—1.22	E	*interp.*
13.	$2s3p$–$2s3d$	${}^1P^\circ$–${}^1D$				3	5		0.055		—0.78	E	*interp.*
14.		${}^3P^\circ$–${}^3D$				9	15		0.030		—0.57	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XXI

Ground State $1s^2 2s\ {}^2S_{1/2}$

Ionization Potential [1570] eV = [12665000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
8.576	6	9.633	12	13.865	2	28.18	16
8.826	14	9.704	12	14.430	10	40.612	15
8.843	5	10.412	3	14.572	10	58.29	32
8.882	14	10.770	11	14.592	10	89.63	31
9.111	13	10.853	11	22.13	18	239.5	1
9.175	13	13.823	2	23.99	17	291.5	1
9.352	4						

The data are taken from the theoretical analysis of Martin and Wiese [1], which was based on a generalized study of systematic trends for several spectral series of the lithium isoelectronic sequence. For the $3d$–$4f$ transition, the f-value was taken from an earlier study of systematic trends along isoelectronic sequences by Smith and Wiese [2].

Results of the relativistic calculations of Kim and Desclaux [3] were incorporated into the data for the $2s$–$2p$ and $2s$–$3p$ transitions. More recently, Armstrong et al. [4] have reported results of relativistic calculations of f-values for the $2s$–$2p$, $2s$–$3p$, and $2p$–$3d$ transitions which agree well with the final recommended data of ref [1]. For all other transitions, no relativistic calculations were available. However, the relativistic calculations of Younger and Weiss [5] for the hydrogen isoelectronic sequence provide a means of assessing the magnitude of relativistic corrections since the Li sequence is very similar in structure to the H sequence. For those transitions for which relativistic effects were estimated to be significant (specifically, whenever the ratio of the weighted relativistic hydrogenic f-values $g_i f_{ik}$ of any two lines within a multiplet was found to deviate from the corresponding LS-coupling line strength ratio by more than 5% for the appropriate value of the nuclear charge Z), the f-values were excluded from the compilation. A more detailed discussion of this comparison is given in ref. [1].

References

[1] Martin, G. A., and Wiese, W. L., J. Phys. Chem. Ref. Data **5**, 537 (1976).

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[4] Armstrong, L., Jr., Fielder, W. R., and Lin, D. L., Phys. Rev. A **14**, 1114 (1976).

[5] Younger, S. M., and Weiss, A. W., J. Res. Nat. Bur. Stand., Sect. A **79**, 629 (1975).

V XXI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s$–$2p$	^2S–$^2P^o$	*254.6*	0	[*392700*]	2	6	24	0.071	0.12	—0.85	B	1
			[239.5]	0	[417500]	2	4	29	0.050	0.079	—1.00	B	1
			[291.5]	0	[343100]	2	2	16	0.020	0.038	—1.40	B	1
2.	$2s$–$3p$	^2S–$^2P^o$	*13.837*	0	*7227000*	2	6	4.30(+4)[a]	0.370	0.0337	—0.131	B+	1
			13.823	0	7234300	2	4	4.26(+4)	0.244	0.0222	—0.312	B+	1
			13.865	0	7212400	2	2	4.37(+4)	0.126	0.0115	—0.599	B+	1
3.	$2s$–$4p$	^2S–$^2P^o$	10.412	0	9604300	2	6	2.0(+4)	0.099	0.0068	—0.70	C+	1
4.	$2s$–$5p$	^2S–$^2P^o$	9.352	0	10690000	2	6	1.0(+4)	0.040	0.0025	—1.10	C+	1
5.	$2s$–$6p$	^2S–$^2P^o$	8.843	0	11310000	2	6	6030	0.0212	0.00123	—1.373	C+	1
6.	$2s$–$7p$	^2S–$^2P^o$	8.576	0	11660000	2	6	3750	0.0124	7.00(—4)	—1.606	C+	1
7.	$2p$–$5s$	$^2P^o$–^2S				6	2		0.0017		—1.99	D+	1
8.	$2p$–$6s$	$^2P^o$–^2S				6	2		8.4(—4)		—2.30	D	1
9.	$2p$–$7s$	$^2P^o$–^2S				6	2		4.8(—4)		—2.54	D	1
10.	$2p$–$3d$	$^2P^o$–^2D	*14.525*	[*392700*]	[*7277200*]	6	10	1.3(+5)	0.68	0.20	0.61	B	1
			14.572	[417500]	[7280000]	4	6	1.3(+5)	0.63	0.12	0.40	B	*ls*
			14.430	[343100]	[7273100]	2	4	1.1(+5)	0.71	0.067	0.15	B	*ls*
			14.592	[417500]	[7273100]	4	4	2.1(+4)	0.068	0.013	—0.57	C+	*ls*
11.	$2p$–$4d$	$^2P^o$–^2D	*10.825*	[*392700*]	[*9630200*]	6	10	4.1(+4)	0.12	0.026	—0.14	B	1
			10.853	[417500]	[9631500]	4	6	4.2(+4)	0.11	0.016	—0.35	B	*ls*
			10.770	[343100]	[9628200]	2	4	3.5(+4)	0.12	0.0087	—0.61	B	*ls*
			10.853	[417500]	[9628200]	4	4	6700	0.012	0.0017	—1.32	C+	*ls*
12.	$2p$–$5d$	$^2P^o$–^2D	*9.683*	[*392700*]	[10720000]	6	10	1.92(+4)	0.0450	0.00861	—0.569	C+	1
			9.704	[417500]	[10720000]	4	6	1.91(+4)	0.0405	0.00517	—0.791	C+	*ls*
			9.633	[343100]	[10720000]	2	4	1.63(+4)	0.0453	0.00287	—1.043	C+	*ls*
			9.704	[417500]	[10720000]	4	4	3200	0.0045	5.7(—4)	—1.75	C	*ls*
13.	$2p$–$6d$	$^2P^o$–^2D	*9.151*	[*392700*]	[11320000]	6	10	1.05(+4)	0.0220	0.00398	—0.879	C+	1
			9.175	[417500]	[11320000]	4	6	1.04(+4)	0.0198	0.00239	—1.102	C+	*ls*
			9.111	[343100]	[11320000]	2	4	8910	0.0222	0.00133	—1.353	C+	*ls*
			9.175	[417500]	[11320000]	4	4	1800	0.0022	2.7(—4)	—2.05	C	*ls*

V XXI: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
14.	2p–7d	$^2P^o$–^2D	*8.860*	*[392700]*	*[11680000]*	6	10	6420	0.0126	0.00221	—1.121	C+	1
			8.882	[417500]	[11680000]	4	6	6410	0.0114	0.00133	—1.342	C+	*ls*
			8.826	[343100]	[11670000]	2	4	5430	0.0127	7.37(—4)	—1.596	C+	*ls*
			8.882	[417500]	[11670000]	4	4	1100	0.0013	1.5(—4)	—2.29	C	*ls*
15.	3s–4p	^2S–$^2P^o$	[40.612]	[7142000]	9604300	2	6	5800	0.43	0.11	—0.07	C	1
16.	3s–5p	^2S–$^2P^o$	[28.18]	[7142000]	10690000	2	6	3000	0.107	0.0199	—0.67	C	1
17.	3s–6p	^2S–$^2P^o$	[23.99]	[7142000]	11310000	2	6	1800	0.047	0.0074	—1.03	C	1
18.	3s–7p	^2S–$^2P^o$	[22.13]	[7142000]	11660000	2	6	1130	0.0249	0.00363	—1.303	C	1
19.	3p–6s	$^2P^o$–^2S				6	2		0.0038		—1.64	C—	1
20.	3p–7s	$^2P^o$–^2S				6	2		0.0018		—1.97	C—	1
21.	3p–4d	$^2P^o$–^2D	*41.611*	*7227000*	*[9630200]*	6	10	1.4(+4)	0.59	0.48	0.55	B	1
22.	3p–5d	$^2P^o$–^2D	*28.63*	*7227000*	[10720000]	6	10	6740	0.138	0.0780	—0.082	C+	1
23.	3p–6d	$^2P^o$–^2D	*24.43*	*7227000*	[11320000]	6	10	3740	0.0558	0.0269	—0.475	C+	1
24.	3p–7d	$^2P^o$–^2D	*22.46*	*7227000*	*[11680000]*	6	10	2290	0.0289	0.0128	—0.761	C+	1
25.	3d–4f	^2D–$^2F^o$				10	14		1.00		1.000	B	2
26.	4s–5p	^2S–$^2P^o$				2	6		0.471		—0.026	C	1
27.	4s–6p	^2S–$^2P^o$				2	6		0.127		—0.60	C	1
28.	4s–7p	^2S–$^2P^o$				2	6		0.056		—0.95	C	1
29.	4p–6s	$^2P^o$–^2S				6	2		0.0146		—1.057	C—	1
30.	4p–7s	$^2P^o$–^2S				6	2		0.0060		—1.44	C—	1
31.	4p–5d	$^2P^o$–^2D	[89.63]	9604300	[10720000]	6	10	2900	0.582	1.03	0.543	C+	1
32.	4p–6d	$^2P^o$–^2D	[58.29]	9604300	[11320000]	6	10	1660	0.141	0.162	—0.073	C+	1
33.	4p–7d	$^2P^o$–^2D	*48.18*	9604300	*[11680000]*	6	10	1060	0.0616	0.0586	—0.432	C+	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XXII

Ground State $1s^2\ ^1S_0$

Ionization Potential [6851] eV = [55258000] cm^{-1}

Allowed Transitions

For this high ion of the He isoelectronic sequence the data were mainly derived by interpolation from well established systematic trends for the lower ions.

Data used in the interpolation of oscillator strengths for the first eight transitions are taken from the relativistic random phase approximation calculation of Johnson and Lin [1]. Their results exhibit a dramatic drop in the oscillator strengths for $Z > 18$, indicating significant relativistic effects on line strengths. The reduced accuracy of the intercombination lines reflects a sudden change in the systematic trend curve, making precise interpolation difficult. For other transitions, not involving the ground state, it is expected that relativistic effects play a much smaller role.

The Z-expansion calculation of Laughlin [2] has been used for four transitions, where it was found to be in good agreement with the accurate variational calculations of Schiff, Pekeris, and Accad [3] for lower Z.

The remaining multiplets were analyzed by extrapolating the variational calculations of Weiss [4] for $Z \leq 10$, which are expected to be quite accurate. Although these extrapolations do not include relativistic effects, they involve relatively highly excited states where such effects are small.

Data for transitions involving highly excited states not tabulated here may be found in the papers of Ali and Schaad [5] and Brown and Cortez [6].

References

[1] Johnson, W. R., and Lin, C. D., Phys. Rev. A **14**, 565 (1976).
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[4] Weiss, A. W., J. Res. Nat. Bur. Stand., Sect. A **71**, 163 (1967).
[5] Ali, M. A., and Schaad, L. J., Mol. Phys. **17**, 441 (1969).
[6] Brown, R. T., and Cortez, J. M., Astrophys. J. **176**, 267 (1972).

V XXII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$1s^2$–$1s2p$	^1S–$^3P^o$											
			2.3939	0	41773000	1	3	2.4(+5)[a]	0.062	4.9(—4)	—1.21	E	*interp.*
2.		^1S–$^1P^o$	2.3823	0	41976000	1	3	2.9(+6)	0.73	0.0057	—0.14	B	*interp.*
3.	$1s^2$–$1s3p$	^1S–$^3P^o$											
						1	3		0.012		—1.92	E	*interp.*
4.		^1S–$^1P^o$				1	3		0.15		—0.82	B	*interp.*
5.	$1s^2$–$1s4p$	^1S–$^3P^o$											
						1	3		0.0040		—2.40	E	*interp.*
6.		^1S–$^1P^o$				1	3		0.053		—1.28	B	*interp.*
7.	$1s^2$–$1s5p$	^1S–$^3P^o$											
						1	3		0.0021		—2.68	E	*interp.*
8.		^1S–$^1P^o$				1	3		0.025		—1.60	B	*interp.*
9.	$1s2s$–$1s2p$	^1S–$^1P^o$				1	3		0.018		—1.74	E	*interp.*
10.		^3S–$^3P^o$				3	9		0.031		—1.03	E	*interp.*
11.	$1s2s$–$1s3p$	^1S–$^1P^o$				1	3		0.41		—0.39	B	*interp.*
12.		^3S–$^3P^o$				3	9		0.41		0.09	B	*interp.*
13.	$1s2p$–$1s3s$	$^1P^o$–^1S				3	1		0.015		—1.35	C	2
14.		$^3P^o$–^3S				9	3		0.015		—0.87	C	2
15.	$1s2p$–$1s3d$	$^1P^o$–^1D				3	5		0.70		0.32	B	*interp.*
16.		$^3P^o$–^3D				9	15		0.69		0.79	B	*interp.*
17.	$1s3s$–$1s3p$	^1S–$^1P^o$				1	3		0.038		—1.42	C	2
18.		^3S–$^3P^o$				3	9		0.050		—0.82	C	2
19.	$1s3p$–$1s3d$	$^3P^o$–^3D				9	15		0.013		—0.93	C	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

V XXIII

Ground State $1s\ ^2S_{1/2}$

Ionization Potential [7248.8] eV = [58465000] cm^{-1}

Allowed Transitions

The transition probability data for this hydrogen-like ion may be obtained by scaling the data available for the hydrogen spectrum (see NSRDS–NBS 4 [1]) according to

$$f_{\text{V XXIII}} = f_{\text{Hydrogen}},$$
$$A_{\text{V XXIII}} = (23)^4 A_{\text{Hydrogen}},$$
$$S_{\text{V XXIII}} = (23)^{-2} S_{\text{Hydrogen}}.$$

An uncertainty of a few percent arises from the neglect of relativistic effects. Recent theoretical studies [2, 3] indicate that relativistic effects on line strengths for this ion are generally in the few percent range, with the relativistic value usually slightly below the non-relativistic one, although in certain transitions where n increases and l decreases the line strength increases. Younger and Weiss [3] have calculated exact Dirac relativistic hydrogenic line strengths for a number of transitions of interest along the hydrogen isoelectronic sequence.

References

[1] Wiese, W. L., Smith, M. W., and Glennon, B. M., Atomic Transition Probabilities—Hydrogen through Neon (A Critical Data Compilation), Vol. I, 157 pp., Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 4 (May 1966).

[2] Garstang, R. H., *Topics in Modern Physics (A Tribute to Edward U. Condon)*, 153–167, (Ed. Brittin, W. E., and Odabasi, H., Colorado Associated Univ. Press, Boulder, Colorado 1971).

[3] Younger, S. M., and Weiss, A. W., J. Res. Nat. Bur. Stand., Sect. A **79**, 629 (1975).

Chromium

Cr I

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s\ {}^7S_3$

Ionization Potential $6.766\ \text{eV} = 54570\ \text{cm}^{-1}$

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
1999.97	40	2690.25	27	3034.19	21	4057.81	94
2094.93	7	2696.53	14	3037.04	22	4058.77	94
2095.39	7	2700.59	26	3040.85	22	4066.94	52
2095.88	7	2701.99	27	3053.88	21	4161.42	102
2354.30	39	2703.48	27	3148.45	64	4165.52	102
2364.73	6	2716.18	26	3155.15	64	4203.59	43
2365.91	6	2726.50	13	3160.61	64	4211.35	69
2366.81	6	2731.90	13	3163.76	64	4213.18	77
2375.06	38	2736.46	13	3237.73	63	4224.51	77
2383.30	38	2751.58	25	3238.09	63	4238.96	68
2385.72	38	2752.85	25	3351.97	5	4254.35	1
2389.21	37	2757.09	25	3379.17	5	4271.06	76
2408.60	36	2761.74	25	3578.69	4	4274.80	1
2408.72	36	2764.36	25	3593.49	4	4280.41	93
2479.14	35	2769.90	25	3605.33	4	4289.72	1
2492.57	34	2780.70	25	3615.65	3	4293.57	58
2495.08	34	2871.63	24	3635.28	3	4295.76	51
2496.30	34	2879.27	24	3639.80	46	4297.74	93
2499.84	34	2887.00	24	3730.81	2	4305.45	58
2502.55	35	2889.29	24	3732.03	2	4319.64	58
2504.31	34	2893.25	24	3768.73	45	4337.57	18
2508.11	33	2894.17	24	3804.80	71	4339.45	18
2508.97	33	2896.76	24	3849.53	20	4339.72	18
2513.62	33	2899.20	24	3852.22	20	4344.51	18
2527.11	33	2905.48	24	3879.22	70	4346.83	62
2538.95	15	2909.05	24	3883.29	19	4351.05	18
2544.70	15	2910.89	24	3885.22	19	4351.77	18
2549.55	32	2911.15	24	3886.79	19	4359.63	18
2560.70	32	2967.64	23	3894.04	19	4371.28	18
2571.74	32	2971.10	23	3902.92	19	4374.16	62
2577.66	32	2975.48	23	3903.16	19	4375.33	61
2579.14	30	2980.78	23	3908.76	19	4377.55	55
2584.67	31	2988.64	12	3916.24	19	4381.11	51
2588.19	30	2991.88	23	3919.16	19	4384.98	18
2591.84	32	2994.06	12	3921.02	19	4387.50	61
2603.56	30	2995.09	11	3928.64	19	4389.9	67
2618.27	28	2996.57	23	3941.49	19	4397.25	66
2620.48	28	2998.78	12	3963.69	44	4399.82	66
2622.87	29	3000.88	23	3969.75	44	4413.87	91
2625.32	28	3005.06	23	3976.01	44	4432.18	54
2626.60	29	3013.71	21	3981.23	53	4458.54	65
2629.82	28	3020.67	22	3983.91	44	4475.35	57
2669.36	27	3021.56	22	4001.44	95	4482.88	85
2671.98	27	3024.35	21	4031.13	95	4488.05	100
2673.64	27	3029.16	21	4039.10	94	4496.86	10
2678.15	27	3030.25	22	4039.30	94	4498.73	54
2680.33	27	3031.35	22	4048.78	94	4506.85	99

List of tabulated lines—Continued

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
4511.90	75	4689.37	83	4880.06	79	5247.56	16
4526.47	42	4693.95	59	4887.01	72	5261.75	92
4530.76	42	4697.06	50	4903.24	41	5264.15	16
4540.72	75	4700.61	50	4922.27	72	5265.72	16
4544.62	42	4708.04	83	4936.33	78	5272.01	90
4545.96	10	4718.43	83	4942.50	9	5287.19	90
4548.7	98	4723.06	74	4954.81	78	5296.69	16
4565.51	17	4724.42	74	4964.93	9	5298.27	16
4580.06	10	4727.15	59	5013.32	48	5300.75	16
4591.39	17	4729.72	81	5034.6	101	5304.21	90
4595.59	97	4730.71	74	5045.3	101	5312.88	90
4600.75	17	4737.35	74	5139.65	89	5318.78	90
4611.0	60	4745.31	49	5177.43	86	5328.34	56
4613.37	17	4789.35	41	5184.59	86	5340.44	90
4616.14	17	4792.51	80	5192.00	86	5345.81	16
4617.4	60	4801.03	80	5193.49	88	5348.32	16
4626.19	17	4810.73	73	5196.57	89	5400.61	84
4632.18	82	4814.27	73	5200.19	86	5409.79	16
4639.54	83	4825.51	73	5204.52	8	5548.5	87
4646.17	17	4836.86	73	5206.04	8	5566.7	87
4648.3	60	4847.18	73	5208.44	8	5581.6	87
4651.29	17	4870.80	72	5238.97	47	5588.2	87
4652.16	17	4874.65	79	5243.40	86	7170.6	96

For this spectrum we have utilized eleven data sources, which are all recent experiments. These are the total absorption measurements of Bieniewski [1]; anomalous dispersion (hook) measurements (plus a few absorption measurements) of Huber and Sandeman [2] and Penkin [3]; shock tube absorption studies of Huber and Tobey [11]; emission experiments with a shock tube by Wolnik et al. [8,9], and with a hollow cathode by Cocke et al. [10] (the latter measurements were restricted to "branching ratio" determinations in conjunction with available beam-foil lifetimes); and finally four lifetime determinations (refs. [4,5,6,7]) from which oscillator strengths could be directly derived.

Very accurate lifetime measurements are those by Marek [6], who selectively populated the levels under study by means of two-step excitation with two dye lasers and then measured the corresponding lifetimes by the delayed coincidence technique; and those by Becker, Bucka, and Schmidt [4], who employed the level-crossing method. A comparison of their results, as well as those of Marek and Richter [5] and Cocke et al. [7], is possible for some lines in the two multiplets $a\,^7S$–$z\,^7P^\circ$ and $a\,^7S$–$y\,^7P^\circ$, and is presented in the table below. The comparison also includes the absolute scale obtained by Bieniewski. Very weak downward transitions to levels other than the ground state were not included in our lifetime to f-value conversions because of lack of data, but these decay contributions are estimated by Huber and Sandeman to be about 0.5% for the $z\,^7P^\circ$ level and should not be appreciably different for the other upper level involved. The mutual agreement among the selected data sources is quite remarkable. We thus consider the averaged values to be accurate within ±10 percent for these two multiplets.

Multiplet	λ(Å)	f_{ik} (Bieniewski [1])	f_{ik}[a] (Becker, Bucka, and Schmidt [4])[b]	f_{ik}[a] (Marek and Richter [5])[c]	f_{ik}[a] (Marek [6])[d]	f_{ik}[a] (Cocke, Curnutte and Brand [7])[e]
$a\,^7S$–$z\,^7P^\circ$ (1)	4254.35	0.106	0.111	0.111	0.110	0.10
	4274.80	0.082	0.0849	0.0841		
	4289.72	0.059	0.0616	0.0646		
$a\,^7S$–$y\,^7P^\circ$ (4)	3578.69	0.34	0.355	0.402		
	3593.49	0.28	0.271	0.319		
	3605.33	0.21	0.220	0.244		

[a] Listed oscillator strengths have been derived from lifetime measurements.
[b] Level crossing technique.
[c] Phase shift method.
[d] Laser excitation—delayed coincidence technique.
[e] Beam-foil technique.

The above cited lines are of key importance for the spectrum since they provide essentially the basis for the absolute scale. The extensive "hook" data by Huber and Sandeman [2], which we selected as the principal source for this spectrum, are actually based on the scale of Becker et al. only. But that scale, as the table above shows, is so close to the averaged values, that we did adopt the data of Huber and Sandeman without any change. Also, we followed their carefully documented error estimates throughout. The data of Wolnik et al. [8,9], which are systematically lower than those of Huber and Sandeman, have been increased by a factor of 1.35 to be consistent with the adopted absolute scale. The data of Cocke et al. [10] and Penkin [3] agree quite well with those of Huber and Sandeman [2] for overlapping lines, so that we have left their oscillator strength scale unchanged.

In the case of the multiplet $a\,^5S$–$z\,^5P°$, a self-absorption problem may be present. This was brought to our attention by Whaling [12] who recently measured some line ratios involving the 5208.44 and 5206.04 Å lines. Whaling's values, obtained by means of a branching ratio analysis with a hollow cathode, differ by about 30 percent from the analogous ratios measured by Huber and Sandeman and some unpublished results of Bridges [13]. Since we could not resolve the discrepancy, we have lowered the accuracies for this multiplet accordingly. Finally, it should be noted that Wolnik et al. and Cocke et al. are in strong disagreement for a few lines arising from high upper levels ($E_k > 5.8$ eV), and we have therefore omitted these lines.

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Cr I: Allowed transitions

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$a\,^7S$–$z\,^7P°$ (1)	*4269.6*	0	*23415*	7	21	0.312	0.256	25.2	0.254	B	1,4,5,6
		4254.35	0	23499	7	9	0.315	0.110	10.8	—0.114	B	1,4,5,6
		4274.80	0	23386	7	7	0.306	0.0837	8.25	—0.232	B	1,4,5
		4289.72	0	23305	7	5	0.313	0.0617	6.10	—0.365	B	1,4,5
2.	$a\,^7S$–$z\,^5P°$ (2)											
		3732.03	0	26788	7	7	0.0017	3.5(—4)[a]	0.030	—2.61	C	2
		3730.81	0	26796	7	5	0.0017	2.5(—4)	0.021	—2.76	C	2
3.	$a\,^7S$–$z\,^7D°$ (3)											
		3615.65	0	27650	7	9	5.1(—4)	1.3(—4)	0.011	—3.05	C—	2
		3635.28	0	27500	7	7	1.5(—4)	3.1(—5)	0.0026	—3.67	C—	2
4.	$a\,^7S$–$y\,^7P°$ (4)	*3589.9*	0	*27848*	7	21	1.52	0.881	72.9	0.790	B	1,4,5
		3578.69	0	27935	7	9	1.48	0.366	30.2	0.409	B	1,4,5
		3593.49	0	27820	7	7	1.50	0.290	24.0	0.307	B	1,4,5
		3605.33	0	27729	7	5	1.62	0.225	18.7	0.197	B	1,4,5
5.	$a\,^7S$–$y\,^5P°$ (5)											
		3351.97	0	29825	7	7	0.0010	1.7(—4)	0.013	—2.92	C—	2
		3379.17	0	29585	7	5	9.3(—4)	1.1(—4)	0.0088	—3.10	C—	2
6.	$a\,^7S$–$x\,^7P°$ (uv 1)	*2365.6*	0	*42259*	7	21	0.057	0.014	0.78	—1.00	C	2
		2364.73	0	42275	7	9	0.053	0.0057	0.31	—1.40	C	2
		2365.91	0	42254	7	7	0.055	0.0046	0.25	—1.49	C	2
		2366.81	0	42238	7	5	0.069	0.0041	0.22	—1.54	C	2

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
7.	$a\,^7S$–$w\,^7P°$ (uv 2)	*2095.3*	0	*47710*	7	21	0.0114	0.00226	0.109	—1.80	C	2
		2094.93	0	47719	7	9	0.012	9.9(—4)	0.048	—2.16	C	2
		2095.39	0	47709	7	7	0.011	7.3(—4)	0.035	—2.29	C	2
		2095.88	0	47697	7	5	0.011	5.3(—4)	0.026	—2.43	C	2
8.	$a\,^5S$–$z\,^5P°$ (7)	*5206.9*	7593	*26793*	5	15	0.53	0.64	55	0.51	D—	2
		5208.44	7593	26788	5	7	0.51	0.29	25	0.16	D—	2
		5206.04	7593	26796	5	5	0.53	0.21	18	0.03	D—	2
		5204.52	7593	26802	5	3	0.55	0.14	12	—0.17	D—	2
9.	$a\,^5S$–$y\,^7P°$ (9)											
		4942.50	7593	27820	5	7	0.0021	0.0011	0.089	—2.26	D—	9*n*
		4964.93	7593	27729	5	5	0.0018	6.8(—4)	0.056	—2.47	D—	9*n*
10.	$a\,^5S$–$y\,^5P°$ (10)	*4529.6*	7593	*29664*	5	15	0.036	0.034	2.5	—0.78	C—	3
		4496.86	7593	29825	5	7	0.038	0.016	1.2	—1.10	C—	3
		4545.96	7593	29585	5	5	0.036	0.011	0.82	—1.26	C—	3
		4580.06	7593	29421	5	3	0.04	0.007	0.5	—1.5	C—	3
11.	$a\,^5S$–$y\,^5F°$ (uv 3)											
		2995.09	7593	40971	5	5	0.43	0.058	2.8	—0.54	D	2
12.	$a\,^5S$–$x\,^5P°$ (uv 4)	*2992.5*	7593	*41000*	5	15	0.45	0.18	8.9	—0.04	D	2
		2988.64	7593	41043	5	7	0.52	0.098	4.8	—0.31	C	2
		2994.06	7593	40983	5	5	0.25	0.034	1.7	—0.77	E	2
		2998.78	7593	40930	5	3	0.59	0.048	2.4	—0.62	D—	2
13.	$a\,^5S$–$w\,^5P°$ (uv 7)	*2730.3*	7593	*44208*	5	15	0.76	0.256	11.5	0.107	C	2
		2726.50	7593	44259	5	7	0.75	0.12	5.3	—0.23	C	2
		2731.90	7593	44187	5	5	0.78	0.087	3.9	—0.36	C	2
		2736.46	7593	44126	5	3	0.75	0.050	2.3	—0.60	D	2
14.	$a\,^5S$–$v\,^5P°$ (uv 8)											
		2696.53	7593	44667	5	3	0.12	0.0076	0.34	—1.42	D	2
15.	$a\,^5S$–$u\,^5P°$ (uv 9)											
		2544.70	7593	46879	5	7	0.11	0.014	0.61	—1.14	D—	2
		2538.95	7593	46968	5	5	0.11	0.010	0.44	—1.28	E	2
16.	$a\,^5D$–$z\,^5P°$ (18)											
		5409.79	8308	26788	9	7	0.062	0.021	3.4	—0.72	D—	2
		5345.81	8095	26796	7	5	0.057	0.018	2.2	—0.91	D	2
		5296.69	7927	26802	5	3	0.037	0.0094	0.82	—1.33	D—	2
		5348.32	8095	26788	7	7	0.017	0.0073	0.90	—1.29	D—	2
		5298.27	7927	26796	5	5	0.034	0.014	1.3	—1.14	D—	2
		5264.15	7811	26802	3	3	0.044	0.018	0.95	—1.26	D—	2
		5300.75	7927	26788	5	7	0.0048	0.0028	0.25	—1.85	E	2
		5265.72	7811	26796	3	5	0.0096	0.0067	0.35	—1.70	D—	2
		5247.56	7751	26802	1	3	0.027	0.033	0.57	—1.48	C—	3

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
17.	$a\,^5D$–$y\,^5P°$ (21)	*4633.9*	*8090*	*29664*	25	15	0.13	0.025	9.7	—0.20	C—	3,8*n*
		4646.17	8308	29825	9	7	0.087	0.022	3.0	—0.70	C	3
		4652.16	8095	29585	7	5	0.073	0.017	1.8	—0.92	C	3
		4651.29	7927	29421	5	3	0.042	0.0081	0.62	—1.39	D	8*n*
		4600.75	8095	29825	7	7	0.035	0.011	1.2	—1.11	C—	3
		4616.14	7927	29585	5	5	0.047	0.015	1.1	—1.12	C—	3
		4626.19	7811	29421	3	3	0.059	0.019	0.87	—1.24	C—	3
		4565.51	7927	29825	5	7	0.0080	0.0035	0.26	—1.76	C—	3
		4591.39	7811	29585	3	5	0.02	0.008	0.4	—1.6	C—	3
		4613.37	7751	29421	1	3	0.033	0.032	0.49	—1.49	C—	3
18.	$a\,^5D$–$z\,^5F°$ (22)											
		4351.77	8308	31280	9	11	0.12	0.040	5.2	—0.44	C	2
		4344.51	8095	31106	7	9	0.11	0.040	4.0	—0.55	C	2
		4339.45	7927	30965	5	7	0.099	0.039	2.8	—0.71	C	2
		4337.57	7811	30859	3	5	0.080	0.037	1.6	—0.95	C	2
		4339.72	7751	30787	1	3	0.066	0.056	0.80	—1.25	D	2
		4384.98	8308	31106	9	9	0.027	0.0079	1.0	—1.15	D	2
		4371.28	8095	30965	7	7	0.041	0.012	1.2	—1.09	C	2
		4359.63	7927	30859	5	5	0.054	0.016	1.1	—1.11	C	2
		4351.05	7811	30787	3	3	0.066	0.019	0.81	—1.25	D	2
19.	$a\,^5D$–$z\,^5D°$ (23)	*3910.5*	*8090*	*33655*	25	25	0.12	0.028	8.9	—0.16	C—	2
		3919.16	8308	33816	9	9	0.092	0.021	2.5	—0.72	C	2
		3908.76	8095	33672	7	7	0.062	0.014	1.3	—1.00	C—	2
		3902.92	7927	33542	5	5	0.035	0.0080	0.51	—1.40	D	2
		3903.16	7811	33424	3	3	0.018	0.0041	0.16	—1.91	D—	2
		3941.49	8308	33672	9	7	0.028	0.0051	0.59	—1.34	C—	2
		3928.64	8095	33542	7	5	0.052	0.0086	0.78	—1.22	C	2
		3921.02	7927	33424	5	3	0.058	0.0080	0.51	—1.40	C	2
		3916.24	7811	33338	3	1	0.097	0.0075	0.29	—1.65	C	2
		3886.79	8095	33816	7	9	0.022	0.0065	0.58	—1.34	C—	2
		3883.29	7927	33672	5	7	0.039	0.012	0.79	—1.21	C	2
		3885.22	7811	33542	3	5	0.039	0.015	0.56	—1.36	C—	2
		3894.04	7751	33424	1	3	0.039	0.026	0.34	—1.58	C—	2
20.	$a\,^5D$–$z\,^3P°$ (24)											
		3849.53	7927	33897	5	3	0.023	0.0030	0.19	—1.82	E	2
		3852.22	7811	33763	3	1	0.070	0.0052	0.20	—1.81	E	2
21.	$a\,^5D$–$x\,^5P°$ (26)											
		3053.88	8308	41043	9	7	1.2	0.13	12	0.06	C	2
		3029.16	7927	40930	5	3	0.38	0.032	1.6	—0.80	E	2
		3034.19	8095	41043	7	7	0.35	0.048	3.4	—0.47	D	2
		3024.35	7927	40983	5	5	2.3	0.32	16	0.20	C	2
		3013.71	7811	40983	3	5	0.83	0.19	5.6	—0.25	C	2
22.	$a\,^5D$–$y\,^5F°$ (27)											
		3021.56	8308	41393	9	11	3.2	0.53	48	0.68	C	2
		3037.04	8308	41225	9	9	0.54	0.075	6.8	—0.17	C	2
		3030.25	8095	41086	7	7	1.1	0.15	10	0.02	C	2
		3020.67	7811	40906	3	3	1.5	0.21	6.1	—0.21	D—	2
		3040.85	8095	40971	7	5	0.74	0.073	5.1	—0.29	D	2
		3031.35	7927	40906	5	3	0.31	0.026	1.3	—0.89	E	2

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
23.	$a\,^5D$–$y\,^5D^\circ$ (uv 11)											
		3005.06	8308	41575	9	7	0.92	0.097	8.6	—0.06	C—	2
		3000.88	8095	41409	7	5	1.6	0.15	10	0.02	C—	2
		2996.57	7927	41289	5	3	2.0	0.16	7.8	—0.10	C	2
		2991.88	7811	41225	3	1	3.0	0.14	4.0	—0.39	D	2
		2967.64	8095	41782	7	9	0.39	0.067	4.6	—0.33	D	2
		2971.10	7927	41575	5	7	0.71	0.13	6.5	—0.18	C	2
		2975.48	7811	41409	3	5	0.89	0.20	5.8	—0.23	C	2
		2980.78	7751	41289	1	3	0.85	0.34	3.3	—0.47	D	2
24.	$a\,^5D$–$x\,^5D^\circ$ (uv 12)	*2893.5*	*8090*	*42640*	25	25	0.93	0.117	27.9	0.467	C—	2
		2889.29	8308	42909	9	9	0.66	0.082	7.1	—0.13	C	2
		2893.25	8095	42648	7	7	0.52	0.065	4.4	—0.34	C	2
		2896.76	7927	42439	5	5	0.30	0.037	1.8	—0.73	C—	2
		2899.20	7811	42293	3	3	0.15	0.019	0.55	—1.24	D—	2
		2911.15	8308	42648	9	7	0.26	0.025	2.2	—0.64	D	2
		2910.89	8095	42439	7	5	0.34	0.031	2.1	—0.66	D	2
		2909.05	7927	42293	5	3	0.68	0.051	2.5	—0.59	C	2
		2905.48	7811	42218	3	1	1.3	0.053	1.5	—0.80	D	2
		2871.63	8095	42909	7	9	0.12	0.018	1.2	—0.89	D—	2
		2879.27	7927	42648	5	7	0.21	0.036	1.7	—0.74	D	2
		2887.00	7811	42439	3	5	0.27	0.055	1.6	—0.78	D	2
		2874.17	7751	42293	1	3	0.33	0.12	1.2	—0.91	D—	2
25.	$a\,^5D$–$w\,^5P^\circ$ (uv 15)											
		2780.70	8308	44259	9	7	1.4	0.13	11	0.07	C	2
		2769.90	8095	44187	7	5	1.1	0.090	5.8	—0.20	C	2
		2761.74	7927	44126	5	3	0.68	0.047	2.1	—0.63	D	2
		2764.36	8095	44259	7	7	0.37	0.042	2.7	—0.53	D	2
		2757.09	7927	44187	5	5	0.68	0.078	3.5	—0.41	C	2
		2752.85	7811	44126	3	3	0.87	0.098	2.7	—0.53	D	2
		2751.58	7927	44259	5	7	0.069	0.011	0.50	—1.26	D—	2
26.	$a\,^5D$–$v\,^5P^\circ$ (uv 17)											
		2716.18	8308	45113	9	7	0.11	0.0092	0.74	—1.08	C	2
		2700.59	8095	45113	7	7	0.075	0.0082	0.51	—1.24	D	2
27.	$a\,^5D$–$x\,^5F^\circ$ (uv 18)											
		2701.99	8308	45306	9	11	0.21	0.028	2.2	—0.60	C	2
		2678.15	7927	45256	5	7	0.12	0.018	0.79	—1.05	C	2
		2671.98	7811	45225	3	5	0.12	0.022	0.57	—1.19	D—	2
		2669.36	7751	45202	1	3	0.12	0.039	0.34	—1.41	E	2
		2703.48	8308	45286	9	9	0.063	0.0069	0.55	—1.21	D	2
		2690.25	8095	45256	7	7	0.085	0.0092	0.57	—1.19	D	2
		2680.33	7927	45225	5	5	0.10	0.011	0.47	—1.27	D	2
		2673.64	7811	45202	3	3	0.18	0.019	0.51	—1.24	E	2
28.	$a\,^5D$–$y\,^3D^\circ$ (uv 20)											
		2629.82	8095	46109	7	5	0.080	0.0060	0.36	—1.38	E	2
		2620.48	7927	46077	5	3	0.19	0.012	0.50	—1.24	E	2
		2625.32	8095	46174	7	7	0.091	0.0094	0.57	—1.18	E	2
		2618.27	7927	46109	5	5	0.095	0.0098	0.42	—1.31	E	2

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
29.	$a\,^5D$–w $^5D^\circ$ (uv 21)											
		2622.87	8308	46422	9	9	0.13	0.013	1.0	—0.92	D—	2
		2626.60	8308	46368	9	7	0.093	0.0075	0.58	—1.17	E	2
30.	$a\,^5D$–$w\,^5F^\circ$ (uv 22)											
		2603.56	8308	46705	9	11	0.062	0.0077	0.59	—1.16	E	2
		2588.19	8095	46721	7	9	0.088	0.011	0.68	—1.10	E	2
		2579.14	7927	46688	5	7	0.11	0.015	0.64	—1.12	D—	2
31.	$a\,^5D$–$z\,^3G^\circ$ (uv 23)											
		2584.67	8308	46986	9	11	0.061	0.0075	0.58	—1.17	E	2
32.	$a\,^5D$–$u\,^5P^\circ$ (uv 24)											
		2591.84	8308	46879	9	7	0.65	0.051	3.9	—0.34	C	2
		2571.74	8095	46968	7	5	0.64	0.045	2.7	—0.50	E	2
		2577.66	8095	46879	7	7	0.26	0.025	1.5	—0.75	D—	2
		2560.70	7927	46968	5	5	0.43	0.042	1.8	—0.68	D—	2
		2549.55	7811	47022	3	3	0.48	0.047	1.2	—0.85	D—	2
33.	$a\,^5D$–$v\,^5D^\circ$ (uv 30)											
		2527.11	8308	47866	9	9	0.53	0.051	3.8	—0.34	E	2
		2508.11	7927	47786	5	5	0.21	0.020	0.81	—1.01	D—	2
		2508.97	7927	47772	5	3	0.38	0.021	0.89	—0.97	C—	2
		2513.62	8095	47866	7	9	0.11	0.014	0.81	—1.01	C	2
34.	$a\,^5D$–$u\,^5F^\circ$ (uv 31)											
		2504.31	8095	48014	7	9	0.45	0.054	3.1	—0.42	C	2
		2496.30	7927	47975	5	7	0.56	0.073	3.0	—0.44	C	2
		2492.57	7811	47918	3	5	0.45	0.070	1.7	—0.68	C	2
		2499.84	7927	47918	5	5	0.16	0.015	0.61	—1.13	E	2
		2495.08	7811	47878	3	3	0.27	0.025	0.62	—1.12	C	2
35.	$a\,^5D$–$t\,^5F^\circ$ (uv 32)											
		2502.55	8095	48043	7	9	0.22	0.026	1.5	—0.74	D	2
		2479.14	7924	48252	5	7	0.098	0.013	0.51	—1.20	D	2
36.	$a\,^5D$–$t\,^5P^\circ$ (uv 36)											
		2408.60	8308	49812	9	7	0.67	0.045	3.2	—0.39	D—	2
		2408.72	8095	49598	7	5	0.29	0.018	1.0	—0.90	D—	2
37.	$a\,^5D$–$x\,^3F^\circ$ (uv 37)											
		2389.21	7811	49653	3	5	0.23	0.033	0.77	—1.01	D—	2
38.	$a\,^5D$–$s\,^5F^\circ$ (uv 39)											
		2383.30	8303	50253	9	11	0.41	0.042	3.0	—0.42	D—	2
		2385.72	8308	50211	9	9	0.17	0.014	1.0	—0.89	D—	2
		2375.06	7927	50019	5	3	0.17	0.0085	0.33	—1.37	E	2
39.	$a\,^5D$–$u\,^5D^\circ$ (uv 40)											
		2354.30	8095	50558	7	9	0.081	0.0086	0.47	—1.22	D—	2

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
40.	$a\,^5D$–$r\,^5D^\circ$ (uv 48)											
		1999.97	8308	58293	9	9	1.4	0.082	4.9	—0.13	D—	2
41.	$a\,^5G$–$y\,^5F^\circ$ (31)											
		4789.35	20520	41393	13	11	0.076	0.022	4.5	—0.54	D	9*n*
		4903.24	20517	40906	5	3	0.074	0.016	1.3	—1.10	D	9*n*
42.	$a\,^5G$–$z\,^5G^\circ$ (33)											
		4526.47	20520	42606	13	13	0.20	0.062	12	—0.09	D	8*n*
		4530.76	20525	42589	11	11	0.20	0.063	10	—0.16	D	8*n*
		4544.62	20517	42515	5	5	0.26	0.081	6.1	—0.39	D	8*n*
43.	$a\,^5G$–$y\,^5G^\circ$ (35)											
		4203.59	20517	44300	5	5	0.057	0.015	1.0	—1.12	D	9*n*
44.	$a\,^5G$–$y\,^5H^\circ$ (38)											
		3963.69	20520	45741	13	15	1.3	0.36	61	0.67	D—	2
		3969.75	20524	45707	11	13	1.2	0.35	50	0.58	D—	2
		3983.91	20521	45615	7	9	1.05	0.32	29	0.35	C—	10
		3976.01	20520	45663	13	11	0.0023	4.6(—4)	0.078	—2.22	D	10
45.	$a\,^5G$–$x\,^5G^\circ$ (43)											
		3768.73	20521	47047	7	5	0.22	0.033	2.8	—0.64	D	11
46.	$a\,^5G$–$u\,^5F^\circ$ (47)											
		3639.80	20520	47986	13	11	1.8	0.30	47	0.59	D	11
47.	$a\,^5P$–$x\,^5P^\circ$ (59)											
		5238.97	21848	40930	5	3	0.045	0.011	0.95	—1.26	D	9*n*
48.	$a\,^5P$–$y\,^5D^\circ$ (60)											
		5013.32	21841	41782	7	9	0.035	0.017	2.0	—0.92	D	9*n*
49.	$a\,^5P$–$x\,^5D^\circ$ (61)											
		4745.31	21841	42909	7	9	0.020	0.0087	0.95	—1.22	D	9*n*
50.	$a\,^5P$–$z\,^5S^\circ$ (62)											
		4697.06	21841	43125	7	5	0.072	0.017	1.8	—0.92	D	9*n*
		4700.61	21857	43125	3	5	0.043	0.024	1.1	—1.14	D	9*n*
51.	$a\,^5P$–$v\,^5P^\circ$ (64)											
		4295.76	21841	45113	7	7	0.098	0.027	2.7	—0.72	D	9*n*
		4381.11	21848	44667	5	3	0.10	0.018	1.3	—1.05	D	9*n*
52.	$a\,^5P$–$w\,^5D^\circ$ (66)											
		4066.94	21841	46422	7	9	0.060	0.019	1.8	—0.88	D	9*n*

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
53.	$a\,^5P$–$u\,^5P°$ (67)											
		3981.23	21857	46968	3	5	0.11	0.045	1.8	—0.87	D	9*n*
54.	$a\,^3P$–$y\,^3P°$ (81)											
		4498.73	23512	45734	3	5	0.089	0.045	2.0	—0.87	D	9*n*
		4432.18	23163	45719	1	3	0.17	0.15	2.2	—0.82	D	9*n*
55.	$a\,^3P$–$w\,^3D°$ (83)											
		4377.55	23512	46350	3	5	0.067	0.032	1.4	—1.02	D	9*n*
56.	$z\,^7P°$–$e\,^7D$ (94)											
		5328.34	23499	42261	9	11	0.60	0.31	49	0.45	D	8*n*
57.	$z\,^7P°$–$f\,^7S$ (95)											
		4475.35	23305	45643	5	7	0.050	0.021	1.5	—0.98	D	9*n*
58.	$z\,^7P°$–$f\,^7D$ (96)											
		4293.57	23499	46783	9	9	0.043	0.012	1.5	—0.97	D	9*n*
		4305.45	23305	46525	5	5	0.076	0.021	1.5	—0.98	D	9*n*
		4319.64	23305	46449	5	3	0.18	0.030	2.1	—0.82	D	9*n*
59.	$a\,^3H$–$z\,^3H°$ (99)											
		4727.15	24200	45349	13	13	0.051	0.017	3.4	—0.66	D	9*n*
		4693.95	24056	45354	11	11	0.042	0.014	2.4	—0.81	D	9*n*
60.	$a\,^3H$–$y\,^5H°$											
		[4617.4]	24056	45707	11	13	5.1(—4)	1.9(—4)	0.032	—2.67	D—	10
		[4648.3]	24200	45707	13	13	0.0015	4.9(—4)	0.097	—2.20	D—	10
		[4611.0]	23934	45615	9	9	0.0020	6.4(—4)	0.087	—2.24	D—	10
61.	$a\,^3H$–$z\,^3G°$ (103)											
		4387.50	24200	46986	13	11	0.066	0.016	3.0	—0.68	D	9*n*
		4375.33	24056	46905	11	9	0.072	0.017	2.7	—0.73	D	9*n*
62.	$a\,^3H$–$y\,^3G°$ (104)											
		4374.16	24200	47055	13	11	0.10	0.024	4.5	—0.50	C—	10
		4346.83	24056	47055	11	9	0.099	0.023	3.6	—0.60	D	9*n*
63.	$a\,^3H$–$v\,^3H°$ (114)											
		3238.09	24056	54930	11	11	0.20	0.032	3.7	—0.46	D	11
		3237.73	23934	54811	9	9	1.3	0.20	19	0.25	D	11
64.	$a\,^3H$–$x\,^3I°$ (115)											
		3163.76	24200	55799	13	15	0.52	0.090	12	0.07	C—	10
		3155.15	24056	55741	11	13	0.54	0.095	11	0.02	C—	10
		3148.45	23934	55686	9	11	0.59	0.11	10	—0.02	C—	10
		3160.61	24056	55686	11	11	0.038	0.0057	0.65	—1.20	D	10

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
65.	$b\ ^5D$–$w\ ^5F°$ (127)											
		4458.54	24282	46705	9	11	0.13	0.046	6.1	—0.38	D	9*n*
66.	$b\ ^5D$–$u\ ^5P°$ (129)											
		4399.82	24300	47022	5	3	0.098	0.017	1.2	—1.07	D	9*n*
		4397.25	24287	47022	3	3	0.10	0.029	1.3	—1.06	D	9*n*
67.	$b\ ^5D$–$y\ ^3G°$											
		[4389.9]	24282	47055	9	11	2.0(—4)	7.1(—5)	0.0092	—3.20	E	10
68.	$b\ ^5D$–$v\ ^5D°$ (131)											
		4238.96	24282	47866	9	9	0.071	0.019	2.4	—0.77	D	9*n*
69.	$b\ ^5D$–$t\ ^5F°$ (133)											
		4211.35	24304	48043	7	9	0.085	0.029	2.8	—0.69	D	9*n*
70.	$b\ ^5D$–$s\ ^5F°$ (138)											
		3879.22	24287	50058	3	5	0.56	0.21	8.0	—0.20	D	9*n*
71.	$b\ ^5D$–$u\ ^5D°$ (139)											
		3804.80	24282	50558	9	9	0.69	0.15	17	0.13	D	8*n*
72.	$a\ ^3G$–$z\ ^3H°$ (143)											
		4922.27	25039	45349	11	13	0.40	0.17	30	0.27	D	8*n*
		4887.01	24898	45354	9	11	0.32	0.14	20	0.10	D	8*n*
		4870.80	24834	45359	7	9	0.35	0.16	18	0.05	D	8*n*
73.	$a\ ^3G$–$y\ ^5H°$ (144)											
		4836.86	25039	45707	11	13	0.019	0.0079	1.4	—1.06	C—	10
		4814.27	24898	45663	9	11	0.016	0.0068	0.97	—1.21	C—	10
		4810.73	24834	45615	7	9	0.016	0.0071	0.79	—1.30	D	10
		4847.18	25039	45668	11	11	0.0035	0.0012	0.22	—1.87	D	10
		4825.51	24898	45615	9	9	0.0036	0.0013	0.18	—1.95	D—	10
74.	$a\ ^3G$–$y\ ^3F°$ (145)											
		4737.35	24898	46000	9	7	0.24	0.064	9.0	—0.24	D	9*n*
		4730.71	24834	45966	7	5	0.28	0.066	7.2	—0.34	D	9*n*
		4724.42	24898	46058	9	9	0.063	0.021	2.9	—0.72	D	9*n*
		4723.06	24834	46000	7	7	0.093	0.031	3.4	—0.66	D	9*n*
75.	$a\ ^3G$–$y\ ^3G°$ (150)											
		4540.72	25039	47055	11	11	0.23	0.071	12	—0.11	D	10
		4511.90	24898	47055	9	9	0.13	0.041	5.5	—0.43	D	9*n*
76.	$a\ ^3G$–$y\ ^3H°$ (154)											
		4271.06	25039	48445	11	13	0.053	0.017	2.6	—0.73	D	9*n*

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
77.	$a\,^3G$–$x\,^3G^\circ$ (155)											
		4224.51	24898	48562	9	9	0.067	0.018	2.3	—0.79	D	9*n*
		4213.18	24834	48562	7	9	0.079	0.027	2.6	—0.72	D	9*n*
78.	$a\,^3F$–$z\,^3H^\circ$ (166)											
		4954.81	25177	45354	9	11	0.12	0.055	8.1	—0.31	D	9*n*
		4936.33	25106	45359	7	9	0.14	0.066	7.5	—0.34	D	9*n*
79.	$a\,^3F$–$y\,^5H^\circ$ (167)											
		4880.06	25177	45663	9	11	0.0064	0.0028	0.40	—1.60	D	10
		4874.65	25106	45615	7	9	0.0069	0.0032	0.36	—1.66	D	10
80.	$a\,^3F$–$y\,^3F^\circ$ (168)											
		4801.03	25177	46000	9	7	0.23	0.063	9.0	—0.25	D	9*n*
		4792.51	25106	45966	7	5	0.26	0.064	7.1	—0.35	D	9*n*
81.	$a\,^3F$–$y\,^3D^\circ$ (169)											
		4729.72	24941	46077	5	3	0.17	0.035	2.7	—0.76	D	9*n*
82.	$a\,^3F$–$w\,^5F^\circ$ (171)											
		4632.18	25106	46688	7	7	0.071	0.023	2.5	—0.79	D	9*n*
83.	$z\,^7F^\circ$–$f\,^7D$ (186)											
		4718.43	25771	46959	13	11	0.42	0.12	24	0.19	D	8*n*
		4708.04	25549	46783	11	9	0.37	0.10	17	0.04	D	8*n*
		4689.37	25206	46525	7	5	0.23	0.054	5.8	—0.42	D	9*n*
		4639.54	25089	46637	5	7	0.095	0.043	3.3	—0.67	D	9*n*
84.	$b\,^3P$–$y\,^3P^\circ$ (191)											
		5400.61	27223	45734	5	5	0.16	0.068	6.0	—0.47	D	9*n*
85.	$b\,^3P$–$y\,^3S^\circ$ (197)											
		4482.88	27176	49477	3	3	0.30	0.090	4.0	—0.57	D	9*n*
86.	$z\,^7D^\circ$–$f\,^7D$ (201)											
		5243.40	27382	46449	5	3	0.20	0.049	4.2	—0.61	D	9*n*
		5177.43	27650	46959	9	11	0.061	0.030	4.6	—0.57	D	9*n*
		5184.59	27500	46783	7	9	0.11	0.056	6.7	—0.41	D	9*n*
		5192.00	27382	46637	5	7	0.14	0.081	6.9	—0.39	D	9*n*
		5200.19	27300	46525	3	5	0.16	0.11	5.6	—0.48	D	9*n*
87.	$b\,^3G$–$y\,^5H^\circ$											
		[5588.2]	27817	45707	11	13	0.0011	6.1(—4)	0.12	—2.17	E	10
		[5566.7]	27704	45663	9	11	0.0015	8.5(—4)	0.14	—2.12	D	10
		[5548.5]	27597	45615	7	9	0.0019	0.0011	0.14	—2.10	D—	10
		[5581.6]	27704	45615	9	9	0.0019	8.9(—4)	0.15	—2.10	E	10
88.	$b\,^5G$–$z\,^3G^\circ$ (206)											
		5193.49	27597	46847	7	7	0.017	0.0070	0.84	—1.31	D	9*n*

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
89.	$b\,^3G$–$y\,^3G^\circ$ (207)											
		5139.65	27597	47048	7	7	0.13	0.050	5.9	—0.46	D	9*n*
		5196.57	27817	47055	11	9	0.12	0.040	7.5	—0.36	D	10
90.	$y\,^7P^\circ$–$f\,^7D$ (225)											
		5272.01	27820	46783	7	9	0.11	0.060	7.3	—0.38	D	9*n*
		5287.19	27729	46637	5	7	0.078	0.046	4.0	—0.64	D	9*n*
		5304.21	27935	46783	9	9	0.066	0.028	4.4	—0.60	D	9*n*
		5312.88	27820	46637	7	7	0.11	0.048	5.9	—0.47	D	9*n*
		5318.78	27729	46525	5	5	0.13	0.057	5.0	—0.55	D	9*n*
		5340.44	27729	46449	5	3	0.16	0.041	3.6	—0.69	D	9*n*
91.	$a\,^3D$–$w\,^3P^\circ$ (234)											
		4413.87	28637	51287	7	5	0.41	0.085	8.6	—0.23	D	9*n*
92.	$y\,^5P^\circ$–$f\,^5D$ (237)											
		5261.75	29825	48825	7	9	0.13	0.069	8.4	—0.32	D	9*n*
93.	$a\,^3I$–$z\,^3K^\circ$ (247)											
		4280.41	31049	54405	13	15	0.47	0.15	27	0.29	D	9*n*
		4297.74	31055	54317	11	13	0.49	0.16	25	0.25	D	9*n*
94.	$a\,^3I$–$x\,^3I^\circ$ (251)											
		4039.10	31048	55799	15	15	0.68	0.17	33	0.40	C—	10
		4048.78	31049	55741	13	13	0.65	0.16	28	0.32	D	9*n*,10
		4058.77	31055	55686	11	11	0.69	0.17	25	0.27	D	9*n*,10
		4057.81	31049	55686	13	11	0.0072	0.0015	0.26	—1.71	D	10
		4039.30	31049	55799	13	15	0.043	0.012	2.1	—0.80	D	10
95.	$a\,^5F$–$v\,^5G^\circ$ (268)											
		4001.44	31378	56362	9	11	0.65	0.19	23	0.23	D	9*n*
		4031.13	31352	56155	3	5	0.79	0.32	13	—0.02	D	9*n*
96.	$b\,^3F$–$y\,^3G^\circ$											
		[7170.6]	33113	47055	9	11	0.0025	0.0024	0.50	—1.67	E	10
97.	$b\,^1I$–$y\,^1I^\circ$ (286)	4595.59	33763	55517	13	13	0.47	0.15	30	0.29	D	9*n*
98.	$b\,^1I$–$x\,^3I^\circ$											
		[4548.7]	33763	55741	13	13	6.1(—5)	1.9(—5)	0.0037	—3.61	E	10
99.	$b\,^1I$–$y\,^1H^\circ$ (288)	4506.85	33763	55945	13	11	0.27	0.069	13	—0.05	D	9*n*
100.	$c\,^3D$–$v\,^5G^\circ$ (293)											
		4488.05	33935	56210	7	7	0.63	0.19	20	0.12	D	9*n*

Cr I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
101.	$b\,^3H$–$x\,^3I°$											
		[5034.6]	35884	55741	11	13	0.018	0.0081	1.5	—1.05	D	10
		[5045.3]	35871	55686	9	11	0.018	0.0084	1.3	—1.12	D	10
102.	$b\,^3H$–$w\,^3I°$ (305)											
		4161.42	35934	59957	13	15	0.80	0.24	43	0.49	D	9n
		4165.52	35884	59884	11	13	0.75	0.23	35	0.40	D	9n

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr II

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5\ {}^6S_{5/2}$

Ionization Potential 16.50 eV = 133060 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
2653.57	3	2843.24	1	2966.03	17	3295.42	20
2658.59	3	2849.83	1	2971.90	13	3336.32	6
2666.02	3	2851.35	14	2979.73	13	3339.81	6
2668.71	3	2856.77	8	2985.32	13	3342.57	6
2671.80	3	2857.40	8	2989.18	13	3347.83	6
2672.83	3	2860.92	1	3040.91	25	3358.49	6
2693.53	15	2862.57	1	3041.73	30	3360.30	10
2727.25	19	2866.72	1	3050.14	25	3368.04	6
2740.09	2	2867.09	8	3093.47	34	3378.36	10
2744.97	12	2867.65	1	3096.11	35	3379.39	10
2768.59	33	2870.43	8	3107.57	34	3382.68	5
2774.44	37	2873.81	8	3118.64	7	3391.41	5
2778.06	37	2878.45	1	3120.36	7	3393.00	10
2782.36	23	2880.86	8	3122.59	21	3393.85	10
2785.69	23	2888.73	31	3128.69	7	3394.31	10
2787.61	12	2898.53	18	3136.68	7	3402.43	10
2792.16	23	2921.81	18	3152.21	28	3408.76	5
2800.77	22	2927.09	36	3180.70	9	3421.19	5
2818.36	22	2930.83	11	3183.33	29	3422.73	5
2822.01	22	2935.12	11	3209.19	9	3433.29	5
2832.45	27	2953.34	11	3217.40	9	3511.83	4
2838.78	32	2953.70	26	3234.06	24	4242.36	16
2840.01	14			3238.76	24		

For this spectrum, we have chosen the results of a very recent experiment by Musielok and Wujec [1], who measured oscillator strengths in emission with a wall-stabilized arc. They used two very different diagnostic approaches, both involving the beam-foil lifetime data of Engman et al. [2], to obtain their data on an absolute scale. One of these approaches involves only relative intensity measurements and is a direct way to normalize their intensity data with the lifetimes of ref. [2]. Therefore, the data based on this diagnostic technique have been used.

We have been rather conservative in our error estimates for this spectrum, since there are essentially no other reliable data sources that can be used for comparison purposes. One exception is the overlap of two experimental values by Huber and Tobey [3] with the chosen data for the 3382.68 Å and 3421.19 Å lines. Huber and Tobey used the shock-tube absorption technique, which has been shown to be fairly reliable in the case of Fe I. Nevertheless, the f-values of Musielok and Wujec are about sixty percent higher than those of Huber and Tobey

for both lines. However, we feel that because of the utilization of the fairly accurate lifetime data of Engman et al., Musielok and Wujec's absolute scale is more reliable than that of Huber and Tobey. We have thus assigned accuracies of ±50 percent to the tabulated data.

References

[1] Musielok, J., and Wujec, T., private communication (1977).
[2] Engman, B., Gaupp, A., Curtis, L. J., and Martinson, I., Phys. Scr. **12**, 220 (1975).
[3] Huber, M., and Tobey, F. L., Jr., Astrophys. J. **152**, 609 (1968).

Cr II: Allowed transitions

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$a\,^6D$–$z\,^6F°$ (uv 5)											
		2843.24	12304	47465	8	10	0.64	0.097	7.3	—0.11	D	1
		2849.83	12148	47228	6	8	0.92	0.15	8.4	—0.05	D	1
		2860.92	11962	46906	2	4	0.69	0.17	3.2	—0.47	D	1
		2862.57	12304	47228	8	8	0.63	0.077	5.8	—0.21	D	1
		2866.72	12033	46906	4	4	1.2	0.15	5.6	—0.23	D	1
		2867.65	11962	46824	2	2	1.1	0.14	2.6	—0.57	D	1
		2878.45	12497	47228	10	8	0.074	0.0074	0.70	—1.13	D—	1
2.	$a\,^6D$–$z\,^6P°$ (uv 6)											
		2740.09	12148	48632	6	8	0.11	0.017	0.89	—1.00	D—	1
3.	$a\,^6D$–$z\,^6D°$ (uv 8)											
		2672.83	12304	49706	8	6	0.55	0.044	3.1	—0.45	D	1
		2671.80	12148	49565	6	4	1.0	0.071	3.8	—0.37	D	1
		2668.71	12033	49493	4	2	1.4	0.075	2.6	—0.52	D	1
		2666.02	12148	49646	6	8	0.59	0.084	4.4	—0.30	D	1
		2653.57	12033	49706	4	6	0.35	0.055	1.9	—0.65	D	1
		2658.59	11962	49565	2	4	0.58	0.12	2.2	—0.61	D	1
4.	$a\,^4D$–$z\,^6P°$ (2)											
		3511.83	20024	48491	8	6	0.079	0.011	1.0	—1.06	D—	1
5.	$a\,^4D$–$z\,^4P°$ (3)											
		3408.76	20024	49352	8	6	0.95	0.12	11	—0.00	D	1
		3422.73	19798	49006	6	4	1.4	0.16	11	—0.01	D	1
		3433.29	19631	48750	4	2	1.3	0.11	5.2	—0.34	D	1
		3382.68	19798	49352	6	6	0.45	0.077	5.2	—0.33	D	1
		3421.19	19528	48750	2	2	1.7	0.30	6.7	—0.22	D	1
		3391.41	19528	49006	2	4	0.19	0.066	1.5	—0.88	D	1
6.	$a\,^4D$–$z\,^6D°$ (4)											
		3342.57	19798	49706	6	6	0.39	0.065	4.3	—0.41	D	1
		3339.81	19631	49565	4	4	0.49	0.082	3.6	—0.48	D	1
		3336.32	19528	49493	2	2	0.42	0.070	1.5	—0.85	D	1
		3368.04	20024	49706	8	6	1.4	0.18	16	0.15	D	1
		3358.49	19798	49565	6	4	1.1	0.12	8.2	—0.13	D	1
		3347.83	19631	49493	4	2	0.52	0.044	1.9	—0.76	D	1
7.	$a\,^4D$–$z\,^4F°$ (5)											
		3120.36	19631	51670	4	6	1.5	0.33	13	0.12	D	1
		3118.64	19528	51584	2	4	1.7	0.50	10	—0.00	D	1
		3136.68	19798	51670	6	6	0.64	0.094	5.8	—0.25	D	1
		3128.69	19631	51584	4	4	0.81	0.12	4.9	—0.32	D	1

Cr II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
8.	$a\,^4D$–$z\,^4D^\circ$ (uv 11)											
		2870.43	19798	54626	6	6	1.3	0.16	9.1	—0.02	D	1
		2867.09	19631	54500	4	4	1.1	0.14	5.1	—0.27	D	1
		2880.86	19798	54500	6	4	0.79	0.066	3.7	—0.41	D	1
		2873.81	19631	54418	4	2	0.88	0.054	2.1	—0.66	D	1
		2857.40	19798	54785	6	8	0.28	0.046	2.6	—0.56	D	1
		2856.77	19631	54626	4	6	0.43	0.079	3.0	—0.50	D	1
9.	$a\,^4G$–$z\,^4F^\circ$ (9)											
		3180.70	20513	51943	12	10	0.70	0.088	11	0.03	D	1
		3209.19	20518	51670	8	6	0.68	0.079	6.7	—0.20	D	1
		3217.40	20513	51584	6	4	0.77	0.080	5.1	—0.32	D	1
10.	$b\,^4D$–$z\,^4D^\circ$ (21)											
		3360.30	25034	54785	8	8	1.3	0.22	19	0.25	D	1
		3393.85	25043	54500	4	4	0.66	0.11	5.1	—0.34	D	1
		3402.43	25036	54418	2	2	0.80	0.14	3.1	—0.56	D	1
		3378.36	25034	54626	8	6	0.41	0.053	4.7	—0.38	D	1
		3394.31	25047	54500	6	4	0.75	0.086	5.8	—0.29	D	1
		3379.39	25043	54626	4	6	0.48	0.12	5.5	—0.31	D	1
		3393.00	25036	54500	2	4	0.46	016	3.5	—0.50	D	1
11.	$b\,^4P$–$y\,^4D^\circ$ (uv 55)											
		2935.12	30865	64924	6	8	1.8	0.31	18	0.27	D	1
		2930.83	29952	64062	2	4	1.1	0.28	5.5	—0.25	D	1
		2953.34	29952	63802	2	2	1.8	0.24	4.6	—0.33	D	1
12.	$b\,^4P$–$y\,^4P^\circ$ (uv 58)											
		2787.61	30865	66727	6	6	1.5	0.17	9.6	0.02	D	1
		2744.97	30308	66727	4	6	0.85	0.14	5.2	—0.24	D	1
13.	$a\,^4H$–$z\,^4H^\circ$ (uv 80)											
		2971.90	30392	64031	14	14	2.0	0.26	36	0.57	D	1
		2979.73	30299	63849	12	12	1.8	0.24	28	0.46	D	1
		2985.32	30219	63707	10	10	2.2	0.29	29	0.47	D	1
		2989.18	30157	63601	8	8	2.2	0.29	23	0.37	D	1
14.	$a\,^4H$–$z\,^4I^\circ$ (uv 82)											
		2840.01	30219	65420	10	12	2.7	0.39	37	0.59	D	1
		2851.35	30157	65218	8	10	2.2	0.34	25	0.43	D	1
15.	$a\,^4H$–$y\,^4G^\circ$ (uv 84)											
		2693.53	30219	67354	10	8	1.4	0.12	11	0.09	D	1
16.	$a\,^4F$–$z\,^4D^\circ$ (31)											
		4242.36	31219	54785	10	8	0.12	0.026	36	—0.59	D	1
17.	$a\,^4F$–$y\,^4D^\circ$ (uv 94)											
		2966.03	31219	64924	10	8	0.54	0.057	5.6	—0.24	D	1

Cr II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
18.	$a\,^4F$–$z\,^4G°$ (uv 95)											
		2898.53	31219	65710	10	12	1.2	0.18	17	0.26	D	1
		2921.81	31169	65384	8	10	0.90	0.14	11	0.06	D	1
19.	$a\,^4F$–$x\,^4D°$ (uv 102)											
		2727.25	31219	67876	10	8	1.7	0.15	14	0.18	D	1
20.	$b\,^4G$–$z\,^4H°$ (51)											
		3295.42	33694	64031	12	14	0.32	0.061	7.9	—0.14	D	1
21.	$b\,^4G$–$z\,^4G°$ (54)											
		3122.59	33694	65710	12	12	0.44	0.064	7.9	—0.11	D	1
22.	$b\,^4G$–$y\,^4H°$ (uv 182)											
		2800.77	33694	69388	12	14	2.2	0.30	33	0.56	D	1
		2818.36	33521	68993	8	10	2.2	0.33	24	0.42	D	1
		2822.01	33418	68844	6	8	2.3	0.37	20	0.34	D	1
23.	$b\,^4G$–$x\,^4F°$ (uv 183)											
		2792.16	33694	69498	12	10	2.3	0.22	25	0.43	D	1
		2785.69	33619	69506	10	8	2.1	0.20	18	0.29	D	1
		2782.36	33418	69348	6	4	1.6	0.12	6.8	—0.13	D	1
24.	$a\,^2H$–$z\,^2G°$ (63)											
		3238.76	34813	65680	12	10	0.54	0.071	9.1	—0.07	D	1
		3234.06	34631	65543	10	8	0.92	0.12	12	0.06	D	1
25.	$a\,^2H$–$z\,^2I°$ (65)											
		3050.14	34813	67589	12	14	1.8	0.29	35	0.55	D	1
		3040.91	34631	67506	10	12	4.8	0.80	80	0.90	D	1
26.	$a\,^2H$–$z\,^2H°$ (uv 192)											
		2953.70	34631	68477	10	10	0.92	0.12	12	0.08	D	1
27.	$a\,^2H$–$y\,^2G°$ (uv 195)											
		2832.45	34813	70108	12	10	1.3	0.13	15	0.19	D	1
28.	$a\,^2P$–$z\,^2P°$ (71)											
		3152.21	35356	67070	4	4	1.8	0.27	11	0.03	D	1
29.	$b\,^2F$–$z\,^2D°$ (82)											
		3183.33	35608	67012	8	6	0.87	0.099	8.3	—0.10	D	1
30.	$b\,^2H$–$z\,^2H°$ (95)											
		3041.73	35611	68477	10	10	3.1	0.43	43	0.63	D	1
31.	$a\,^2G$–$x\,^4G°$ (uv 238)											
		2888.73	36273	70880	10	12	0.88	0.13	13	0.12	D	1

Cr II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
32.	$c\,^4D$–$w\,^4D^\circ$ (uv 250)											
		2838.78	38270	73486	8	8	2.7	0.33	24	0.42	D	I
33.	$c\,^4D$–$w\,^4F^\circ$ (uv 252)											
		2768.59	38315	74424	6	8	2.8	0.43	23	0.41	D	I
34.	$b\,^2G$–$x\,^4G^\circ$ (125)											
		3093.47	38563	70880	10	12	0.67	0.12	12	0.06	D	1
		3107.57	38509	70679	8	10	0.62	0.11	9.2	—0.05	D	1
35.	$b\,^2G$–$y\,^2F^\circ$ (126)											
		3096.11	38563	70852	10	8	0.75	0.086	8.8	—0.06	D	1
36.	$b\,^2G$–$x\,^2G^\circ$ (uv 256)											
		2927.09	38563	72717	10	10	2.8	0.36	35	0.56	D	1
37.	$c\,^2G$–$w\,^2G^\circ$ (uv 266)											
		2778.06	39825	75810	10	10	3.2	0.37	34	0.57	D	1
		2774.44	39684	75717	8	8	1.7	0.20	14	0.20	D	1

Cr V

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2\ ^3F_2$

Ionization Potential [71] eV = [523000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
433.12	3	451.61	5	1103.4	22	1603.2	15
434.18	3	456.27	9	1106.3	22	1607.0	15
434.31	3	456.36	9	1117.6	21	1611.3	15
435.14	3	456.64	9	1127.63	24	1622.6	14
435.64	3	456.74	9	1146.7	23	1631.0	14
436.35	3	457.03	9	1465.9	20	1638.5	14
436.60	3	457.50	9	1477.8	16	1639.4	14
437.42	2	464.02	11	1481.7	16	1644.1	14
437.66	2	469.31	8	1482.8	16	1652.6	14
438.62	2	469.63	4	1484.7	16	1655.6	14
441.06	7	469.89	8	1489.7	16	1705.6	13
442.243	1	470.57	8	1498.0	16	1706.0	18
445.75	6	470.70	8	1519.0	19	1728.5	18
446.67	10	470.98	8	1579.7	15	1837.4	17
451.14	5	529.74	12	1591.7	15		

Oscillator strengths for several hundred transitions in Cr V have been calculated by Kurucz and Peytremann using a scaled Thomas-Fermi method including limited configuration interaction [1]. Of these lines, we have listed only a small number for reasons discussed in detail in the general introduction.

It is expected that for the relatively simple, essentially two-electron spectrum of Cr V, Kurucz and Peytremann's data should be fairly reliable. This conjecture seems to be supported by the good consistency between similarly calculated values and lifetime measurements for the isoelectronic ion Ti III [2].

For this compilation we have selected lines which have been experimentally observed, using the wavelength list of Ekberg [3]. For one line in the spectrum we have used the result of Warner and Kirkpatrick's Thomas-Fermi (without configuration interaction) calculation [4].

References

[1] Kurucz, R. L., and Peytremann, E., Smithsonian Astrophysical Observatory Special Report 362 (1975).

[2] Wiese, W. L., and Fuhr, J. R., J. Phys. Chem. Ref. Data **4**, 263 (1975).

[3] Ekberg, J. O., Phys. Scr. **7**, 59 (1973).

[4] Warner, B., and Kirkpatrick, R., Publication of the Department of Astronomy, University of Texas at Austin, Vol. III, No. 2 (1969).

Cr v: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3d^2$–$3d4p$	^{3}F–^{1}D°											
			442.243	0	226120	5	5	3.0	0.0087	0.064	—1.36	D	1
2.		^{3}F–^{3}D°											
			438.62	1141.7	229121	9	7	19	0.042	0.55	—0.42	D	1
			438.62	508.2	228489	7	5	21	0.043	0.44	—0.52	D	1
			438.62	0	228002	5	3	45	0.078	0.56	—0.41	D	1
			437.42	508.2	229121	7	7	14	0.039	0.40	—0.56	D	1
			437.66	0	228489	5	5	13	0.038	0.27	—0.72	D	1
3.		^{3}F–^{3}F°	*434.90*	*658.7*	*230596*	21	21	22	0.063	1.8	0.12	D	1
			434.31	1141.7	231393	9	9	15	0.042	0.54	—0.42	D	1
			435.14	508.2	230316	7	7	2.9	0.0082	0.082	—1.24	D—	1
			435.64	0	229552	5	5	2.8	0.0080	0.057	—1.40	D—	1
			436.35	1141.7	230316	9	7	24	0.053	0.69	—0.32	D	1
			436.60	508.2	229552	7	5	21	0.043	0.43	—0.52	D	1
			433.12	508.2	231393	7	9	0.99	0.0036	0.036	—1.60	D—	1
			434.18	0	230316	5	7	0.48	0.0019	0.014	—2.02	D—	1
4.		^{1}D–^{1}D°	469.63	13188.0	226120	5	5	23	0.076	0.59	—0.42	D—	1
5.		^{1}D–^{3}P°											
			451.14	13188.0	234846	5	5	0.043	1.3(—4)[a]	9.8(—4)	—3.18	D—	1
			451.61	13188.0	234618	5	3	2.0	0.0036	0.027	—1.74	D	1
6.		^{1}D–^{1}F°	445.75	13188.0	237530	5	7	1.9	0.0078	0.057	—1.41	D	1
7.		^{1}D–^{1}P°	441.06	13188.0	239918	5	3	23	0.040	0.29	—0.70	D	1
8.		^{3}P–^{3}D°											
			469.31	16041.0	229121	5	7	3.9	0.018	0.14	—1.04	D	1
			469.89	15676.6	228489	3	5	4.9	0.027	0.13	—1.09	D	1
			470.57	15491.8	228002	1	3	4.9	0.049	0.076	—1.31	D	1
			470.70	16041.0	228489	5	5	0.48	0.0016	0.012	—2.10	D—	1
			470.98	15676.6	228002	3	3	2.0	0.0068	0.032	—1.69	D—	1
9.		^{3}P–^{3}P°	*456.85*	*15858.5*	*234750*	9	9	33	0.10	1.4	—0.03	D	1
			457.03	16041.0	234846	5	5	27	0.083	0.63	—0.38	D	1
			456.74	15676.6	234618	3	3	9.1	0.028	0.13	—1.07	D	1
			457.50	16041.0	234618	5	3	12	0.023	0.18	—0.93	D	1
			456.64	15676.6	234669	3	1	33	0.035	0.16	—0.98	D	1
			456.27	15676.6	234846	3	5	6.7	0.035	0.16	—0.98	D	1
			456.36	15491.8	234618	1	3	9.5	0.089	0.13	—1.05	D	1
10.		^{3}P–^{1}P°											
			446.67	16041.0	239918	5	3	2.0	0.0036	0.026	—1.75	D	1
11.		^{1}G–^{1}F°	464.02	22019.2	237530	9	7	54	0.14	1.9	0.09	D	1
12.		^{1}S–^{1}P°	529.74	51146.4	239918	1	3	11	0.14	0.25	—0.85	D	4

Cr v: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^6 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
13.	$3d4s$–$3d4p$	^3D–$^1D°$											
			1705.6	167491	226120	5	5	0.80	0.035	0.98	—0.76	D	1
14.		^3D–$^3D°$	*1639.9*	*167708*	*228687*	15	15	7.0	0.28	23	0.63	D	1
			1638.5	168090	229121	7	7	6.8	0.27	10	0.28	D	1
			1639.4	167491	228489	5	5	4.9	0.20	5.3	—0.01	D	1
			1644.1	167176	228002	3	3	5.0	0.20	3.3	—0.22	D	1
			1655.6	168090	228489	7	5	1.6	0.048	1.8	—0.47	D—	1
			1652.6	167491	228002	5	3	2.5	0.062	1.7	—0.51	D—	1
			1622.6	167491	229121	5	7	0.74	0.041	1.1	—0.69	D—	1
			1631.0	167176	228489	3	5	0.16	0.011	0.17	—1.50	D—	1
15.		^3D–$^3F°$											
			1579.7	168090	231393	7	9	8.6	0.41	15	0.46	D	1
			1591.7	167491	230316	5	7	7.3	0.39	10	0.29	D	1
			1603.2	167176	229552	3	5	7.0	0.45	7.1	0.13	D	1
			1607.0	168090	230316	7	7	0.83	0.032	1.2	—0.65	D—	1
			1611.3	167491	229552	5	5	0.23	0.0089	0.24	—1.35	D—	1
16.		^3D–$^3P°$	*1491.6*	*167708*	*234750*	15	9	10	0.20	15	0.48	D—	1
			1498.0	168090	234846	7	5	7.5	0.18	6.2	0.10	D	1
			1489.7	167491	234618	5	3	6.6	0.13	3.2	—0.18	D	1
			1481.7	167176	234669	3	1	10	0.11	1.7	—0.47	D—	1
			1484.7	167491	234846	5	5	2.2	0.073	1.8	—0.44	D	1
			1482.8	167176	234618	3	3	3.5	0.12	1.7	—0.46	D	1
			1477.8	167176	234846	3	5	0.18	0.010	0.15	—1.52	D—	1
17.		^1D–$^1D°$	1837.4	171698	226120	5	5	4.3	0.22	6.6	0.040	D	1
18.		^1D–$^3F°$											
			1706.0	171698	230316	5	7	0.048	0.0030	0.083	—1.83	D—	1
			1728.5	171698	229552	5	5	0.45	0.020	0.57	—1.00	D	1
19.		^1D–$^1F°$	1519.0	171698	237530	5	7	9.5	0.46	11	0.36	D	1
20.		^1D–$^1P°$	1465.9	171698	239918	5	3	11	0.21	5.1	0.020	D	1
21.	$3d4p$–$3d4d$	$^3D°$–^3D											
			1117.6	229121	318602	7	7	6.2	0.12	3.0	—0.09	D	1
22.		$^3D°$–^3G											
			1106.3	229121	319517	7	9	12	0.29	7.4	0.31	D	1
			1103.4	228489	319119	5	7	2.4	0.062	1.1	—0.51	D—	1
23.		$^3F°$–^3D											
			1146.7	231393	318602	9	7	1.3	0.020	0.69	—0.74	D	1
24.		$^3F°$–^3G											
			1127.63	231393	320074	9	11	35	0.80	27	0.86	D	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr VI

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d\ ^2D_{3/2}$

Ionization Potential 90.56 eV = 730400 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
137.11	1	162.565	3	164.159	5	170.569	7
137.12	1	162.764	3	164.564	5	171.400	7
137.30	1	163.014	3	164.833	5	172.204	8
161.68	2	163.514	4	168.088	6	172.487	8
161.687	2	163.801	4	168.355	6	172.841	8
161.930	2			169.435	6		

Oscillator strengths for eight multiplets of Cr VI are from Cowan's single configuration Hartree-Fock calculation with intermediate coupling [1].

Biemont has calculated multiplet oscillator strengths for transitions of type ns–$n'p$ and np–$n'd$ where $n, n' = 4, 5, 6, 7, 8$, using a single configuration Hartree-Fock approximation [2]. We have not tabulated this material, however, since appreciable configuration interaction is expected with the $3d$ states, which makes Biemont's results unreliable. (The transitions considered by Cowan involve low-level excitations from the ground state, and should not be seriously affected by configuration interaction until further into the isoelectronic sequence.)

References

[1] Cowan, R. D., Astrophys. J. **147**, 377 (1967).
[2] Biemont, E., Physica C **81**, 158 (1976).

Cr VI: Allowed transitions

No.	Transition array	Multiplet	λ (Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S (at.u.)	log gf	Accuracy	Source
1.	$3p^6 3d$–$3p^5 3d(^1P^\circ)4s$	^2D–$^2P^\circ$	*137.22*	*560*	[*729310*]	10	6	130	0.022	0.099	—0.66	D	1
			[137.30]	940	[729290]	6	4	110	0.021	0.057	—0.90	D	1
			[137.11]	0	[729340]	4	2	130	0.019	0.034	—1.12	D	1
			[137.12]	0	[729290]	4	4	16	0.0045	0.0081	—1.74	D	1
2.	$3p^6 3d$–$3p^5 3d(^3D^\circ)4s$	^2D–$^2D^\circ$	*161.73*	*560*	*618860*	10	10	230	0.092	0.49	—0.04	D	1
			161.687	940	618491	6	6	200	0.080	0.26	—0.32	D	1
			161.687	0	619419	4	4	180	0.072	0.15	—0.54	D	1
			161.930	940	619419	6	4	37	0.0097	0.031	—1.24	D	1
			[161.68]	0	618491	4	6	36	0.021	0.045	—1.08	D	1
3.	$3p^6 3d$–$3p^5 3d(^1F^\circ)4s$	^2D–$^2F^\circ$	*162.66*	*560*	*615350*	10	14	98	0.054	0.29	—0.27	D	1
			162.565	940	616079	6	8	100	0.054	0.17	—0.49	D	1
			162.764	0	614385	4	6	11	0.0068	0.015	—1.57	D	1
			163.014	940	614385	6	6	80	0.032	0.10	—0.72	D	1
4.	$3p^6 3d$–$3p^5 3d(^1D^\circ)4s$	^2D–$^2D^\circ$											
			163.514	0	611568	4	4	77	0.031	0.067	—0.91	D	1
			163.801	0	610497	4	6	30	0.018	0.039	—1.14	D	1
5.	$3p^6 3d$–$3p^5 3d(^3D^\circ)4s$	^2D–$^4D^\circ$											
			164.833	940	607615	6	8	8.3	0.0045	0.015	—1.57	D	1
			164.564	940	608631	6	6	14	0.0057	0.019	—1.47	D	1
			164.159	0	609166	4	4	11	0.0043	0.0093	—1.76	D	1

Cr VI: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
6.	$3p^6 3d$–$3p^5 3d(^3F^\circ)4s$	^2D–$^2F^\circ$	*168.86*	*560*	*592760*	10	14	190	0.11	0.63	0.05	D	1
			169.435	940	591137	6	8	170	0.097	0.32	—0.24	D	1
			168.088	0	594926	4	6	200	0.13	0.29	—0.28	D	1
			168.355	940	594926	6	6	11	0.0048	0.016	—1.54	D	1
7.		^2D–$^4F^\circ$											
			171.400	940	584371	6	8	7.2	0.0042	0.014	—1.60	D	1
			170.569	0	586273	4	6	8.9	0.0058	0.013	—1.63	D	1
8.	$3p^6 3d$–$3p^5 3d(^3P^\circ)4s$	^2D–$^2P^\circ$	*172.58*	*560*	*579990*	10	6	190	0.051	0.29	—0.29	D	1
			172.487	940	580697	6	4	160	0.049	0.17	—0.53	D	1
			172.841	0	578566	4	2	190	0.042	0.096	—0.77	D	1
			172.204	0	580697	4	4	25	0.011	0.025	—1.36	D	1

Cr VII

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6\ ^1S_0$

Ionization Potential 161.1 eV = 1299700 cm^{-1}

Allowed Transitions

Cowan [1] has calculated gf-values for the resonance transition of selected ions in the Ar isoelectronic sequence using a multiconfiguration approach in intermediate coupling with explicit consideration of cancellation in the transition integrand.

Reference

[1] Cowan, R. D., J. Phys. (Paris), Colloq. C4 **31**, 191 (1970).

Cr VII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3p^6$–$3p^5 3d$	^1S–$^3D^\circ$											
			259.18	0	385830	1	3	1.3	0.0039	0.0033	—2.41	E	1
2.		^1S–$^1P^\circ$	202.78	0	493150	1	3	2400	4.5	3.0	0.65	D	1

Cr IX

Ground State $1s^2 2s^2 2p^6 3s^2 3p^4\ ^3P_2$

Ionization Potential 209.8 eV = 1691000 cm^{-1}

Allowed Transitions

The single multiplet oscillator strength presented was derived by graphical interpolation from the systematic trend along the sulfur isoelectronic sequence. The lines within the multiplet are analyzed according to LS coupling.

Cr IX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p^4$–$3s3p^5$	^3P–$^3P°$	*419.01*	*3680*	*242340*	9	9	33	0.086	1.1	—0.11	E	*interp.*
			418.15	0	239150	5	5	25	0.067	0.46	—0.48	E	*ls*
			420.94	7840	245400	3	3	8.3	0.022	0.092	—1.18	E	*ls*
			407.50	0	245400	5	3	15	0.022	0.15	—0.95	E	*ls*
			414.47	7840	249110	3	1	34	0.029	0.12	—1.06	E	*ls*
			432.33	7840	239150	3	5	7.5	0.035	0.15	—0.98	E	*ls*
			424.03	9570	245400	1	3	11	0.086	0.12	—1.07	E	*ls*

Cr X

Ground State $1s^22s^22p^63s^23p^3\ ^4S°_{3/2}$

Ionization Potential [242] eV = [1952000] cm^{-1}

Allowed Transitions

The multiplet oscillator strength for the first multiplet was derived by graphical interpolation from a systematic trend along the phosphorus isoelectronic sequence.

The data for the second multiplet are the result of calculations by Ali and Joy, done in a single configuration Hartree-Fock approximation [1]. Thus configuration interaction was not taken into account, which may be important for this transition. However, a comparison of the transition integral calculated by Ali with the nuclear charge expansion method (unpublished result), which includes limited configuration interaction, shows good agreement. We calculated our f-values from the "free" form of Ali's transition integral instead of using his published gf-value directly, in order to take advantage of better energy level data now available.

We estimate that all listed data are outside the ±50% accuracy range, but the first multiplet may not be uncertain by more than a factor of two.

Reference

[1] Ali, M. A., and Joy, H. W., J. Phys, B **3**, 1552 (1970).

Cr X: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p^3$–$3s3p^4$	$^4S°$–^4P	*421.09*	0	*237480*	4	12	25	0.20	1.1	—0.10	E	*interp.*
			427.49	0	233920	4	6	24	0.098	0.55	—0.41	E	*ls*
			416.57	0	240060	4	4	26	0.067	0.37	—0.57	E	*ls*
			411.57	0	242970	4	2	26	0.033	0.18	—0.88	E	*ls*
2.	$3p^3$–$3p^2(^3P)3d$	$^4S°$–^4P	*225.34*	0	*443780*	4	12	710	1.6	4.8	0.81	E	1
			226.24	0	442010	4	6	700	0.81	2.4	0.51	E	*ls*
			224.74	0	444960	4	4	710	0.54	1.6	0.33	E	*ls*
			223.86	0	446710	4	2	720	0.27	0.80	0.04	E	*ls*

Cr XI

Ground State $1s^22s^22p^63s^23p^2\ ^3P_0$

Ionization Potential [270.0]eV = [2177800] cm^{-1}

Allowed Transitions

The multiplet oscillator strengths were derived by graphical interpolation from systematic trends along the silicon isoelectronic sequence. The lines within the multiplets are analyzed according to LS coupling.

Cr XI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p^2$–$3s3p^3$	^3P–$^3D^\circ$	*427.5*	*8498.1*	*[242400]*	9	15	10	0.047	0.60	—0.37	D	*interp.*
			431.07	11974	243950	5	7	10	0.039	0.28	—0.70	D	*ls*
			421.99	5537.7	242510	3	5	8.1	0.036	0.15	—0.97	D	*ls*
			[419.2]	0	[238500]	1	3	6.1	0.049	0.067	—1.31	D	*ls*
			[433.77]	11974	242510	5	5	2.5	0.0070	0.050	—1.46	D	*ls*
			[429.3]	5537.7	[238500]	3	3	4.3	0.012	0.050	—1.45	D	*ls*
			[441.5]	11974	[238500]	5	3	0.26	4.5(—4)[a]	0.0033	—2.64	D	*ls*
2.		^3P–$^3P^\circ$				9	9		0.066		—0.23	D	*interp.*
3.		^1D–$^1D^\circ$	370.87	36987	306620	5	5	41	0.084	0.51	—0.38	D	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XII

Ground State $1s^22s^22p^63s^23p\ ^2P^\circ_{1/2}$

Ionization Potential [297.0] eV = [2395600] cm^{-1}

Allowed Transitions

The oscillator strengths for the first two multiplets are taken from the superposition-of-configurations calculations of Froese Fischer [1,2]. The calculation of Ref. [2] is an improvement over that of Ref. [1] in that more configurations are included. While the full effect of electron correlation has not been included in these calculations, comparisons with experiment for a few lower ions of the Al sequence suggest that the results should be accurate to within 50 percent.

Data for the third multiplet were obtained by interpolation from graphs of systematic trends along the Al isoelectronic sequence.

References

[1] Froese Fischer, C., J. Quant. Spectrosc. Radiat. Transfer **8**, 755 (1968).

[2] Froese Fischer, C., Fourth International Conference on Atomic Physics, Abstracts of Contributed Papers, Eds. Kowalski, J., and Weber, H. G., Heidelberg (1974).

Cr XII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p$–$3s3p^2$	$^2P^\circ$–^2D	*404.86*	*8001*	*255000*	6	10	12	0.051	0.41	—0.51	D	1
			410.91	12002	255360	4	6	12	0.046	0.25	—0.73	D	*ls*
			393.00	0	254450	2	4	12	0.054	0.14	—0.97	D	*ls*
			412.46	12002	254450	4	4	2.0	0.0050	0.027	—1.70	E	*ls*
2.	$3p$–$3d$	$^2P^\circ$–^2D	*249.25*	*8001*	*409210*	6	10	350	0.54	2.7	0.51	D	2
			251.52	12002	409580	4	6	340	0.48	1.6	0.29	D	*ls*
			244.70	0	408660	2	4	310	0.56	0.90	0.05	D	*ls*
			[252.11]	12002	408660	4	4	57	0.054	0.18	—0.66	E	*ls*
3.	$3p$–$4s$	$^2P^\circ$–^2S				6	2		0.068		—0.39	D	*interp.*

Cr XIII

Ground State $1s^2 2s^2 2p^6 3s^2\ {}^1S_0$

Ionization Potential 354.8 eV = 2862000 cm^{-1}

Allowed Transitions

Oscillator strengths for this ion of the Mg isoelectronic sequence were derived by interpolation from graphs of systematic trends along isoelectronic sequences. The low accuracies reflect the general scarcity of data for high ions. Furthermore, for some transitions a level crossing occurs at Cl VI, which greatly complicates extrapolation of lower Z data. It is expected that data marked "E" are accurate to within a factor of two.

Victor, Stewart, and Laughlin [1] have recently presented data for a large number of transitions in the ions Mg I to Cl VI, which may be useful in the construction of additional systematic trends for transitions not presented here. Caution must be exercised when constructing such trends, however, for the reasons mentioned above.

Reference

[1] Victor, G. A., Stewart, R. F., and Laughlin, C., Astrophys. J. **31**, 237 (1976).

Cr XIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2$–$3s3p$	${}^1S$–${}^1P^\circ$	328.29	0	304610	1	3	180	0.87	0.94	—0.06	C+	*interp.*
2.	$3s3p$–$3p^2$	${}^3P^\circ$–${}^3P$	*355.11*	[*211630*]	[*493230*]	9	9	160	0.31	3.3	0.45	D	*interp.*
			353.81	[216150]	[498780]	5	5	130	0.24	1.4	0.08	D	*ls*
			356.12	[206960]	[487810]	3	3	42	0.080	0.28	—0.62	D	*ls*
			368.06	[216150]	[487810]	5	3	62	0.076	0.46	—0.42	D	*ls*
			363.96	[206960]	[481720]	3	1	160	0.10	0.37	—0.51	D	*ls*
			342.69	[206960]	[498780]	3	5	46	0.14	0.46	—0.39	D	*ls*
			351.14	[203030]	[487810]	1	3	58	0.32	0.37	—0.49	D	*ls*
3.		${}^1P^\circ$–${}^1D$				3	5		0.10		—0.52	D	*interp.*
4.		${}^1P^\circ$–${}^1S$	377.60	304610	569440	3	1	150	0.11	0.41	—0.48	D	*interp.*
5.	$3s3p$–$3s3d$	${}^3P^\circ$–${}^3D$	*264.87*	[*211630*]	[*589180*]	9	15	220	0.38	3.0	0.53	D	*interp.*
			267.65	[216150]	[589770]	5	7	210	0.32	1.4	0.20	D	*ls*
			261.83	[206960]	[588890]	3	5	170	0.29	0.75	—0.06	D	*ls*
			259.59	[203030]	[588290]	1	3	130	0.39	0.33	—0.41	D	*ls*
			[268.28]	[216150]	[588890]	5	5	52	0.057	0.25	—0.55	D	*ls*
			262.22	[206960]	[588290]	3	3	94	0.097	0.25	—0.54	D	*ls*
			[268.72]	[216150]	[588290]	5	3	5.9	0.0038	0.017	—1.72	D	*ls*
6.		${}^1P^\circ$–${}^1D$	560.11	304610	483150	3	5	91	0.71	3.9	0.33	E	*interp.*
7.	$3s3p$–$3s4s$	${}^1P^\circ$–${}^1S$				3	1		0.075		—0.65	E	*interp.*
8.		${}^3P^\circ$–${}^3S$	*85.239*	[*211630*]	[1384800]	9	3	1500	0.053	0.13	—0.32	E	*interp.*
			85.566	[216150]	[1384800]	5	3	780	0.051	0.072	—0.59	E	*ls*
			84.898	[206960]	[1384800]	3	3	470	0.051	0.043	—0.81	E	*ls*
			84.616	[203030]	[1384800]	1	3	160	0.050	0.014	—1.30	E	*ls*

Cr XIV

Ground State $1s^2 2s^2 2p^6 3s\ ^2S_{1/2}$

Ionization Potential 384.30 eV = 3099630 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
45.835	6	63.933	11	117.6	18	301.81	7
46.125	6	64.005	11	118.3	18	346.4	26
46.468	3	64.044	11	125.2	23	346.5	26
46.527	3	68.594	8	125.3	23	346.7	26
50.821	9	69.213	8	125.4	23	389.81	1
51.172	9	69.247	8	148.5	16	411.99	1
51.181	9	80.916	4	149.1	16	788.6	19
52.321	14	81.838	4	157.1	20	818.3	19
52.363	14	86.057	12	158.4	20	823.7	19
52.369	14	86.164	12	189.0	17	993.1	15
53.760	5	86.182	12	191.0	17	1049	15
54.164	5	100.87	10	221.5	22	1637	25
60.699	13	101.05	10	221.9	22	1704	25
60.756	13	101.42	10	222.9	22	1712	25
60.763	13	109.7	21	289.74	7	2032	24
63.324	2	110.40	21	300.27	7	2150	24
63.539	2						

The data are taken primarily from the Hartree-Fock calculations of Biemont [1]. Data for several multiplets not given by Biemont were derived by interpolation from graphs of oscillator strengths along the Na isoelectronic sequence. Line strengths within multiplets are given according to *LS* coupling.

Reference

[1] Biemont, E., J. Quant. Spectrosc. Radiat. Transfer **15**, 531 (1975).

Cr XIV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	3*s*–3*p*	^{2}S–^{2}P°	*396.94*	0	*251930*	2	6	61	0.434	1.13	—0.061	C	1
			389.81	0	256540	2	4	64	0.29	0.75	—0.23	C	*ls*
			411.99	0	242720	2	2	55	0.139	0.377	—0.56	C	*ls*
2.	3*s*–4*p*	^{2}S–^{2}P°	*63.395*	0	*1577400*	2	6	1160	0.210	0.088	—0.377	C	1
			63.324	0	1579200	2	4	1200	0.14	0.059	—0.55	C	*ls*
			63.539	0	1573800	2	2	1100	0.069	0.029	—0.86	C—	*ls*
3.	3*s*–5*p*	^{2}S–^{2}P°	*46.488*	0	*2151100*	2	6	670	0.065	0.020	—0.89	C	1
			46.468	0	2152000	2	4	660	0.042	0.013	—1.07	C	*ls*
			46.527	0	2149300	2	2	670	0.022	0.0067	—1.36	C	*ls*
4.	3*p*–4*s*	^{2}P°–^{2}S	*81.528*	*251930*	1478500	6	2	2000	0.066	0.11	—0.40	C	1
			81.838	256540	1478500	4	2	1300	0.068	0.073	—0.57	C	*ls*
			80.916	242720	1478500	2	2	710	0.069	0.037	—0.86	C	*ls*
5.	3*p*–5*s*	^{2}P°–^{2}S	*54.029*	*251930*	2102800	6	2	880	0.0129	0.0138	—1.111	C	1
			53.760	256540	2102800	4	2	600	0.013	0.0092	—1.28	C	*ls*
			54.164	242720	2102800	2	2	293	0.0129	0.00460	—1.59	C	*ls*
6.	3*p*–6*s*	^{2}P°–^{2}S	*46.028*	*251930*	2424500	6	2	470	0.0050	0.0045	—1.52	C	*interp.*
			46.125	256540	2424500	4	2	310	0.0049	0.0030	—1.70	C	*ls*
			45.835	242720	2424500	2	2	160	0.0050	0.0015	—2.00	C	*ls*

Cr XIV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
7.	*3p–3d*	$^2P°–^2D$	*296.77*	*251930*	*588890*	6	10	148	0.325	1.91	0.290	C	1
			300.27	256540	589570	4	6	143	0.291	1.15	0.066	C	*ls*
			289.74	242720	587870	2	4	130	0.34	0.64	—0.17	C	*ls*
			301.81	256540	587870	4	4	23.4	0.0320	0.127	—0.89	C—	*ls*
8.	*3p–4d*	$^2P°–^2D$	*69.005*	*251930*	*1701100*	6	10	2380	0.283	0.386	0.230	C	1
			69.213	256540	1701400	4	6	2360	0.255	0.232	0.008	C	*ls*
			68.594	242720	1700600	2	4	2020	0.286	0.129	—0.243	C	*ls*
			69.247	256540	1700600	4	4	392	0.0282	0.0257	—0.95	C—	*ls*
9.	*3p–5d*	$^2P°–^2D$	*51.055*	*251930*	*2210600*	6	10	1400	0.093	0.094	—0.25	C	1
			51.172	256540	2210700	4	6	1400	0.083	0.056	—0.48	C	*ls*
			50.821	242720	2210400	2	4	1200	0.093	0.031	—0.73	C	*ls*
			[51.181]	256540	2210400	4	4	240	0.0093	0.0063	—1.43	C—	*ls*
10.	*3d–4p*	$^2D–^2P°$	*101.16*	*588890*	*1577400*	10	6	478	0.0440	0.147	—0.357	C	1
			101.05	589570	1579200	6	4	430	0.044	0.088	—0.58	C	*ls*
			101.42	587870	1573800	4	2	476	0.0367	0.0490	—0.83	C	*ls*
			[100.87]	587870	1579200	4	4	48	0.0074	0.0098	—1.53	C—	*ls*
11.	*3d–5p*	$^2D–^2P°$	*64.012*	*588890*	*2151100*	10	6	180	0.0068	0.014	—1.17	C	1
			64.005	589570	2152000	6	4	160	0.0066	0.0084	—1.40	C	*ls*
			[64.044]	587870	2149300	4	2	180	0.0056	0.0047	—1.65	C	*ls*
			[63.933]	587870	2152000	4	4	18	0.0011	9.3(—4)[a]	—2.35	C	*ls*
12.	*3d–4f*	$^2D–^2F°$	*86.124*	*588890*	*1750000*	10	14	5900	0.92	2.6	0.96	C	*interp.*
			86.164	589570	1750100	6	8	5900	0.88	1.5	0.72	C	*ls*
			86.057	587870	1749900	4	6	5300	0.88	1.0	0.55	C	*ls*
			[86.182]	589570	1749900	6	6	390	0.043	0.074	—0.58	C—	*ls*
13.	*3d–5f*	$^2D–^2F°$	*60.735*	*588890*	*2235400*	10	14	2200	0.170	0.340	0.230	C	*interp.*
			60.756	589570	2235500	6	8	2190	0.162	0.194	—0.013	C	*ls*
			60.699	587870	2235300	4	6	2050	0.170	0.136	—0.167	C	*ls*
			[60.763]	589570	2235300	6	6	150	0.0081	0.0097	—1.31	C—	*ls*
14.	*3d–6f*	$^2D–^2F°$	*52.348*	*588890*	*2499200*	10	14	1100	0.064	0.11	—0.19	C	1
			52.363	589570	2499300	6	8	1100	0.061	0.063	—0.44	C	*ls*
			52.321	587870	2499100	4	6	1000	0.064	0.044	—0.59	C	*ls*
			[52.369]	589570	2499100	6	6	73	0.0030	0.0031	—1.75	C—	*ls*
15.	*4s–4p*	$^2S–^2P°$	*1011*	1478500	*1577400*	2	6	14	0.63	4.2	0.10	C	1
			[993.1]	1478500	1579200	2	4	14	0.43	2.8	—0.07	C	*ls*
			[1049]	1478500	1573800	2	2	12	0.20	1.4	—0.39	C	*ls*
16.	*4s–5p*	$^2S–^2P°$	*148.7*	1478500	*2151100*	2	6	222	0.221	0.216	—0.355	C	1
			[148.5]	1478500	2152000	2	4	223	0.147	0.144	—0.53	C	*ls*
			[149.1]	1478500	2149300	2	2	220	0.073	0.072	—0.83	C	*ls*
17.	*4p–5s*	$^2P°–^2S$	*190.3*	*1577400*	2102800	6	2	620	0.113	0.425	—0.169	C	1
			[191.0]	1579200	2102800	4	2	411	0.113	0.283	—0.347	C	*ls*
			[189.0]	1573800	2102800	2	2	213	0.114	0.142	—0.64	C	*ls*
18.	*4p–6s*	$^2P°–^2S$	*118.0*	*1577400*	2424500	6	2	316	0.0220	0.051	—0.88	C	*interp.*
			[118.3]	1579200	2424500	4	2	210	0.022	0.034	—1.06	C	*ls*
			[117.6]	1573800	2424500	2	2	110	0.022	0.017	—1.36	C	*ls*
19.	*4p–4d*	$^2P°–^2D$	*808.4*	*1577400*	*1701100*	6	10	31	0.51	8.1	0.49	C	1
			[818.3]	1579200	1701400	4	6	30	0.45	4.9	0.26	C	*ls*
			[788.6]	1573800	1700600	2	4	28	0.52	2.7	0.02	C	*ls*
			[823.7]	1579200	1700600	4	4	4.9	0.050	0.54	—0.70	C—	*ls*

Cr XIV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
20.	4p–5d	$^2P°–^2D$	*157.9*	*1577400*	*2210600*	6	10	384	0.239	0.75	0.157	C	1
			[158.4]	1579200	2210700	4	6	380	0.22	0.45	—0.06	C	*ls*
			[157.1]	1573800	2210400	2	4	330	0.24	0.25	—0.32	C	*ls*
			[158.4]	1579200	2210400	4	4	64	0.024	0.050	—1.02	C—	*ls*
21.	4p–6d	$^2P°–^2D$	*110.2*	*1577400*	*2485100*	6	10	260	0.080	0.17	—0.32	D	*interp.*
			[110.4]	1579200	2485200	4	6	250	0.069	0.10	—0.56	D	*ls*
			[109.7]	1573800	2485000	2	4	220	0.079	0.057	—0.80	D	*ls*
			[110.4]	1579200	2485000	4	4	41	0.0076	0.011	—1.52	D—	*ls*
22.	4d–5p	$^2D–^2P°$	*222.2*	*1701100*	*2151100*	10	6	220	0.098	0.72	—0.01	C	1
			[221.9]	1701400	2152000	6	4	200	0.098	0.43	—0.23	C	*ls*
			[222.9]	1700600	2149300	4	2	220	0.082	0.24	—0.49	C	*ls*
			[221.5]	1700600	2152000	4	4	22	0.016	0.048	—1.18	C—	*ls*
23.	4d–6f	$^2D–^2F°$	*125.3*	*1701100*	*2499200*	10	14	540	0.179	0.74	0.25	C	1
			[125.3]	1701400	2499300	6	8	540	0.17	0.42	0.01	C	*ls*
			[125.2]	1700600	2499100	4	6	520	0.18	0.30	—0.14	C	*ls*
			[125.4]	1701400	2499100	6	6	36	0.0085	0.021	—1.29	C—	*ls*
24.	5s–5p	$^2S–^2P°$	*2070*	2102800	*2151100*	2	6	4.0	0.78	11	0.19	C	1
			[2032]	2102800	2152000	2	4	4.4	0.55	7.3	0.04	C	*ls*
			[2150]	2102800	2149300	2	2	3.8	0.26	3.7	—0.28	C	*ls*
25.	5p–5d	$^2P°–^2D$	*1681*	*2151100*	*2210600*	6	10	9.6	0.68	23	0.61	C	1
			[1704]	2152000	2210700	4	6	9.6	0.62	14	0.40	C	*ls*
			[1637]	2149300	2210400	2	4	8.9	0.71	7.7	0.15	C	*ls*
			[1712]	2152000	2210400	4	4	1.5	0.067	1.5	—0.57	C—	*ls*
26.	5d–6f	$^2D–^2F°$	*346.5*	*2210600*	*2499200*	10	14	250	0.64	7.3	0.81	C	1
			[346.5]	2210700	2499300	6	8	260	0.61	4.2	0.57	C	*ls*
			[346.4]	2210400	2499100	4	6	240	0.64	2.9	0.41	C	*ls*
			[346.7]	2210700	2499100	6	6	17	0.031	0.21	—0.74	C—	*ls*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XV

Ground State $1s^2 2s^2 2p^6\ ^1S_0$

Ionization Potential 1011 eV = 8151600 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
13.294	17	20.863	2	373.4	21	424.6	20
13.416	16	21.153	1	390.3	20	440.0	25
13.862	14	226.4	23	390.5	21	457.5	19
13.991	13	265.9	28	400.5	27	458.7	18
15.06	12	297.5	22	403.7	26	459.8	26
15.21	11	299.3	21	404.4	19	506.8	18
15.509	4	317.1	22	404.7	21	551.3	26
15.788	3	341.3	19	417.9	19	714.3	18
18.497	10	353.1	21	424.3	19	759.9	24
18.782	9						

Two theoretical studies are available for this ion of the Ne sequence, the parametric-potential method of Crance [1] and the self-consistent field calculations by Kastner et al. [2]. Both authors obtain very similar results for the oscillator strengths, with agreement of 25 percent or better in every case.

Since the two sources use rather equivalent approaches, but Crance's calculations are more complete, we have applied his work exclusively for this compilation. Some transitions are represented in *jl*-coupling notation, as given by Crance.

Both calculations have been done in a single-configuration approximation only, but this should not lead to significant uncertainties for this highly ionized species. However, the weaker lines are expected to be affected by uncertainties in the calculated intermediate coupling coefficients more than the stronger lines, and the accuracy ratings have been correspondingly lowered. Also, a configuration interaction calculation for Fe XVII by Loulergue [3] indicates that some of Crance's data could be too low by as much as a factor of two. Systematic trends along the sequence have not yet been definitively established, since sufficient data are only available for the first few ions.

References

[1] Crance, M., At. Data **5**, 185 (1973).
[2] Kastner, S. O., Omidvar, K., and Underwood, J. H., Astrophys. J. **148**, 269 (1967).
[3] Loulergue, M., Astron. Astrophys. **15**, 216 (1971).

Cr XV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2p^6$–$2p^5 3s$	^1S–[1½]°	21.153	0	4727500	1	3	3200	0.065	0.0045	—1.19	D—	1
2.		^1S–[½]°	20.863	0	4793200	1	3	3200	0.063	0.0043	—1.20	D—	1
3.	$2p^6$–$2p^5 4s$	^1S–[1½]°	15.788	0	6333900	1	3	1500	0.017	8.8 (—4) [a]	—1.77	D—	1
4.		^1S–[½]°	15.509	0	6447900	1	3	920	0.010	5.1 (—4)	—2.00	D—	1
5.	$2p^6$–$2p^5 5s$	^1S–[1½]°				1	3		0.0067		—2.17	E	1
6.		^1S–[½]°				1	3		0.0037		—2.43	E	1
7.	$2p^6$–$2p^5 6s$	^1S–[1½]°				1	3		0.0034		—2.47	E	1
8.		^1S–[½]°				1	3		0.0018		—2.74	E	1
9.	$2p^6$–$2p^5 3d$	^1S–^3D°											
			18.782	0	5324200	1	3	3.0 (+4)	0.48	0.030	—0.32	D	1
10.		^1S–^1P°	18.497	0	5406300	1	3	1.5 (+5)	2.37	0.14	0.37	D	1
11.	$2p^6$–$2p^5 4d$	^1S–^3D°											
			15.21	0	6576000	1	3	3.1 (+4)	0.32	0.016	—0.49	D	1
12.		^1S–^1P°	15.06	0	6641000	1	3	4.0 (+4)	0.41	0.020	—0.39	D	1
13.	$2p^6$–$2p^5 5d$	^1S–^3D°											
			13.991	0	7147500	1	3	1.6 (+4)	0.14	0.0064	—0.85	D	1
14.		^1S–^1P°	13.862	0	7214000	1	3	2.0 (+4)	0.17	0.0078	—0.77	D	1
15.	$2p^6$–$2p^5 6d$	^1S–^3P°											
						1	3		0.0010		—3.00	E	1
16.		^1S–^3D°											
			13.416	0	7453800	1	3	7700	0.062	0.0027	—1.21	E	1
17.		^1S–^1P°	13.294	0	7522200	1	3	1.2 (+4)	0.095	0.0042	—1.02	E	1
18.	$2p^5 3s$–$2p^5 3p$	^3P°–^3S	*494.1*	*[4722400]*	[4924800]	9	3	28	0.034	0.50	—0.51	D	1
			[458.7]	[4706800]	[4924800]	5	3	33	0.062	0.47	—0.51	D	1
			[506.8]	4727500	[4924800]	3	3	1.3	0.0050	0.025	—1.82	E	1
			[714.3]	[4784800]	[4924800]	1	3	0.17	0.0039	0.0092	—2.41	E	1

Cr XV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
19.		$^3P^o$–^3D											
			[404.4]	[4706800]	[4954100]	5	7	53	0.18	1.2	—0.04	D	1
			[457.5]	4727500	[4946100]	3	5	20	0.10	0.47	—0.50	D	1
			[424.3]	[4784800]	[5020500]	1	3	20	0.16	0.23	—0.79	D	1
			[417.9]	[4706800]	[4946100]	5	5	23	0.060	0.41	—0.52	D	1
			[341.3]	4727500	[5020500]	3	3	0.17	3.0(—4)	0.0010	—3.05	E	1
20.		$^3P^o$–^1P											
			[390.3]	[4706800]	[4963000]	5	3	2.7	0.0037	0.024	—1.73	E	1
			[424.6]	4727500	[4963000]	3	3	44	0.12	0.50	—0.45	D	1
21.		$^3P^o$–^3P											
			[373.4]	[4706800]	[4974600]	5	5	35	0.073	0.45	—0.44	D	1
			[299.3]	[4706800]	[5040900]	5	3	5.3	0.0043	0.021	—1.67	E	1
			[353.1]	4727500	[5010700]	3	1	54	0.034	0.12	—1.00	D	1
			[404.7]	4727500	[4974600]	3	5	24	0.098	0.39	—0.53	E	1
			[390.5]	[4784800]	[5040900]	1	3	33	0.23	0.29	—0.65	E	1
22.		$^3P^o$–^1D											
			[297.5]	[4706800]	[5042900]	5	5	0.89	0.0012	0.0058	—2.23	E	1
			[317.1]	4727500	[5042900]	3	5	0.97	0.0024	0.0076	—2.14	E	1
23.		$^3P^o$–^1S											
			[226.4]	4727500	[5169300]	3	1	100	0.026	0.057	—1.11	E	1
24.		$^1P^o$–^3S											
			[759.9]	4793200	[4924800]	3	3	0.16	0.0014	0.010	—2.38	E	1
25.		$^1P^o$–^3D											
			[440.0]	4793200	[5020500]	3	3	24	0.070	0.30	—0.68	D	1
26.		$^1P^o$–^3P											
			[551.3]	4793200	[4974600]	3	5	0.30	0.0023	0.012	—2.17	E	1
			[403.7]	4793200	[5040900]	3	3	22	0.054	0.21	—0.79	D	1
			[459.8]	4793200	[5010700]	3	1	12	0.013	0.058	—1.42	E	1
27.		$^1P^o$–^1D	[400.5]	4793200	[5042900]	3	5	54	0.22	0.86	—0.19	D	1
28.		$^1P^o$–^1S	[265.9]	4793200	[5169300]	3	1	130	0.046	0.12	—0.86	D	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XVI

Ground State $1s^2 2s^2 2p^5\ ^2P^o_{3/2}$

Ionization Potential [1093] eV = [8816000] cm^{-1}

Allowed Transitions

The multiplet strength for the single multiplet presented here is taken from Safronova's many-body perturbation theory calculation [1]. At lower Z, this calculation is in excellent agreement with the non-closed shell many-electron theory of Sinanoglu [2]. As an expansion in Z^{-1} Safronova's results should improve with increasing Z, and should be fairly accurate for Cr XVI. The data resulting from the expansion in Z^{-1} of the line strength by Cohen and Dalgarno [3] were found to lie above both Safronova's and Sinanoglu's values by about 20%.

Additional data for this ion are available from the work of Ali [4,5], who has calculated multiplet strengths for the fairly strong $3s$–$3p$ and $3p$–$3d$ transitions, again using an expansion in Z^{-1}. We did not tabulate this material, however, since the relevant wavelengths and energy levels are not known.

References

[1] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 231 (1975).
[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).
[3] Cohen, M., and Dalgarno, A., Proc. R. Soc. London, Ser. A **280**, 258 (1964).
[4] Ali, M. A., Int. J. Quantum Chem., Symp. **3**, 359 (1970).
[5] Ali, M. A., J. Quant. Spectrosc. Radiat. Transfer **11**, 503 (1971).

Cr XVI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^22p^5$–$2s2p^6$	$^2P^\circ$–^2S	*109.34*	*23521*	938090	6	2	850	0.051	0.11	—0.51	D	1
			106.60	0	938090	4	2	610	0.052	0.073	—0.68	D	*ls*
			115.27	70562	938090	2	2	240	0.049	0.037	—1.01	D	*ls*

Cr XVII

Ground State $1s^22s^22p^4\ ^3P_2$

Ionization Potential [1182]eV = [9533700] cm^{-1}

Allowed Transitions

The transition probabilities for lines of the first seven multiplets are from the Z-expansion calculation of Safronova [1]. Relativistic effects are included, and the results are in good agreement with the many-electron theory of Sinanoglu [2] for nearby ions of the same isoelectronic sequence, e.g., Mn XVIII.

References

[1] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 223 (1975).
[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

Cr XVII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^22p^4$–$2s2p^5$	^3P–$^3P^\circ$	*123.44*	*26590*	*836710*	9	9	370	0.085	0.31	—0.12	D	1
			122.91	0	813600	5	5	290	0.066	0.13	—0.48	D	1
			125.35	60380	858150	3	3	97	0.023	0.028	—1.16	D	1
			116.53	0	858150	5	3	160	0.020	0.038	—1.01	D	1
			120.84	60380	887920	3	1	440	0.032	0.038	—1.02	D	1
			132.76	60380	813600	3	5	83	0.037	0.048	—0.96	D	1
			125.00	58150	858150	1	3	110	0.077	0.032	—1.11	D	1
2.		^3P–$^1P^\circ$											
			[90.1]			5	3	200	0.015	0.022	—1.14	D	1
			[95.3]			3	3	47	0.0064	0.0060	—1.72	D	1
3.		^1D–$^3P^\circ$											
			[138]			5	3	35	0.0060	0.014	—1.52	D	1
4.		^1D–$^1P^\circ$	101.91			5	3	1100	0.10	0.17	—0.29	D	1
5.		^1S–$^1P^\circ$	[117.72]?			1	3	69	0.043	0.017	—1.37	D	1
6.	$2s2p^5$–$2p^6$	$^1P^\circ$–^1S	[128]			3	1	1200	0.098	0.12	—0.53	D	1

Cr XVII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
7.		$^3P^\circ$–^1S											
			[96.9]			3	1	53	0.0025	0.0024	—2.13	D	1
8.	$2p^3(^4S^\circ)3s$–$2p^3(^4S^\circ)3p$	$^3S^\circ$–^3P				3	9		0.38		0.06	D	*interp.*
9.		$^5S^\circ$–^5P				5	15		0.18		—0.05	D	*interp.*

Cr XVIII

Ground State $1s^2 2s^2 2p^3\ ^4S^\circ_{3/2}$

Ionization Potential [1295] eV = [10445000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
95.76	3	119.20	6	129	2	149.66	1
102.32	3	119.62	5	133.07	8	149.89	4
104.94	3	122	7	136.52	1	151	4
105.93	6	123.84	7	139.87	1	155.41	9
110.41	6	124.38	5	140.79	9	157.30	9
112.27	7	125.44	5	143.52	4	175.77	9
114.00	6	128.10	2	147.72	8		

Transition probabilities for lines of the first nine multiplets are the results of the many-body perturbation theory calculations by Safronova and Bolotin [1]. These results are in good agreement with extrapolations from lower charged ions, based mainly on the non-closed shell many-electron theory of Sinanoglu [2].

Oscillator strengths for the last five multiplets were obtained by graphical interpolation of systematic trends along the nitrogen isoelectronic sequence.

References

[1] Safronova, U. I., and Bolotin, A. B., Czech. J. Phys., Sect. B **26**, 945 (1976).
[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

Cr XVIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p^3$–$2s2p^4$	$^4S^\circ$–^4P	*143.99*	0	*694490*	4	12	120	0.12	0.22	—0.33	C+	1
			149.66	0	668180	4	6	110	0.055	0.11	—0.65	C+	1
			139.87	0	714950	4	4	140	0.041	0.076	—0.78	C+	1
			136.52	0	732490	4	2	150	0.021	0.038	—1.08	C+	1
2.		$^2D^\circ$–^2D	*129*			10	10	260	0.066	0.28	—0.18	C	1
			128.10			6	6	250	0.062	0.16	—0.43	C+	1
			125.44			4	4	310	0.073	0.12	—0.53	C+	1
			[129]			6	4	2.4	4.0(—4)[a]	0.0010	—2.62	D	1
3.		$^2D^\circ$–^2P	*104*			10	6	720	0.070	0.24	—0.15	C+	1
			104.94			6	4	800	0.088	0.18	—0.28	C+	1
			95.76			4	2	390	0.027	0.034	—0.97	C	1
			102.32			4	4	140	0.022	0.030	—1.06	C	1
4.		$^2P^\circ$–^2D	*148*			6	10	42	0.023	0.068	—0.86	C	1
			149.89			4	6	50	0.025	0.050	—1.00	C+	1
			[143.52]			2	4	26	0.016	0.015	—1.49	C+	1
			[151]			4	4	4.0	0.0014	0.0027	—2.26	D	1

Cr XVIII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
5.		$^2P^o$–^2S	*121*			6	2	330	0.024	0.057	—0.84	C	1
			[124.38]?			4	2	43	0.0050	0.0082	—1.70	D	1
			119.62			2	2	290	0.062	0.049	—0.91	C+	1
6.		$^2P^o$–^2P	*116*			6	6	300	0.061	0.14	—0.44	C+	1
			119.20			4	4	87	0.019	0.029	—1.13	C+	1
			105.93			2	2	41	0.0069	0.0048	—1.86	C+	1
			110.41			4	2	700	0.064	0.093	—0.59	C+	1
			114.00			2	4	62	0.024	0.018	—1.32	C+	1
7.	$2s2p^4$–$2p^5$	^2D–$^2P^o$											
			123.84			6	4	350	0.054	0.13	—0.49	C+	1
			112.27			4	2	380	0.036	0.053	—0.84	C+	1
			[122]			4	4	110	0.025	0.039	—1.01	C	1
8.		^2S–$^2P^o$											
			[147.72]			2	4	68	0.044	0.043	—1.05	C+	1
			[133.07]			2	2	8.9	0.0024	0.0021	—2.33	D	1
9.		^2P–$^2P^o$											
			[157.30]			4	4	250	0.093	0.19	—0.43	C+	1
			[155.41]			2	2	250	0.091	0.093	—0.74	C+	1
			[140.79]			4	2	230	0.034	0.063	—0.86	C+	1
			[175.77]			2	4	16	0.015	0.017	—1.53	C	1
10.	$2p^2(^3P)3s$–$2p^2(^3P)3p$	^4P–$^4D^o$				12	20		0.15		0.26	E	*interp.*
11.		^4P–$^4P^o$				12	12		0.10		0.08	E	*interp.*
12.		^2P–$^2D^o$				6	10		0.16		—0.02	E	*interp.*
13.	$2p^2(^1D)3s$–$2p^2(^1D)3p$	^2D–$^2F^o$				10	14		0.11		0.04	E	*interp.*
14.	$2p^2(^1D)3p$–$2p^2(^1D)3d$	$^2F^o$–^2G				14	18		0.15		0.32	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XIX

Ground State $1s^2 2s^2 2p^2\ ^3P_0$

Ionization Potential [1394] eV = [11244000] cm^{-1}

Allowed Transitions

The data have been obtained by the generation and analysis of systematic trends along the carbon isoelectronic sequence and the subsequent determination of interpolated oscillator strengths. For many transitions our final recommended data agree well with the interpolated values given by Smith and Wiese [1]. However, in some cases the dependence of the oscillator strength on the inverse nuclear charge, $1/Z$, has been reinterpreted as a result of the availability of new f-value data (or, in some cases, of wavelength data which enabled us to convert previously published line strengths to oscillator strengths).

To single out some of the principal contributing sources, the nuclear charge expansion method has been used by Safronova [2], Laughlin and Dalgarno [3], and Cohen and Dalgarno [4] to calculate line strengths for the entire isoelectronic sequence, so that f-values could be derived whenever wavelength data existed. In addition, the extrapolated values given by Sinanoglu [5] for the higher ions

of the sequence, which were based on data calculated according to his many-electron theory for the lower ions, were helpful in establishing some systematic trends, as were the self-consistent field (SCF) calculations in intermediate coupling by Fawcett et al. [6] for Fe XXI.

It should be noted that uncertainties in the interpolated data are expected to be fairly large, mainly since relativistic effects should become significant at about this point and have either not at all, or only roughly, been accounted for in the existing calculated data.

References

[1] Smith, M. W., and Wiese, W. L., Astrophys. J. Suppl. Ser. **23**, No. 196, 103 (1971).

[2] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 231 (1975).

[3] Laughlin, C., and Dalgarno, A., J. Chem. Phys. **60**, 1688 (1974).

[4] Cohen, M., and Dalgarno, A., Proc. R. Soc. London, Ser. A **280**, 258 (1964).

[5] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

[6] Fawcett, B. C., Cowan, R. D., and Hayes, R. W., Astrophys. J. **187**, 377 (1974).

Cr XIX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^22p^2$–$2s2p^3$	^{3}P–^{3}D°				9	15		0.046		—0.38	C	*interp.*
2.		^{3}P–^{3}P°				9	9		0.046		—0.38	C	*interp.*
3.		^{3}P–^{3}S°	*111.37*	*61660*	959600	9	3	860	0.053	0.17	—0.32	C	*interp.*
			113.99	82330	959600	5	3	430	0.050	0.094	—0.60	C—	*ls*
			109.67	47770	959600	3	3	290	0.053	0.057	—0.80	C—	*ls*
			104.21	0	959600	1	3	110	0.055	0.019	—1.26	C—	*ls*
4.		^{1}D–^{1}D°	126.30			5	5	260	0.062	0.13	—0.51	C	*interp.*
5.		^{1}D–^{1}P°	110.38			5	3	550	0.060	0.11	—0.52	C	*interp.*
6.		^{1}S–^{1}P°				1	3		0.11		—0.96	C	*interp.*
7.	$2p^2$–$2p3s$	^{3}P–^{3}P°				9	9		0.044		—0.40	C	*interp.*
8.		^{1}D–^{1}P°				5	3		0.041		—0.69	C	*interp.*
9.		^{1}S–^{1}P°				1	3		0.044		—1.36	C	*interp.*
10.	$2p^2$–$2p3d$	^{1}D–^{1}F°	[14.91]			5	7	2.0(+5)[a]	0.95	0.23	0.68	C	*interp.*
11.		^{1}S–^{1}P°				1	3		1.22		0.086	C	*interp.*
12.	$2p^2$–$2p4s$	^{3}P–^{3}P°				9	9		0.010		—1.05	D	*interp.*
13.	$2s2p^3$–$2p^4$	^{3}D°–^{3}P				15	9		0.052		—0.11	D—	*interp.*
14.		^{3}P°–^{3}P				9	9		0.032		—0.54	D	*interp.*
15.	$2p3s$–$2p3p$	^{3}P°–^{3}D				9	15		0.098		—0.05	D	*interp.*
16.		^{3}P°–^{3}S				9	3		0.022		—0.70	D	*interp.*
17.		^{3}P°–^{3}P				9	9		0.079		—0.15	D	*interp.*
18.		^{1}P°–^{1}P				3	3		0.054		—0.79	D	*interp.*
19.		^{1}P°–^{1}D				3	5		0.16		—0.32	D	*interp.*
20.	$2p3p$–$2p3d$	^{1}P–^{1}D°				3	5		0.10		—0.52	D	*interp.*
21.		^{1}P–^{1}P°				3	3		0.034		—0.99	D	*interp.*
22.		^{3}D–^{3}P°				15	9		0.0017		—1.59	D	*interp.*
23.		^{3}D–^{3}F°				15	21		0.039		—0.23	D—	*interp.*
24.		^{3}D–^{3}D°				15	15		0.036		—0.27	D	*interp.*
25.		^{3}S–^{3}P°				3	9		0.083		—0.60	D	*interp.*
26.		^{3}P–^{3}D°				9	15		0.057		—0.29	D	*interp.*
27.		^{3}P–^{3}P°				9	9		0.039		—0.45	D	*interp.*
28.		^{1}D–^{1}D°				5	5		0.0034		—1.77	D	*interp.*

Cr XIX: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
29.		^1D–$^1F°$				5	7		0.12		—0.22	D	*interp.*
30.		^1D–$^1P°$				5	3		6.6(—4)		—2.48	D	*interp.*
31.		^1S–$^1P°$				1	3		0.074		—1.13	D	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XX

Ground State $1s^2 2s^2 2p\ ^2P°_{1/2}$

Ionization Potential [1493] eV = [12042000] cm^{-1}

Allowed Transitions

The oscillator strength data were derived by interpolation from graphs of systematic trends along the boron isoelectronic sequence. Although in most cases these trends are fairly well established for low Z, Cr XX lies at a point in the sequence where significant relativistic changes on line strengths and energy levels are expected to occur. Mainly for this reason, it is estimated that the values presented are uncertain within a factor of two.

Cr XX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p$–$2s 2p^2$	$^2P°$–^2D				6	10		0.045		—0.57	E	*interp.*
2.		$^2P°$–^2S				6	2		0.027		—0.79	E	*interp.*
3.		$^2P°$–^2P				6	6		0.010		—1.22	E	*interp.*
4.	$2s 2p^2$–$2p^3$	^4P–$^4S°$				12	4		0.040		—0.32	E	*interp.*
5.		^2D–$^2D°$				10	10		0.047		—0.33	E	*interp.*
6.		^2D–$^2P°$				10	6		0.028		—0.55	E	*interp.*
7.		^2P–$^2D°$				6	10		0.050		—0.52	E	*interp.*
8.		^2P–$^2P°$				6	6		0.057		—0.47	E	*interp.*
9.	$2p$–$3s$	$^2P°$–^2S				6	2		0.020		—0.92	E	*interp.*
10.	$2p$–$3d$	$^2P°$–^2D				6	10		0.66		0.60	E	*interp.*
11.	$3s$–$3p$	^2S–$^2P°$				2	6		0.16		—0.49	E	*interp.*
12.	$3p$–$3d$	$^2P°$–^2D				6	10		0.050		—0.52	E	*interp.*

Cr XXI

Ground State $1s^2 2s^2\ ^1S_0$

Ionization Potential [1627]eV = [13123000] cm^{-1}

Allowed Transitions

Oscillator strengths were derived by interpolation from graphs of systematic trends along the Be isoelectronic sequence.

The data marked "E" are estimated to be accurate to within a factor of two.

Cr XXI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2$–$2s2p$	^1S–$^1P^\circ$	[149.89]	0	[667160]	1	3	160	0.16	0.079	—0.80	C	*interp.*
2.	$2s^2$–$2s3p$	^1S–$^1P^\circ$	[13]	0	[7700000]	1	3	8.3(+4)[a]	0.63	0.027	—0.20	C	*interp.*
3.	$2s^2$–$2s4p$	^1S–$^1P^\circ$				1	3		0.16		—0.80	E	*interp.*
4.	$2s2p$–$2p^2$	$^3P^\circ$–^3P				9	9		0.065		—0.23	D	*interp.*
5.		$^1P^\circ$–^1D				3	5		0.070		—0.68	D	*interp.*
6.		$^1P^\circ$–^1S				3	1		0.040		—0.92	D	*interp.*
7.	$2s2p$–$2s3s$	$^3P^\circ$–^3S				9	3		0.030		—0.57	E	*interp.*
8.		$^1P^\circ$–^1S				3	1		0.0060		—1.74	E	*interp.*
9.	$2s2p$–$2s3d$	$^3P^\circ$–^3D				9	15		0.75		0.83	D	*interp.*
10.		$^1P^\circ$–^1D	[14]	[667160]	[7800000]	3	5	1.1(+5)	0.54	0.075	0.21	D	*interp.*
11.	$2s3s$–$2s3p$	^3S–$^3P^\circ$				3	9		0.18		—0.27	E	*interp.*
12.		^1S–$^1P^\circ$				1	3		0.055		—1.26	E	*interp.*
13.	$2s3p$–$2s3d$	$^1P^\circ$–^1D				3	5		0.050		—0.82	E	*interp.*
14.		$^3P^\circ$–^3D				9	15		0.030		—0.57	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XXII

Ground State $1s^2 2s\ ^2S_{1/2}$

Ionization Potential [1721.9] eV = [13887700] cm^{-1}

Allowed Transitions

The data are taken from the theoretical analysis of Martin and Wiese [1], which was based on a generalized study of systematic trends for several spectral series of the lithium isoelectronic sequence. For the $3d$–$4f$ transition, the f-value was taken from an earlier study of systematic trends along isoelectronic sequences by Smith and Wiese [2].

Results of the relativistic calculations of Kim and Desclaux [3] were incorporated into the data for the $2s$–$2p$ and $2s$–$3p$ transitions. More recently, Armstrong et al. [4] have reported results of relativistic calculations of f-values for the $2s$–$2p$, $2s$–$3p$, and $2p$–$3d$ transitions which agree well with the recommended data of ref. [1]. For all other transitions, no relativistic calculations were available. However, the relativistic calculations of Younger and Weiss [5] for the hydrogen isoelectronic sequence provide a means of assessing the magnitude of relativistic corrections since the Li sequence is very similar in structure to the H sequence. For those transitions for which relativistic effects were estimated to be significant (specifically, whenever the ratio of the weighted relativistic hydrogenic f-values $g_i f_{ik}$ of any two lines within a multiplet was found to deviate from the corresponding LS-coupling line strength ratio by more than 5% for the appropriate value of the nuclear charge Z), the f-values were excluded from the compilation. A more detailed discussion of this comparison is given in ref. [1].

References

[1] Martin, G. A., and Wiese, W. L., J. Phys. Chem. Ref. Data **5**, 537 (1976).

[2] Smith, M. W., and Wiese, W. L., Astrophys. J. Suppl. Ser. **23**, No. 196, 103 (1971).

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Cr XXII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	2*s*–2*p*	^2S–$^2P^o$	*239.16*	0	*418130*	2	6	27	0.070	0.11	—0.85	B	1
			223.00	0	448430	2	4	33	0.049	0.072	—1.01	B	1
			279.69	0	357540	2	2	17	0.020	0.037	—1.40	B	1
2.	2*s*–3*p*	^2S–$^2P^o$	*12.634*	0	*7915100*	2	6	5.19(+4)[a]	0.373	0.0310	—0.128	B+	1
			12.620	0	7923900	2	4	5.13(+4)	0.245	0.0204	—0.310	B+	1
			12.662	0	7897600	2	2	5.28(+4)	0.127	0.0106	—0.595	B+	1
3.	2*s*–4*p*	^2S–$^2P^o$	9.493	0	10530000	2	6	2.5(+4)	0.10	0.0063	—0.70	C+	1
4.	2*s*–5*p*	^2S–$^2P^o$	[8.51]	0	[11800000]	2	6	1.2(+4)	0.040	0.0022	—1.10	C+	1
5.	2*s*–6*p*	^2S–$^2P^o$				2	6		0.0212		—1.373	C+	1
6.	2*s*–7*p*	^2S–$^2P^o$				2	6		0.0124		—1.606	C+	1
7.	2*p*–3*d*	$^2P^o$–^2D	*13.245*	*418130*	*7967900*	6	10	1.6(+5)	0.68	0.18	0.61	B	1
			13.294	448430	7970600	4	6	1.6(+5)	0.63	0.11	0.40	B	*ls*
			13.147	357540	7963800	2	4	1.3(+5)	0.69	0.060	0.14	B	*ls*
			[13.306]	448430	7963800	4	4	2.6(+4)	0.068	0.012	—0.56	C+	*ls*
8.	2*p*–4*d*	$^2P^o$–^2D	*9.841*	*418130*	*10580000*	6	10	5.0(+4)	0.12	0.023	—0.14	B	1
			9.865	448430	10590000	4	6	4.9(+4)	0.11	0.014	—0.37	B	*ls*
			9.809	357540	10570000	2	4	4.1(+4)	0.12	0.0077	—0.62	B	*ls*
			9.865	448430	10570000	4	4	7900	0.012	0.0015	—1.34	C+	*ls*
9.	2*p*–5*d*	$^2P^o$–^2D				6	10		0.0450		—0.569	C+	1
10.	2*p*–6*d*	$^2P^o$–^2D				6	10		0.0220		—0.879	C+	1
11.	2*p*–7*d*	$^2P^o$–^2D				6	10		0.0126		—1.121	C+	1
12.	3*s*–4*p*	^2S–$^2P^o$	[37.00]	7827000	10530000	2	6	7000	0.43	0.10	—0.07	C	1
13.	3*s*–5*p*	^2S–$^2P^o$	[25.2]	7827000	[11800000]	2	6	3750	0.107	0.0178	—0.67	C	1
14.	3*s*–6*p*	^2S–$^2P^o$				2	6		0.047		—1.03	C	1
15.	3*s*–7*p*	^2S–$^2P^o$				2	6		0.0249		—1.303	C	1
16.	3*p*–7*s*	$^2P^o$–^2S				6	2		0.0018		—1.97	C—	1
17.	3*p*–4*d*	$^2P^o$–^2D	*37.52*	*7915100*	*10580000*	6	10	1.7(+4)	0.59	0.44	0.55	B	1
18.	3*p*–5*d*	$^2P^o$–^2D				6	10		0.138		—0.082	C+	1
19.	3*p*–6*d*	$^2P^o$–^2D				6	10		0.0558		—0.475	C+	1
20.	3*p*–7*d*	$^2P^o$–^2D				6	10		0.0289		—0.761	C+	1
21.	3*d*–4*f*	^2D–$^2F^o$				10	14		1.00		1.000	B	2
22.	4*s*–5*p*	^2S–$^2P^o$				2	6		0.473		—0.024	C	1
23.	4*s*–6*p*	^2S–$^2P^o$				2	6		0.128		—0.59	C	1
24.	4*s*–7*p*	^2S–$^2P^o$				2	6		0.056		—0.95	C	1
25.	4*p*–7*s*	$^2P^o$–^2S				6	2		0.0060		—1.44	C—	1
26.	4*p*–5*d*	$^2P^o$–^2D				6	10		0.583		0.544	C+	1
27.	4*p*–6*d*	$^2P^o$–^2D				6	10		0.141		—0.073	C+	1
28.	4*p*–7*d*	$^2P^o$–^2D				6	10		0.0616		—0.432	C+	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XXIII

Ground State $1s^2\ {}^1S_0$

Ionization Potential [7482] eV = [60348000] cm^{-1}

Allowed Transitions

For this high ion of the He isoelectronic sequence the data were mainly derived by interpolation from well established systematic trends for the lower ions.

Data used in the interpolation of oscillator strengths for the first eight transitions are taken from the relativistic random phase approximation calculation of Johnson and Lin [1]. Their results exhibit a dramatic drop in the oscillator strengths for $Z>18$, indicating significant relativistic effects on line strengths. The reduced accuracy of the intercombination lines reflects a sudden change in the systematic trend curve, making precise interpolation difficult. For other transitions, not involving the ground state, it is expected that relativistic effects play a much smaller role.

The Z-expansion calculation of Laughlin [2] has been used for four transitions, where it was found to be in good agreement with the accurate variational calculations of Schiff, Pekeris, and Accad [3] for lower Z.

The remaining multiplets were analyzed by extrapolating the variational calculations of Weiss [4] for $Z\leq 10$, which are expected to be quite accurate. Although these extrapolations do not include relativistic effects, they involve relatively highly excited states, where such effects are small.

Data for transitions involving highly excited states not tabulated here may be found in the papers of Ali and Schaad [5] and Brown and Cortez [6].

References

[1] Johnson, W. R., and Lin, C. D., Phys. Rev. A **14**, 565 (1976).
[2] Laughlin, C., J. Phys. B **6**, 1942 (1973).
[3] Schiff, B., Pekeris, C. L., and Accad, Y., Phys. Rev. A **4**, 885 (1971).
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[6] Brown, R. T., and Cortez, J. M., Astrophys. J. **176**, 267 (1972).

Cr XXIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$1s^2$–$1s2p$	${}^1S$–${}^3P^o$											
			2.20	0	45500000	1	3	3.3(+5)[a]	0.071	5.1(—4)	—1.15	E	*interp.*
2.		${}^1S$–${}^1P^o$	2.20	0	45500000	1	3	3.3(+6)	0.72	0.0052	—0.14	B	*interp.*
3.	$1s^2$–$1s3p$	${}^1S$–${}^3P^o$											
						1	3		0.014		—1.85	E	*interp.*
4.		${}^1S$–${}^1P^o$				1	3		0.14		—0.85	B	*interp.*
5.	$1s^2$–$1s4p$	${}^1S$–${}^3P^o$											
						1	3		0.0049		—2.31	E	*interp.*
6.		${}^1S$–${}^1P^o$				1	3		0.052		—1.28	B	*interp.*
7.	$1s^2$–$1s5p$	${}^1S$–${}^3P^o$											
						1	3		0.0025		—2.60	E	*interp.*
8.		${}^1S$–${}^1P^o$				1	3		0.025		—1.60	B	*interp.*
9.	$1s2s$–$1s2p$	${}^1S$–${}^1P^o$				1	3		0.017		—1.77	E	*interp.*
10.		${}^3S$–${}^3P^o$				3	9		0.030		—1.08	E	*interp.*
11.	$1s2s$–$1s3p$	${}^1S$–${}^1P^o$				1	3		0.41		—0.39	B	*interp.*
12.		${}^3S$–${}^3P^o$				3	9		0.41		0.09	B	*interp.*
13.	$1s2p$–$1s3s$	${}^1P^o$–${}^1S$				3	1		0.015		—1.35	C	2
14.		${}^3P^o$–${}^3S$				9	3		0.015		—0.87	C	2

Cr XXIII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
15.	1s2p–1s3d	^{1}P°–^{1}D				3	5		0.70		0.32	B	*interp.*
16.		^{3}P°–^{3}D				9	15		0.69		0.79	B	*interp.*
17.	1s3s–1s3p	^{1}S–^{1}P°				1	3		0.036		—1.43	C	2
18.		^{3}S–^{3}P°				3	9		0.048		—0.84	C	2
19.	1s3p–1s3d	^{3}P°–^{3}D				9	15		0.013		—0.93	C	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Cr XXIV

Ground State $1s\ ^2S_{1/2}$

Ionization Potential [7894.5] eV = [64401000] cm^{-1}

Allowed Transitions

The transition probability data for this hydrogen-like ion may be obtained by scaling the data available for the hydrogen spectrum (see NSRDS-NBS 4 [1]) according to

$$f_{\text{Cr XXIV}} = f_{\text{Hydrogen}},$$
$$A_{\text{Cr XXIV}} = (24)^4 A_{\text{Hydrogen}},$$
$$S_{\text{Cr XXIV}} = (24)^{-2} S_{\text{Hydrogen}}.$$

An uncertainty of a few percent arises from the neglect of relativistic effects. Recent theoretical studies [2, 3] indicate that relativistic effects on line strengths for this ion are generally in this range, with the relativistic value usually slightly below the non-relativistic one, although in certain transitions where n increases and l decreases the line strength increases. Younger and Weiss [3] have calculated exact Dirac relativistic hydrogenic line strengths for a number of transitions of interest along the hydrogen isoelectronic sequence.

References

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[3] Younger, S. M., and Weiss, A. W., J. Res. Nat. Bur. Stand., Sect. A **79**, 629 (1975).

Manganese

Mn I

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2\ {}^6S_{5/2}$

Ionization Potential 7.435 eV = 59970 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
2794.82	4	3148.86	85	3296.88	12	3652.29	99
2798.27	4	3149.93	26	3298.23	42	3657.91	77
2801.08	4	3151.42	106	3300.94	41	3660.40	127
3007.65	36	3152.25	148	3303.28	42	3663.37	127
3011.17	36	3155.78	106	3307.00	42	3667.71	127
3011.38	36	3159.95	25	3308.78	11	3668.20	145
3016.45	36	3160.16	105	3311.90	12	3668.55	128
3041.22	35	3161.05	17	3330.66	12	3675.67	128
3043.14	35	3167.83	25	3334.56	41	3676.96	127
3043.36	35	3169.36	148	3343.72	12	3680.15	126
3044.57	14	3170.43	85	3350.41	66	3682.09	127
3045.59	35	3175.36	67	3351.66	24	3684.87	127
3045.80	35	3175.58	105	3355.48	66	3685.56	77
3046.59	107	3175.71	104	3360.68	54	3692.82	8
3047.03	35	3177.04	25	3364.19	52	3696.55	22
3048.86	35	3177.62	25	3365.14	83	3700.30	40
3054.36	14	3178.50	17	3376.53	100	3701.73	8
3062.12	14	3189.96	105	3410.80	81	3706.08	76
3066.02	14	3192.24	104	3418.28	52	3706.66	40
3070.27	14	3201.11	105	3420.79	82	3708.87	126
3073.18	14	3202.21	104	3428.78	50	3709.83	154
3079.64	14	3203.13	103	3429.16	131	3710.75	49
3081.34	14	3206.91	13	3429.74	130	3711.59	49
3082.71	86	3212.89	13	3440.04	53	3713.79	98
3091.10	56	3216.95	3	3446.82	81	3715.53	112
3093.35	86	3224.76	3	3450.61	82	3718.13	112
3097.76	87	3226.05	13	3451.48	50	3718.92	76
3098.09	46	3227.04	103	3458.84	51	3720.91	76
3103.28	44	3228.09	13	3463.66	132	3726.95	22
3106.75	87	3230.23	101	3470.01	132	3727.99	49
3108.63	44	3230.72	13	3494.86	131	3728.89	22
3110.68	45	3238.72	101	3507.54	16	3729.52	97
3113.12	44	3240.41	12	3509.07	10	3731.01	75
3113.36	87	3240.61	13	3511.83	129	3731.94	76
3113.80	86	3240.88	102	3535.30	129	3746.62	75
3114.12	43	3243.78	13	3538.00	129	3750.77	22
3115.46	44	3249.89	101	3559.81	129	3752.55	75
3115.75	55	3251.13	13	3577.87	9	3753.30	153
3116.82	86	3252.95	13	3583.68	23	3754.22	59
3117.51	55	3254.04	12	3591.81	23	3756.64	75
3118.10	55	3255.51	101	3595.11	9	3763.37	22
3121.07	87	3256.14	13	3601.27	147	3766.05	59
3122.88	86	3258.41	13	3607.53	9	3767.70	75
3126.85	87	3260.24	13	3608.49	9	3768.18	96
3132.28	106	3263.04	84	3610.30	9	3771.44	164
3132.79	86	3264.71	12	3615.38	80	3772.96	59
3135.19	30	3267.79	84	3623.78	9	3773.86	164
3136.96	43	3268.72	66	3626.30	79	3774.67	59
3138.22	26	3270.35	84	3629.74	9	3776.29	160
3141.82	26	3273.02	84	3635.70	146	3776.54	7
3142.67	25	3278.06	84	3643.02	78	3785.42	59
3146.32	31	3278.55	12	3646.71	8	3786.84	111
3148.18	17	3290.97	11	3648.70	127	3790.21	7

List of tabulated lines—Continued

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
3791.08	153	3982.58	33	4094.07	157	4329.43	139
3799.26	7	3982.90	161	4096.68	120	4337.41	61
3800.55	59	3984.17	33	4099.40	157	4359.64	115
3801.90	34	3985.24	33	4105.37	89	4359.82	137
3803.07	95	3986.82	33	4107.87	110	4368.88	138
3804.02	34	3987.09	33	4113.88	89	4381.70	150
3806.72	7	3987.46	33	4114.38	90	4388.09	137
3808.51	34	3988.67	64	4116.60	120	4408.08	108
3809.59	7	3989.95	33	4119.01	37	4410.49	61
3810.68	34	3990.74	48	4122.37	89	4411.87	136
3811.66	34	3991.60	48	4122.76	89	4414.89	19
3816.75	7	3993.86	48	4123.28	89	4419.77	136
3823.51	7	3996.10	64	4123.54	37	4433.72	136
3823.89	7	3999.57	71	4125.81	156	4434.14	150
3826.62	29	4001.19	48	4132.28	165	4451.58	19
3829.68	7	4002.17	48	4135.03	69	4452.53	108
3833.87	7	4003.26	121	4137.27	37	4453.01	19
3834.37	7	4007.04	48	4141.06	69	4455.82	27
3839.78	7	4008.02	48	4147.53	37	4457.04	27
3843.99	7	4011.54	62	4148.80	69	4457.55	27
3845.01	94	4011.91	158	4151.66	118	4458.26	27
3855.11	65	4016.67	92	4152.57	156	4461.09	27
3870.82	125	4018.11	6	4154.22	117	4462.03	27
3871.67	39	4020.07	47	4155.53	37	4464.68	19
3872.13	124	4021.35	47	4158.69	133	4470.14	19
3873.20	123	4025.94	47	4164.98	133	4472.79	19
3876.71	94	4026.44	32	4166.21	119	4479.40	155
3888.84	125	4028.60	32	4167.20	118	4490.08	19
3889.46	163	4030.76	2	4176.61	68	4496.64	114
3891.62	73	4031.79	32	4182.25	142	4498.90	19
3894.71	38	4033.07	2	4189.99	68	4502.22	19
3898.37	64	4034.49	2	4201.78	68	4503.87	113
3899.34	65	4038.73	47	4203.11	109	4523.40	114
3911.14	58	4041.36	6	4220.61	61	4529.80	149
3912.75	65	4048.75	6	4221.56	117	4544.42	149
3914.21	57	4052.48	93	4224.34	141	4605.37	134
3919.33	159	4055.55	6	4225.08	60	4626.54	134
3920.66	122	4058.94	6	4230.14	21	4642.80	135
3923.33	74	4059.39	28	4239.74	20	4671.69	18
3924.08	58	4061.74	28	4257.67	20	4701.15	18
3926.48	58	4063.53	6	4258.37	140	4709.71	18
3928.31	144	4065.08	70	4259.35	116	4727.46	18
3929.66	74	4066.24	157	4261.30	140	4739.11	18
3931.52	143	4068.01	6	4265.93	20	4754.05	15
3935.54	74	4070.28	6	4278.68	140	4761.53	18
3936.77	74	4073.98	62	4279.55	140	4762.38	18
3937.76	74	4075.25	91	4281.10	20	4765.86	18
3942.88	57	4079.42	6	4284.08	20	4766.43	18
3951.98	63	4082.95	6	4290.11	116	4783.43	15
3952.84	62	4083.63	6	4300.19	115	4823.53	15
3954.58	143	4085.48	152	4305.67	116	5394.68	1
3975.88	63	4088.57	162	4312.55	20	5407.43	5
3977.08	63	4089.94	70	4326.18	115	5420.37	5
3978.78	72	4090.62	91	4326.75	139	5432.56	1
3980.14	158	4092.39	91	4327.95	151	5516.78	5
3982.16	62			4328.68	88		

We have selected the following data sources for this spectrum: (1) the atomic beam absorption measurements of Bell et al. [1]; (2) the anomalous dispersion (hook) experiment of Ostrovskii and Penkin [2]; (3) the lifetime measurements of Marek [3], based on stepwise excitation with two dye lasers; (4) the absorption experiment of Blackwell and Collins [4] with an advanced King-type furnace; and (5) the emission experiment of Woodgate [5] with a vortex-stabilized arc.

The first three data sources, including the lifetime experiment, have provided absolute values for very few lines—in the case of the atomic beam experiment [1], only one line has been measured. The other two approaches, (4) and especially (5), have yielded many

relative f-value data and are used for the bulk of the material in these tables. However, since they are only on a relative scale, these data had to be normalized.

With regard to this normalization, we have found the data from refs. [1,2,3] mutually consistent. For the 4030.76 Å line, the only line investigated by Bell et al., their f-value could be directly compared to that of Ostrovskii and Penkin. The results differ by only nine percent, which is clearly within the mutually estimated error limits. As a further check, the data of Blackwell and Collins [4], which were normalized by these authors to the data of Bell et al., could be compared for eleven other lines either with the results of Woodgate, who normalized his data to the scale of Ostrovskii and Penkin, or with these latter authors directly. It was found that for these lines, with the exception of the 4048.75 Å line, the data agree well, confirming the close agreement between Bell et al. and Ostrovskii and Penkin for the 4030.76 Å line.

As a third consistency check, the lifetime data of Marek could be compared to Woodgate's transition probability data for three $e\,^6$D levels ($J=9/2,\ 7/2,\ 5/2$). In order to obtain complete sums of transition probabilities for all possible downward transitions from these levels, we also employed renormalized data from Corliss and Bozman [6] for a few weak transitions, as well as some LS coupling values for other missing lines. Still, we had to neglect contributions for a few far infrared lines which, however, are estimated to have rather small transition probabilities because of the low transition frequencies involved.

The results of these comparisons given in the table below show that Woodgate's f-values are in close agreement with Marek's lifetimes, indicating again that all three above cited experiments are mutually consistent within the estimated error ranges.

State	Lifetimes via laser excitation [ns] (Ref. [3])	$(\Sigma A_{ki})^{-1}$ [ns] (Ref. [5])
$e\,^6D_{9/2}$	16.5±1.6	20.4
$e\,^6D_{7/2}$	17.0±1.7	19.5
$e\,^6D_{5/2}$	15.8±1.6	13.7

For the bulk of the data, we have used Woodgate's f-values as he normalized them against the scale of Ostrovskii and Penkin. (Any further renormalization would not produce any significant improvement in the consistency.) Woodgate generated the Mn I line spectrum with a special vortex-stabilized high current arc (50–80 A). He struck the arc for short time periods ($\approx$ 15 s) through a rapidly rotating, narrow sintered tube, which consisted of Mn_3O_4 and some carrier material (SiO_2), so that the tube gradually evaporated. The spectra were recorded photographically from end-on observations. Time resolved spectra showed weak fluctuations, indicating a fairly quiescent source. Since the principal critical factors in emission studies were adequately taken into account by Woodgate and his relative values are normalized to a reliably established absolute scale (which eliminated the need for difficult density measurements in his experiment), it is estimated that his absolute numbers are generally accurate to within fifty percent. This error estimate has been obtained by us by treating as independent errors (a) the uncertainties in the absolute scale, (b) uncertainties in Woodgate's temperature determination, and (c) uncertainties quoted by Woodgate due to his intensity measurement technique. The uncertainties under (c) are often the largest source of error and depend appreciably on wavelength, due to changes in the photographic plate sensitivity.

References

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[6] Corliss, C. H., and Bozman, W. R., Nat. Bur. Stand. (U.S.), Monogr. 53 (July 1962).

Mn I: Allowed transitions

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$a\,^6S$–$z\,^8P°$ (1)											
		5394.68	0	18532	6	8	9.9(—5)[a]	5.8(—5)	0.0062	—3.46	C—	4
		5432.56	0	18402	6	6	6.7(—5)	3.0(—5)	0.0032	—3.75	C—	4
2.	$a\,^6S$–$z\,^6P°$ (2)	*4032.4*	0	*24792*	6	18	0.19	0.14	11	—0.08	C+	1,4
		4030.76	0	24802	6	8	0.19	0.061	4.9	—0.44	C+	1
		4033.07	0	24788	6	6	0.18	0.044	3.5	—0.58	C+	4
		4034.49	0	24779	6	4	0.18	0.029	2.3	—0.76	C+	4
3.	$a\,^6S$–$z\,^4P°$ (3)											
		3224.76	0	31001	6	6	0.0034	5.3(—4)	0.034	—2.50	C	2
		3216.95	0	31076	6	4	0.0027	2.8(—4)	0.018	—2.77	C	2
4.	$a\,^6S$–$y\,^6P°$ (uv 1)	*2797.3*	0	*35738*	6	18	3.7	1.3	77	0.89	C+	2
		2794.82	0	35770	6	8	3.7	0.57	32	0.53	C+	2
		2798.27	0	35726	6	6	3.6	0.42	23	0.40	C+	2
		2801.08	0	35690	6	4	3.7	0.29	16	0.24	C+	2
5.	$a\,^6D$–$y\,^6P°$ (4)											
		5420.37	17282	35726	8	6	0.019	0.0064	0.92	—1.29	C+	4
		5407.43	17282	35770	8	8	0.0084	0.0037	0.53	—1.53	C+	4
		5516.78	17568	35690	4	4	0.0097	0.0045	0.32	—1.75	C+	4
6.	$a\,^6D$–$z\,^6D°$ (5)											
		4041.36	17052	41789	10	10	1.0	0.26	34	0.41	C+	4
		4055.55	17282	41933	8	8	0.61	0.15	16	0.08	C+	4
		4063.53	17452	42054	6	6	0.22	0.054	4.3	—0.49	C+	4
		4068.01	17568	42144	4	4	0.014	0.0035	0.18	—1.86	E	5
		4070.28	17637	42199	2	2	0.23	0.056	1.5	—0.95	C+	4
		4018.11	17052	41933	10	8	0.33	0.065	8.5	—0.19	C+	4
		4048.75	17452	42144	6	4	0.75	0.12	9.9	—0.13	C+	4
		4058.94	17568	42199	4	2	1.0	0.13	6.7	—0.30	C+	4
		4083.63	17452	41933	6	8	0.28	0.094	7.6	—0.25	C+	4
		4082.95	17568	42054	4	6	0.37	0.14	7.4	—0.26	C+	4
		4079.42	17637	42144	2	4	0.38	0.19	5.1	—0.42	C+	4
7.	$a\,^6D$–$z\,^6F°$ (6)											
		3806.72	17052	43314	10	12	0.38	0.10	13	0.00	C	5
		3823.51	17282	43429	8	10	0.44	0.12	12	—0.02	C	5
		3834.37	17452	43524	6	8	0.52	0.15	12	—0.04	D	5
		3843.99	17637	43644	2	4	0.29	0.13	3.3	—0.59	C	5
		3790.21	17052	43429	10	10	0.045	0.0098	1.2	—1.01	D	5
		3809.59	17282	43524	8	8	0.20	0.044	4.4	—0.45	C	5
		3823.89	17452	43596	6	6	0.36	0.078	5.9	—0.33	C	5
		3833.87	17568	43644	4	4	0.52	0.11	5.8	—0.34	C	5
		3839.78	17637	43673	2	2	0.58	0.13	3.3	—0.59	C	5
		3776.54	17052	43524	10	8	0.0023	3.9(—4)	0.048	—2.41	E	5
		3799.26	17282	43596	8	6	0.013	0.0021	0.21	—1.77	C	5
		3816.75	17452	43644	6	4	0.054	0.0078	0.59	—1.33	D	5
		3829.68	17568	43673	4	2	0.15	0.016	0.81	—1.19	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
8.	$a\,^6D$–$z\,^4F°$ (7)											
		3701.73	17282	44289	8	10	0.0050	0.0013	0.13	—1.99	C	5
		3692.82	17452	44523	6	8	0.0034	9.2(—4)	0.067	—2.26	C—	5
		3646.71	17282	44696	8	6	5.4(—4)	8.1(—5)	0.0078	—3.19	E	5
9.	$a\,^6D$–$x\,^6P°$ (8)											
		3577.87	17052	44994	10	8	0.94	0.14	17	0.16	C	5
		3595.11	17452	45259	6	4	0.18	0.023	1.6	—0.86	C	5
		3607.53	17282	44994	8	8	0.23	0.045	4.3	—0.44	C	5
		3608.49	17452	45156	6	6	0.36	0.071	5.1	—0.37	C	5
		3610.30	17568	45259	4	4	0.42	0.083	3.9	—0.48	C	5
		3629.74	17452	44994	6	8	0.028	0.0074	0.53	—1.35	C	5
		3623.78	17568	45156	4	6	0.097	0.029	1.4	—0.94	C	5
10.	$a\,^6D$–$z\,^4D°$											
		3509.07	17452	45941	6	6	6.2(—4)	1.2(—4)	0.0080	—3.16	E	5
11.	a ^6D–$w\,^6P°$											
		3290.97	17282	47660	8	6	0.0021	2.6(—4)	0.022	—2.69	D—	5
		3308.78	17568	47782	4	4	0.0049	8.1(—4)	0.035	—2.49	E	5
12.	$a\,^6D$–$y\,^6D°$											
		3240.41	17052	47904	10	10	0.064	0.010	1.1	—1.00	D	5
		3278.55	17282	47775	8	8	0.0091	0.0015	0.13	—1.93	D—	5
		3343.72	17568	47467	4	4	0.0086	0.0014	0.063	—2.24	E	5
		3254.04	17052	47775	10	8	0.017	0.0021	0.23	—1.67	D	5
		3330.66	17452	47467	6	4	0.074	0.0082	0.54	—1.31	D	5
		3264.71	17282	47904	8	10	0.14	0.029	2.5	—0.64	D	5
		3296.88	17452	47775	6	8	0.015	0.0032	0.21	—1.72	D	5
		3311.90	17568	47754	4	6	0.020	0.0049	0.21	—1.71	C	5
13.	$a\,^6D$–$y\,^6F°$ (14)											
		3228.09	17052	48021	10	12	0.64	0.12	13	0.08	D	5
		3256.14	17568	48271	4	6	0.50	0.12	5.1	—0.32	D	5
		3260.24	17637	48301	2	4	0.38	0.12	2.6	—0.62	D	5
		3212.89	17052	48168	10	10	0.16	0.025	2.7	—0.60	D	5
		3230.72	17282	48226	8	8	0.35	0.055	4.6	—0.36	D	5
		3243.78	17452	48271	6	6	0.53	0.084	5.4	—0.30	D	5
		3252.95	17568	48301	4	4	0.18	0.028	1.2	—0.95	D	5
		3258.41	17637	48318	2	2	0.97	0.15	3.3	—0.51	D	5
		3206.91	17052	48226	10	8	0.010	0.0013	0.14	—1.89	D	5
		3226.05	17282	48271	8	6	0.049	0.0057	0.49	—1.34	D	5
		3240.61	17452	48301	6	4	0.098	0.010	0.66	—1.21	D	5
		3251.13	17568	48318	4	2	0.23	0.019	0.79	—1.13	D	5
14.	$a\,^6D$–$v\,^6P°$ (15)											
		3044.57	17052	49888	10	8	0.57	0.063	6.3	—0.20	D	5
		3054.36	17282	50013	8	6	0.46	0.049	3.9	—0.41	D	5
		3062.12	17452	50099	6	4	0.13	0.012	0.73	—1.14	D	5
		3066.02	17282	49888	8	8	0.16	0.023	1.8	—0.74	D	5
		3070.27	17452	50013	6	6	0.19	0.026	1.6	—0.80	D	5
		3073.18	17568	50099	4	4	0.37	0.052	2.1	—0.68	D	5
		3081.34	17568	50013	4	6	0.030	0.0064	0.26	—1.59	D	5
		3079.64	17637	50099	2	4	0.16	0.047	0.95	—1.03	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
15.	$z\,^8P°–e\,^8S$ (16)	*4792.8*	*18572*	39431	24	8	1.2	0.14	53	0.53	D	4,5
		4823.53	18705	39431	10	8	0.45	0.13	20	0.10	D	5
		4783.43	18532	39431	8	8	0.39	0.13	17	0.03	D	5
		4754.05	18402	39431	6	8	0.38	0.17	16	0.01	D	4
16.	$z\,^8P°–e\,^6D$											
		3507.54	18705	47207	10	10	5.9(—4)	1.1(—4)	0.013	—2.96	E	5
17.	$z\,^8P°–f\,^8S$ (19)	*3165.0*	*18572*	50158	24	8	0.18	0.0088	2.2	—0.68	D	5
		3178.50	18705	50158	10	8	0.037	0.0045	0.47	—1.35	D	5
		3161.05	18532	50158	8	8	0.048	0.0072	0.60	—1.24	D	5
		3148.18	18402	50158	6	8	0.088	0.017	1.1	—0.98	D	5
18.	$a\,^4D–z\,^4F°$ (21)	*4758.5*	*23509*	*44518*	20	28	0.49	0.23	72	0.66	D	5
		4762.38	23297	44289	8	10	0.57	0.24	31	0.29	D	5
		4766.43	23549	44523	6	8	0.45	0.21	19	0.09	D	5
		4765.86	23720	44696	4	6	0.28	0.14	9.0	—0.24	D	5
		4761.53	23819	44815	2	4	0.28	0.19	6.0	—0.42	D	5
		4709.71	23297	44523	8	8	0.077	0.026	3.2	—0.69	D	5
		4727.46	23549	44696	6	6	0.084	0.028	2.6	—0.77	D	5
		4739.11	23720	44815	4	4	0.063	0.021	1.3	—1.07	D	5
		4671.69	23297	44696	8	6	0.0045	0.0011	0.14	—2.05	D—	5
		4701.15	23549	44815	6	4	0.0061	0.0014	0.13	—2.09	D—	5
19.	$a\,^4D–z\,^4D°$ (22)											
		4451.58	23297	45754	8	8	0.71	0.21	25	0.23	D	5
		4464.68	23549	45941	6	6	0.26	0.078	6.9	—0.33	D	5
		4470.14	23720	46084	4	4	0.13	0.038	2.2	—0.82	D	5
		4472.79	23819	46170	2	2	0.12	0.035	1.0	—1.15	D	5
		4414.89	23297	45941	8	6	0.18	0.039	4.5	—0.51	D	5
		4453.01	23720	46170	4	2	0.23	0.035	2.0	—0.86	D	5
		4502.22	23549	45754	6	8	0.078	0.032	2.8	—0.72	D	5
		4498.90	23720	45941	4	6	0.11	0.049	2.9	—0.71	D	5
		4490.08	23819	46084	2	4	0.089	0.054	1.6	—0.97	D	5
20.	$a\,^4D–y\,^4P°$ (23)											
		4239.74	23720	47299	4	2	0.39	0.052	2.9	—0.68	D	5
		4281.10	23549	46901	6	6	0.23	0.063	5.4	—0.42	D	5
		4265.93	23720	47155	4	4	0.35	0.095	5.3	—0.42	D	5
		4257.67	23819	47299	2	2	0.37	0.10	2.8	—0.70	D	5
		4312.55	23720	46901	4	6	0.014	0.0060	0.34	—1.62	D	5
		4284.08	23819	47155	2	4	0.033	0.018	0.51	—1.44	D	5
21.	$a\,^4D–y\,^6D°$											
		4230.14	23819	47452	2	2	0.017	0.0045	0.12	—2.05	D—	5
22.	$a\,^4D–y\,^4F°$ (24)											
		3696.55	23297	50341	8	10	0.044	0.011	1.1	—1.05	C	5
		3728.89	23549	50359	6	8	0.037	0.010	0.76	—1.21	C	5
		3750.77	23720	50373	4	6	0.030	0.0095	0.47	—1.42	C	5
		3763.37	23819	50383	2	4	0.039	0.017	0.41	—1.48	C	5
		3726.95	23549	50373	6	6	0.013	0.0026	0.19	—1.80	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
23.	$a\,^4D$–$x\,^4P°$ (25)											
		3583.68	23549	51446	6	4	0.035	0.0045	0.32	—1.57	C	5
		3591.81	23720	51553	4	2	0.022	0.0021	0.098	—2.08	C—	5
24.	$a\,^4D$–$y\,^4D°$											
		3351.66	23297	53124	8	8	0.0080	0.0013	0.12	—1.97	C—	5
25.	$a\,^4D$–$x\,^4D°$											
		3142.67	23297	55108	8	8	0.041	0.0061	0.51	—1.31	D	5
		3159.95	23549	55186	6	6	0.031	0.0047	0.29	—1.55	D	5
		3167.83	23549	55108	6	8	0.0072	0.0015	0.091	—2.06	D—	5
		3177.04	23720	55186	4	6	0.011	0.0025	0.10	—2.00	D—	5
		3177.62	23819	55280	2	4	0.012	0.0037	0.078	—2.13	D—	5
26.	$a\,^4D$–$w\,^4P°$											
		3141.82	23549	55369	6	4	0.0067	6.6(—4)	0.041	—2.40	E	5
		3149.93	23720	55457	4	2	0.019	0.0014	0.060	—2.24	E	5
		3138.22	23549	55405	6	6	0.011	0.0016	0.10	—2.01	D—	5
27.	$z\,^6P°$–$e\,^6D$ (28)											
		4462.03	24802	47207	8	10	0.43	0.16	19	0.11	D	5
		4458.26	24788	47212	6	8	0.28	0.11	9.9	—0.17	D	5
		4455.82	24779	47216	4	6	0.17	0.077	4.5	—0.51	D	5
		4461.09	24802	47212	8	8	0.17	0.052	6.1	—0.38	D	5
		4457.55	24788	47216	6	6	0.38	0.11	9.9	—0.17	D	5
		4457.04	24788	47218	6	4	0.20	0.040	3.5	—0.62	D	5
28.	$z\,^6P°$–$f\,^6S$ (29)											
		4061.74	24802	49415	8	6	0.19	0.034	3.7	—0.56	D	5
		4059.39	24788	49415	6	6	0.14	0.034	2.7	—0.69	D	5
29.	$z\,^6P°$–$g\,^6S$											
		3826.62	24779	50905	4	6	0.0033	0.0011	0.055	—2.36	D—	5
30.	$z\,^6P°$–$i\,^6D$											
		3135.19	24779	56666	4	2	0.028	0.0021	0.086	—2.08	D—	5
31.	$z\,^6P°$–$e\,^4D$											
		3146.32	24788	56562	6	6	0.0050	7.4(—4)	0.046	—2.35	D—	5
32.	$a\,^4G$–$z\,^4H°$											
		4026.44	25266	50095	12	14	0.089	0.025	4.0	—0.52	D	5
		4031.79	25285	50081	10	12	0.073	0.021	2.8	—0.67	D	5
		4028.60	25266	50081	12	12	0.0038	9.1(—4)	0.15	—1.96	D—	5
33.	$a\,^4G$–$y\,^4F°$ (33)											
		3986.82	25266	50341	12	10	0.11	0.021	3.3	—0.60	D	5
		3987.09	25285	50359	10	8	0.10	0.019	2.5	—0.72	D	5
		3985.24	25288	50373	8	6	0.097	0.017	1.8	—0.86	D	5
		3982.58	25281	50383	6	4	0.23	0.036	2.9	—0.66	D	5
		3989.95	25285	50341	10	10	0.015	0.0036	0.48	—1.44	D	5
		3987.46	25288	50359	8	8	0.018	0.0042	0.44	—1.47	D	5
		3984.17	25281	50373	6	6	0.023	0.0054	0.42	—1.49	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
34.	$a\,^4G$–$z\,^4G°$											
		3801.90	25266	51561	12	12	0.064	0.014	2.1	—0.78	C	5
		3810.68	25281	51516	6	6	0.053	0.012	0.87	—1.16	C	5
		3804.02	25266	51546	12	10	0.0028	5.0(—4)	0.075	—2.22	D	5
		3811.66	25288	51516	8	6	0.0038	6.3(—4)	0.063	—2.30	D	5
		3808.51	25281	51531	6	8	0.0057	0.0017	0.13	—2.00	D	5
35.	$a\,^4G$–$y\,^4G°$											
		3047.03	25266	58075	12	12	0.61	0.085	10	0.01	D	5
		3045.59	25285	58110	10	10	0.67	0.093	9.4	—0.03	D	5
		3043.36	25288	58137	8	8	0.59	0.083	6.6	—0.18	D	5
		3043.14	25285	58137	10	8	0.14	0.015	1.6	—0.81	D	5
		3041.22	25288	58160	8	6	0.11	0.012	0.93	—1.03	D	5
		3048.86	25285	58075	10	12	0.091	0.015	1.5	—0.82	D	5
		3045.80	25288	58110	8	10	0.17	0.030	2.4	—0.62	D	5
36.	$a\,^4G$–$y\,^4H°$											
		3016.45	25285	58427	10	12	0.29	0.047	4.6	—0.33	D	5
		3011.38	25288	58486	8	10	0.31	0.053	4.2	—0.37	D	5
		3007.65	25281	58520	6	8	0.18	0.033	2.0	—0.70	D	5
		3011.17	25285	58486	10	10	0.11	0.014	1.4	—0.84	D	5
37.	$a\,^4P$–$x\,^4P°$ (37)											
		4147.53	27202	51305	6	6	0.066	0.017	1.4	—0.79	D	5
		4119.01	27282	51553	2	2	0.011	0.0029	0.078	—2.24	E	5
		4123.54	27202	51446	6	4	0.038	0.0065	0.53	—1.41	D	5
		4155.53	27248	51305	4	6	0.021	0.0081	0.44	—1.49	D	5
		4137.27	27282	51446	2	4	0.031	0.016	0.43	—1.50	D	5
38.	$a\,^4P$–$x\,^6D°$											
		3894.71	27202	52870	6	8	0.025	0.0076	0.59	—1.34	C	5
39.	$a\,^4P$–$y\,^4D°$											
		3871.67	27282	53103	2	4	0.0097	0.0044	0.11	—2.06	C—	5
40.	$a\,^4P$–$z\,^4S°$											
		3700.30	27202	54219	6	4	0.095	0.013	0.95	—1.11	C	5
		3706.66	27248	54219	4	4	0.027	0.0055	0.27	—1.66	C	5
41.	$a\,^4P$–$v\,^4P°$											
		3300.94	27202	57487	6	6	0.0097	0.0016	0.10	—2.02	C—	5
		3334.56	27248	57228	4	2	0.024	0.0020	0.089	—2.09	D—	5
42.	$a\,^4P$–$y\,^4S°$	*3301.5*	*27231*	57512	12	4	0.58	0.031	4.1	—0.42	D	5
		3298.23	27202	57512	6	4	0.28	0.030	2.0	—0.74	D	5
		3303.28	27248	57512	4	4	0.19	0.031	1.4	—0.90	C	5
		3307.00	27282	57512	2	4	0.094	0.031	0.67	—1.21	D	5
43.	$a\,^4P$–$u\,^4P°$											
		3136.96	27248	59117	4	6	0.040	0.0089	0.37	—1.45	D	5
		3114.12	27282	59384	2	4	0.041	0.012	0.25	—1.62	D	5
44.	$a\,^4P$–$x\,^4F°$ (38)											
		3115.46	27202	59290	6	8	0.14	0.026	1.6	—0.80	D	5
		3113.12	27248	59361	4	6	0.051	0.011	0.46	—1.35	D	5
		3108.63	27202	59361	6	6	0.055	0.0080	0.49	—1.32	D	5
		3103.28	27202	59416	6	4	0.063	0.0061	0.37	—1.44	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
45.	$a\,^4P$–$w\,^4D°$											
		3110.68	27202	59340	6	8	0.27	0.052	3.2	—0.51	D	5
46.	$a\,^4P$–$v\,^4D°$											
		3098.09	27202	59470	6	8	0.020	0.0038	0.23	—1.64	D	5
47.	$b\,^4D$–$x\,^4D°$											
		4038.73	30354	55108	8	8	0.047	0.011	1.2	—1.04	D	5
		4025.94	30354	55186	8	6	0.019	0.0035	0.37	—1.55	D	5
		4021.35	30420	55280	6	4	0.014	0.0022	0.17	—1.88	D	5
		4020.07	30412	55280	2	4	0.049	0.024	0.63	—1.32	D	5
48.	$b\,^4D$–$w\,^4P°$											
		3990.74	30354	55405	8	6	0.0043	7.7(—4)	0.081	—2.21	E	5
		4007.04	30420	55369	6	4	0.022	0.0036	0.28	—1.67	D	5
		3993.86	30426	55457	4	2	0.044	0.0052	0.27	—1.68	D	5
		4001.19	30420	55405	6	6	0.024	0.0058	0.46	—1.46	D	5
		4008.02	30426	55369	4	4	0.046	0.011	0.59	—1.35	D	5
		3991.60	30412	55457	2	2	0.21	0.050	1.3	—1.00	D	5
		4002.17	30426	55405	4	6	0.036	0.013	0.68	—1.29	D	5
49.	$b\,^4D$–$v\,^4P°$											
		3710.75	30420	57361	6	4	0.033	0.0045	0.33	—1.57	C	5
		3711.59	30426	57361	4	4	0.031	0.0064	0.31	—1.59	D	5
		3727.99	30412	57228	2	2	0.033	0.0069	0.17	—1.86	D	5
50.	$b\,^4D$–$u\,^4P°$											
		3451.48	30420	59384	6	4	0.086	0.010	0.70	—1.21	C	5
		3428.78	30412	59568	2	2	0.053	0.0093	0.21	—1.73	C	5
51.	$b\,^4D$–$x\,^4F°$ (41)											
		3458.84	30354	59257	8	10	0.0093	0.0021	0.19	—1.78	D	5
52.	$b\,^4D$–$w\,^4D°$											
		3418.28	30354	59600	8	6	0.024	0.0031	0.28	—1.60	C	5
		3364.19	30426	60142	4	2	0.032	0.0027	0.12	—1.97	D—	5
53.	$b\,^4D$–$v\,^4D°$											
		3440.04	30420	59481	6	6	0.029	0.0052	0.35	—1.51	C	5
54.	$b\,^4D$–$z\,^2D°$											
		3360.68	30354	60102	8	6	0.022	0.0027	0.24	—1.66	D	5
55.	$b\,^4D$–$v\,^4F°$											
		3115.75	30420	62505	6	8	0.12	0.024	1.4	—0.85	D	5
		3118.10	30426	62487	4	6	0.17	0.036	1.5	—0.84	D	5
		3117.51	30420	62487	6	6	0.10	0.015	0.94	—1.04	D	5
56.	$b\,^4D$–$w\,^6D°$											
		3091.10	30420	62761	6	6	0.0079	0.0011	0.069	—2.17	D—	5
57.	$z\,^4P°$–$i\,^6D$											
		3942.88	31001	56356	6	8	0.018	0.0055	0.43	—1.48	C	5
		3914.21	31125	56666	2	2	0.012	0.0027	0.071	—2.26	E	5
58.	$z\,^4P°$–$e\,^4D$											
		3926.48	31001	56462	6	8	0.54	0.17	13	0.00	C	5
		3924.08	31125	56602	2	4	0.94	0.44	11	—0.06	D	5
		3911.14	31001	56562	6	6	0.13	0.030	2.3	—0.75	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
59.	$z\,^4P^\circ$–$f\,^4D$ (45)											
		3800.55	31001	57306	6	8	0.27	0.078	5.9	—0.33	C	5
		3785.42	31076	57486	4	6	0.098	0.031	1.6	—0.90	C	5
		3772.96	31125	57622	2	4	0.064	0.027	0.68	—1.26	D	5
		3774.67	31001	57486	6	6	0.053	0.011	0.84	—1.17	C	5
		3766.05	31076	57622	4	4	0.045	0.0095	0.47	—1.42	C	5
		3754.22	31076	57706	4	2	0.14	0.014	0.71	—1.24	D	5
60.	$b\,^4P$–$v\,^4P^\circ$											
		4225.08	33825	57487	6	6	0.0034	9.2(—4)	0.076	—2.26	E	5
61.	$b\,^4P$–$y\,^4S^\circ$	*4289.9*	*34208*	57512	12	4	0.23	0.021	3.6	—0.59	D	5
		4220.61	33825	57512	6	4	0.16	0.028	2.3	—0.78	D	5
		4337.41	34463	57512	4	4	0.069	0.019	1.1	—1.11	D	5
		4410.49	34845	57512	2	4	0.011	0.0063	0.18	—1.90	D—	5
62.	$b\,^4P$–$u\,^4P^\circ$											
		3952.84	33825	59117	6	6	0.41	0.096	7.5	—0.24	D	5
		4011.45	34463	59384	4	4	0.082	0.020	1.0	—1.10	D	5
		3982.16	34463	59568	4	2	0.35	0.042	2.2	—0.78	D	5
		4073.98	34845	59384	2	4	0.058	0.029	0.77	—1.24	D	5
63.	$b\,^4P$–$w\,^4D^\circ$											
		3977.08	34463	59600	4	6	0.16	0.059	3.1	—0.63	D	5
		3975.88	34845	59990	2	4	0.18	0.087	2.3	—0.76	D	5
		3951.98	34845	60142	2	2	0.31	0.072	1.9	—0.84	D	5
64.	$b\,^4P$–$v\,^4D^\circ$											
		3898.37	33825	59470	6	8	0.17	0.052	4.0	—0.51	C	5
		3996.10	34463	59481	4	6	0.041	0.015	0.77	—1.23	D	5
		3988.67	34463	59527	4	2	0.16	0.019	0.97	—1.13	D	5
65.	$b\,^4P$–$z\,^2D^\circ$											
		3855.11	34463	60396	4	4	0.032	0.0072	0.37	—1.54	D	5
		3899.34	34463	60102	4	6	0.24	0.081	4.2	—0.49	C	5
		3912.75	34845	60396	2	4	0.042	0.019	0.50	—1.41	C	5
66.	$b\,^4P$–$u\,^4D^\circ$											
		3268.72	33825	64410	6	8	0.33	0.069	4.5	—0.38	D	5
		3350.41	34845	64684	2	4	0.0026	8.7(—4)	0.019	—2.76	E	5
		3355.48	34845	64639	2	2	0.12	0.021	0.46	—1.38	D	5
67.	$b\,^4P$–$w\,^2D^\circ$											
		3175.36	34463	65947	4	6	0.065	0.015	0.62	—1.23	D	5
68.	$a\,^4H$–$y\,^4G^\circ$											
		4176.61	34139	58075	14	12	0.21	0.063	10	—0.12	D	5
		4189.99	34251	58110	12	10	0.20	0.045	7.4	—0.27	D	5
		4201.78	34344	58137	10	8	0.23	0.048	6.6	—0.32	D	5
69.	$a\,^4H$–$y\,^4H^\circ$											
		4135.03	34251	58427	12	12	0.30	0.078	13	—0.03	D	5
		4141.06	34344	58486	10	10	0.26	0.066	9.0	—0.18	D	5
		4148.80	34423	58520	8	8	0.23	0.060	6.5	—0.32	D	5
70.	$a\,^4H$–$z\,^4I^\circ$											
		4065.08	34251	58843	12	14	0.25	0.073	12	—0.06	D	5
		4089.94	34423	58867	8	10	0.17	0.053	5.7	—0.37	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
71.	$a\,^4H$–$w\,^4D°$											
		3999.57	34344	59340	10	8	0.0039	7.4(−4)	0.098	−2.13	D—	5
72.	$a\,^4H$–$v\,^4D°$											
		3978.78	34344	59470	10	8	0.0074	0.0014	0.19	−1.85	D	5
73.	$a\,^4H$–$z\,^2I°$											
		3891.62	34139	59828	14	12	0.011	0.0021	0.37	−1.54	C	5
74.	$a\,^4H$–$x\,^4G°$											
		3923.33	34251	59732	12	10	0.13	0.025	3.9	−0.52	C	5
		3929.66	34344	59784	10	8	0.092	0.017	2.2	−0.77	C	5
		3936.77	34423	59818	8	6	0.12	0.022	2.3	−0.76	C	5
		3935.54	34251	59653	12	12	0.024	0.0056	0.88	−1.17	C	5
		3937.76	34344	59732	10	10	0.030	0.0069	0.90	−1.16	C	5
75.	$a\,^4H$–$x\,^4H°$											
		3746.62	34251	60934	12	12	0.16	0.034	5.0	−0.39	C	5
		3756.64	34344	60956	10	10	0.14	0.030	3.7	−0.52	C	5
		3767.70	34423	60957	8	8	0.14	0.029	2.9	−0.63	C	5
		3731.01	34139	60934	14	12	0.035	0.0062	1.1	−1.06	C	5
		3752.55	34251	60891	12	14	0.012	0.0029	0.43	−1.46	D	5
76.	$a\,^4H$–$y\,^4I°$											
		3706.08	34251	61226	12	14	1.4	0.33	49	0.60	C	5
		3718.92	34344	61226	10	12	0.96	0.24	29	0.38	C	5
		3731.94	34423	61211	8	10	1.0	0.27	26	0.33	C	5
		3720.91	34344	61211	10	10	0.025	0.0051	0.63	−1.29	C	5
77.	$a\,^4H$–$w\,^4G°$											
		3657.91	34139	61469	14	12	0.055	0.0094	1.6	−0.88	C	5
		3685.56	34344	61469	10	12	0.024	0.0059	0.71	−1.23	C	5
78.	$a\,^4H$–$y\,^2G°$											
		3643.02	34344	61786	10	8	0.020	0.0032	0.38	−1.50	D	5
79.	$a\,^4H$–$y\,^2I°$											
		3626.30	34251	61819	12	12	0.016	0.0032	0.45	−1.42	D	5
80.	$a\,^4H$–$y\,^2F°$											
		3615.38	34423	62075	8	6	0.13	0.018	1.8	−0.83	C	5
81.	$a\,^4H$–$y\,^2H°$											
		3410.80	34139	63449	14	12	0.015	0.0023	0.36	−1.50	D	5
		3446.82	34344	63348	10	10	0.032	0.0058	0.65	−1.24	C	5
82.	$a\,^4H$–$w\,^4H°$											
		3420.79	34139	63364	14	14	0.12	0.021	3.3	−0.53	D	5
		3450.61	34423	63395	8	8	0.11	0.020	1.8	−0.80	C	5
83.	$a\,^4H$–$x\,^2H°$?											
		3365.14	34344	64052	10	12	0.042	0.0085	0.94	−1.07	D	5
84.	$a\,^4H$–$v\,^4H°$											
		3267.79	34139	64732	14	14	0.35	0.057	8.5	−0.10	D	5
		3270.35	34251	64820	12	12	0.26	0.042	5.4	−0.30	D	5
		3273.02	34344	64888	10	10	0.27	0.044	4.7	−0.36	D	5
		3278.06	34423	64920	8	8	0.11	0.018	1.5	−0.85	D	5
		3263.04	34251	64888	12	10	0.014	0.0018	0.24	−1.66	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
85.	$a\,^4H$–$v\,^4G°$											
		3148.86	34139	65887	14	12	0.089	0.011	1.6	—0.80	D	5
		3170.43	34344	65876	10	8	0.037	0.0045	0.47	—1.35	D	5
86.	$a\,^4H$–$u\,^4H°$											
		3082.71	34139	66569	14	14	0.29	0.041	5.8	—0.24	D	5
		3122.88	34344	66356	10	10	0.19	0.028	2.8	—0.56	D	5
		3132.79	34423	66334	8	8	0.27	0.040	3.3	—0.50	D	5
		3113.80	34251	66356	12	10	0.26	0.032	3.9	—0.42	D	5
		3093.35	34251	66569	12	14	0.028	0.0047	0.57	—1.25	D	5
		3116.82	34344	66419	10	12	0.031	0.0055	0.56	—1.26	D	5
87.	$a\,^4H$–$u\,^4G°$											
		3097.76	34251	66523	12	10	0.056	0.0068	0.83	—1.09	D	5
		3113.36	34344	66454	10	8	0.088	0.010	1.0	—0.99	D	5
		3126.85	34423	66395	8	6	0.23	0.025	2.1	—0.70	D	5
		3106.75	34344	66523	10	10	0.093	0.013	1.4	—0.87	D	5
		3121.07	34423	66454	8	8	0.11	0.016	1.3	—0.90	D	5
88.	$a\,^4F$–$y\,^4G°$											
		4328.68	35041	58137	8	8	0.0029	8.1(—4)	0.092	—2.19	D—	5
89.	$a\,^4F$–$x\,^4F°$ (47)											
		4122.76	35041	59290	8	8	0.058	0.015	1.6	—0.93	D	5
		4123.28	35115	59361	6	6	0.090	0.023	1.9	—0.86	D	5
		4122.37	35165	59416	4	4	0.13	0.033	1.8	—0.88	D	5
		4105.37	34939	59290	10	8	0.17	0.034	4.6	—0.47	D	5
		4113.88	35115	59416	6	4	0.15	0.026	2.1	—0.81	D	5
90.	$a\,^4F$–$w\,^4D°$											
		4114.38	35041	59340	8	8	0.15	0.038	4.1	—0.52	D	5
91.	$a\,^4F$–$v\,^4D°$											
		4075.25	34939	59470	10	8	0.069	0.014	1.9	—0.86	D	5
		4090.62	35041	59481	8	6	0.058	0.011	1.2	—1.06	D	5
		4092.39	35041	59470	8	8	0.14	0.036	3.9	—0.54	D	5
92.	$a\,^4F$–$z\,^2I°$											
		4016.67	34939	59828	10	12	0.024	0.0069	0.91	—1.16	D	5
93.	$a\,^4F$–$x\,^4G°$ (48)											
		4052.48	35115	59784	6	8	0.38	0.12	9.9	—0.13	D	5
94.	$a\,^4F$–$w\,^4F°$											
		3845.01	34939	60939	10	10	0.034	0.0076	0.96	—1.12	C	5
		3876.71	35115	60903	6	8	0.0099	0.0030	0.23	—1.75	C	5
95.	$a\,^4F$–$y\,^4I°$											
		3803.07	34939	61226	10	12	0.0060	0.0015	0.19	—1.81	D	5
96.	$a\,^4F$–$w\,^4G°$											
		3768.18	34939	61469	10	12	0.071	0.018	2.3	—0.74	C	5
97.	$a\,^4F$–$4°$											
		3729.52	34939	61744	10	12	0.066	0.017	2.0	—0.78	D	5
98.	$a\,^4F$–$y\,^2F°$											
		3713.79	35115	62034	6	8	0.045	0.012	0.91	—1.13	C	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
99.	$a\,^4F$–$v\,^4F°$											
		3652.29	35115	62487	6	6	0.074	0.015	1.1	—1.05	D	5
100.	$a\,^4F$–$x\,^2G°$											
		3376.53	35041	64649	8	8	0.023	0.0039	0.34	—1.51	C	5
101.	$a\,^4F$–$v\,^4G°$											
		3230.23	34939	65887	10	12	0.19	0.036	3.9	—0.44	D	5
		3238.72	35041	65909	8	10	0.12	0.023	2.0	—0.73	D	5
		3249.89	35115	65876	6	8	0.081	0.017	1.1	—0.99	D	5
		3255.51	35165	65873	4	6	0.10	0.024	1.0	—1.02	D	5
102.	$a\,^4F$–$w\,^2D°$											
		3240.88	35115	65962	6	4	0.22	0.024	1.5	—0.85	D	5
103.	$a\,^4F$–$u\,^2F°$											
		3203.13	34939	66149	10	8	0.037	0.0046	0.48	—1.34	D	5
		3227.04	35041	66021	8	6	0.10	0.012	0.99	—1.03	D	5
104.	$a\,^4F$–$u\,^4H°$											
		3175.71	34939	66419	10	12	0.12	0.022	2.3	—0.66	D	5
		3192.24	35041	66356	8	10	0.070	0.013	1.1	—0.97	D	5
		3202.21	35115	66334	6	8	0.045	0.0092	0.58	—1.26	D	5
105.	$a\,^4F$–$u\,^4G°$											
		3160.16	34939	66574	10	12	0.14	0.025	2.6	—0.60	D	5
		3175.58	35041	66523	8	10	0.18	0.034	2.8	—0.57	D	5
		3189.96	35115	66454	6	8	0.16	0.033	2.1	—0.70	D	5
		3201.11	35165	66395	4	6	0.22	0.050	2.1	—0.70	D	5
106.	$a\,^4F$–$u\,^4F°$											
		3132.28	34939	66855	10	10	0.21	0.032	3.3	—0.50	D	5
		3151.42	35115	66838	6	6	0.10	0.015	0.92	—1.05	D	5
		3155.78	35165	66844	4	4	0.16	0.023	0.97	—1.03	D	5
107.	$a\,^4F$–$t\,^4G°$											
		3046.59	34939	67753	10	12	0.13	0.022	2.2	—0.65	D	5
108.	$a\,^2I$–$z\,^2I°$											
		4452.53	37164	59617	14	14	0.059	0.018	3.6	—0.61	D	5
		4408.08	37149	59828	12	12	0.034	0.010	1.7	—0.92	D	5
109.	$a\,^2I$–$x\,^4H°$											
		4203.11	37149	60934	12	12	0.0095	0.0025	0.42	—1.52	D	5
110.	$a\,^2I$–$w\,^4G°$											
		4107.87	37149	61485	12	10	0.097	0.020	3.3	—0.61	D	5
111.	$a\,^2I$–$z\,^2H°$											
		3786.84	37149	63548	12	10	0.035	0.0063	0.95	—1.12	D	5
112.	$a\,^2I$–$x\,^2H°$											
		3718.13	37164	64052	14	12	0.025	0.0044	0.75	—1.21	C	5
		3715.53	37149	64055	12	10	0.024	0.0042	0.61	—1.30	C	5
113.	$b\,^4G$–$z\,^2I°$											
		4503.87	37420	59617	12	14	0.083	0.030	5.3	—0.45	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
114.	$b\,^4G–x\,^4G°$											
		4496.64	37420	59653	12	12	0.036	0.011	2.0	—0.88	D	5
		4523.40	37631	59732	10	10	0.014	0.0044	0.65	—1.36	D	5
115.	$b\,^4G–z\,^2G°$											
		4300.19	37420	60668	12	10	0.087	0.020	3.4	—0.62	D	5
		4326.18	37631	60739	10	8	0.011	0.0025	0.36	—1.60	D	5
		4359.64	37737	60668	8	10	0.0099	0.0035	0.40	—1.55	D	5
116.	$b\,^4G–x\,^4H°$											
		4259.35	37420	60891	12	14	0.019	0.0059	0.99	—1.15	D	5
		4290.11	37631	60934	10	12	0.034	0.011	1.6	—0.95	D	5
		4305.67	37737	60956	8	10	0.034	0.012	1.4	—1.02	D	5
117.	$b\,^4G–w\,^4G°$											
		4221.56	37790	61471	6	6	0.026	0.0069	0.58	—1.38	D	5
		4154.22	37420	61485	12	10	0.0035	7.6(—4)	0.12	—2.04	D—	5
118.	$b\,^4G–z\,^2F°$											
		4151.66	37631	61711	10	8	0.024	0.0049	0.67	—1.31	D	5
		4167.20	37737	61727	8	6	0.019	0.0038	0.41	—1.52	D	5
119.	$b\,^4G–y\,^2G°$											
		4166.21	37790	61786	6	8	0.024	0.0082	0.67	—1.31	D	5
120.	$b\,^4G–y\,^2F°$											
		4096.68	37631	62034	10	8	0.025	0.0050	0.68	—1.30	D	5
		4116.60	37790	62075	6	6	0.12	0.030	2.4	—0.75	D	5
121.	$b\,^4G–v\,^4F°$											
		4003.26	37420	62393	12	10	0.11	0.022	3.5	—0.58	D	5
122.	$b\,^4G–x\,^2F°$											
		3920.66	37790	63289	6	8	0.027	0.0084	0.65	—1.30	D	5
123.	$b\,^4G–z\,^2H°$											
		3873.20	37737	63548	8	10	0.11	0.031	3.2	—0.60	C	5
124.	$b\,^4G–y\,^2H°$											
		3872.13	37631	63449	10	12	0.077	0.021	2.7	—0.68	C	5
125.	$b\,^4G–w\,^4H°$											
		3870.82	37631	63458	10	12	0.021	0.0056	0.72	—1.25	C	5
		3888.84	37737	63445	8	10	0.042	0.012	1.2	—1.02	D	5
126.	$b\,^4G–x\,^2G°$											
		3680.15	37420	64585	12	10	0.19	0.032	4.7	—0.41	C	5
		3708.87	37631	64585	10	10	0.052	0.011	1.3	—0.97	C	5
127.	$b\,^4G–v\,^4H°$											
		3660.40	37420	64732	12	14	0.91	0.21	31	0.41	C	5
		3676.96	37631	64820	10	12	0.73	0.18	22	0.25	C	5
		3682.09	37737	64888	8	10	0.76	0.19	19	0.19	D	5
		3684.87	37790	64920	6	8	0.26	0.069	5.1	—0.38	C	5
		3648.70	37420	64820	12	12	0.043	0.0085	1.2	—0.99	C	5
		3667.71	37631	64888	10	10	0.073	0.015	1.8	—0.83	C	5
		3663.37	37631	64920	10	8	0.050	0.0081	0.98	—1.09	D	5
128.	$b\,^4G–w\,^2F°$											
		3668.55	37737	64988	8	8	0.015	0.0029	0.28	—1.63	D	5
		3675.67	37790	64988	6	8	0.22	0.061	4.4	—0.44	C	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
129.	$b\ ^4G$–$v\ ^4G°$											
		3511.83	37420	65887	12	12	0.27	0.050	7.0	—0.22	C	5
		3535.30	37631	65909	10	10	0.17	0.032	3.7	—0.50	C	5
		3559.81	37790	65873	6	6	0.21	0.039	2.7	—0.63	C	5
		3538.00	37631	65887	10	12	0.040	0.0091	1.1	—1.04	C	5
130.	$b\ ^4G$–$u\ ^4H°$											
		3429.74	37420	66569	12	14	0.015	0.0030	0.41	—1.44	D	5
131.	$b\ ^4G$–$u\ ^4G°$											
		3429.16	37420	66574	12	12	0.051	0.0089	1.2	—0.97	D	5
		3494.86	37790	66395	6	6	0.032	0.0059	0.41	—1.45	D	5
132.	$b\ ^4G$–20°											
		3463.66	37737	66600	8	8	0.32	0.057	5.2	—0.34	C	5
		3470.01	37790	66600	6	8	0.24	0.058	4.0	—0.46	C	5
133.	$a\ ^2P$–$z\ ^2P°$											
		4158.69	38352	62391	2	2	0.16	0.043	1.2	—1.07	D	5
		4164.98	38352	62355	2	4	0.11	0.055	1.5	—0.96	D	5
134.	$a\ ^2H$–$z\ ^2I°$											
		4626.54	38009	59617	12	14	0.36	0.14	25	0.21	D	5
		4605.37	38120	59828	10	12	0.36	0.14	21	0.14	D	5
135.	$a\ ^2H$–$x\ ^4G°$											
		4642.80	38120	59653	10	12	0.0096	0.0037	0.57	—1.43	D	5
136.	$a\ ^2H$–$z\ ^2G°$	*4415.5*	*38059*	*60700*	22	18	0.25	0.059	19	0.12	D	5
		4411.87	38009	60668	12	10	0.26	0.063	11	—0.12	D	5
		4419.77	38120	60739	10	8	0.21	0.050	7.3	—0.30	D	5
		4433.72	38120	60668	10	10	0.0073	0.0021	0.31	—1.67	D	5
137.	$a\ ^2H$–$w\ ^4F°$											
		4359.82	38009	60939	12	10	0.0072	0.0017	0.29	—1.69	D	5
		4388.09	38120	60903	10	8	0.024	0.0056	0.81	—1.25	D	5
138.	$a\ ^2H$–$x\ ^4H°$											
		4368.88	38009	60891	12	14	0.0060	0.0020	0.35	—1.62	D	5
139.	$a\ ^2H$–$y\ ^4I°$											
		4326.75	38120	61226	10	12	0.0046	0.0015	0.22	—1.81	D	5
		4329.43	38120	61211	10	10	0.0047	0.0013	0.19	—1.88	D	5
140.	$a\ ^2H$–$w\ ^4G°$											
		4261.30	38009	61469	12	12	0.081	0.022	3.7	—0.58	D	5
		4278.68	38120	61485	10	10	0.068	0.019	2.6	—0.73	D	5
		4258.37	38009	61485	12	10	0.025	0.0056	0.95	—1.17	D	5
		4279.55	38120	61481	10	8	0.029	0.0063	0.89	—1.20	D	5
141.	$a\ ^2H$–$y\ ^2G°$											
		4224.34	38120	61786	10	8	0.011	0.0025	0.34	—1.61	D	5
42.	$a\ ^2H$–$y\ ^2I°$											
		4182.25	38009	61913	12	14	0.092	0.028	4.7	—0.47	D	5
143.	$a\ ^2H$–$z\ ^2H°$											
		3954.58	38009	63289	12	12	0.046	0.011	1.7	—0.89	D	5
		3931.52	38120	63548	10	10	0.082	0.019	2.5	—0.72	C	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	$A_{ki}(10^8 s^{-1})$	f_{ik}	S(at.u.)	log gf	Accuracy	Source
144.	$a\,^2H$–$w\,^4H°$											
		3928.31	38009	63458	12	12	0.039	0.0091	1.4	—0.96	C	5
145.	$a\,^2H$–$w\,^2G°$											
		3668.20	38009	65262	12	10	0.010	0.0017	0.25	—1.69	D	5
146.	$a\,^2H$–$v\,^2F°$											
		3635.70	38120	65617	10	8	0.21	0.033	4.0	—0.48	C	5
147.	$a\,^2H$–18°											
		3601.27	38009	65769	12	10	0.23	0.037	5.3	—0.35	C	5
148.	$a\,^2H$–$v\,^2H°$											
		3152.25	38009	69723	12	12	0.081	0.012	1.5	—0.84	D	5
		3169.36	38120	69663?	10	10	0.075	0.011	1.2	—0.95	D	5
149.	$a\,^2F$–$z\,^2G°$											
		4544.42	38670	60668	8	10	0.030	0.012	1.4	—1.03	D	5
		4529.80	38670	60739	8	8	0.019	0.0057	0.68	—1.34	D	5
150.	$a\,^2F$–$w\,^4G°$											
		4381.70	38670	61485	8	10	0.14	0.050	5.7	—0.40	D	5
		4434.14	38935	61481	6	8	0.015	0.0059	0.52	—1.45	D	5
151.	$a\,^2F$–$y\,^2F°$											
		4327.95	38935	62034	6	8	0.027	0.010	0.88	—1.21	D	5
152.	$a\,^2F$–$x\,^2F°$											
		4085.48	38670	63140	8	6	0.015	0.0028	0.30	—1.65	D	5
153.	$a\,^2F$–$w\,^2G°$											
		3791.08	38935	65305	6	8	0.027	0.0078	0.58	—1.33	D	5
		3753.30	38670	65305	8	8	0.011	0.0023	0.22	—1.74	D	5
154.	$a\,^2F$–$v\,^2F°$											
		3709.83	38670	65617	8	8	0.068	0.014	1.4	—0.95	C	5
155.	$a\,^2G$–$z\,^2H°$											
		4479.40	41230	63548	8	10	0.34	0.13	15	0.01	D	5
156.	$a\,^2G$–$w\,^2G°$											
		4125.81	41031	65262	10	10	0.070	0.018	2.4	—0.75	D	5
		4152.57	41230	65305	8	8	0.011	0.0029	0.32	—1.63	D	5
157.	$a\,^2G$–$v\,^2F°$	*4078.5*	*41119*	*65631*	18	14	0.21	0.041	10	—0.13	D	5
		4066.24	41031	65617	10	8	0.22	0.044	5.8	—0.36	D	5
		4094.07	41230	65649?	8	6	0.076	0.014	1.5	—0.94	D	5
		4099.40	41230	65617	8	8	0.11	0.029	3.1	—0.64	D	5
158.	$a\,^2G$–$u\,^2F°$											
		3980.14	41031	66149	10	8	0.13	0.025	3.2	—0.61	D	5
		4011.91	41230	66149	8	8	0.23	0.055	5.8	—0.36	D	5
159.	$a\,^2G$–$v\,^2G°$?											
		3919.33	41230	66738	8	8	0.088	0.020	2.1	—0.79	D	5
160.	$a\,^2G$–$w\,^2H°$											
		3776.29	41031	67505	10	12	0.050	0.013	1.6	—0.89	D	5

Mn I: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
161.	$e\ ^6S$–19°											
		3982.90	41404	66504	6	4	0.55	0.087	6.9	—0.28	D	5
162.	$b\ ^2I$–$w\ ^2H°$											
		4088.57	43053	67505	14	12	0.046	0.0099	1.9	—0.86	D	5
163.	$b\ ^2I$–$z\ ^2K°$											
		3889.46	43139	68843?	12	14	0.31	0.081	13	—0.01	C	5
164.	$b\ ^2I$–$x\ ^2I°$											
		3771.44	43053	69561?	14	14	0.19	0.041	7.1	—0.24	C	5
		3773.86	43139	69630?	12	12	0.25	0.053	7.8	—0.20	C	5
165.	$z\ ^4F°$–$f\ ^4G$											
		4132.28	44523	68716	8	10	0.15	0.049	5.3	—0.41	D	5

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn II

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s\ ^7S_3$

Ionization Potential 15.640 eV = 126145.0 cm^{-1}

Allowed Transitions

For this ion, the arc emission measurements of Woodgate [1] (discussed in detail in the introduction to Mn I) and the combination "lifetime-branching-ratio" study of Martinson, Curtis, Smith, and Biemont [2] were utilized. The technique of combining beam-foil lifetime results with branching-ratio emission measurements has been shown to yield accurate absolute f-values for other elements of the Fe group and was used as the principal data source. The data of Woodgate and that of Martinson et al. overlapped for five lines; the agreement was within 20 percent for three lines and 32 percent for the other two lines.

References

[1] Woodgate, B., Mon. Not. R. Astron. Soc. **134**, 287 (1966).

[2] Martinson, I., Curtis, L. J., Smith, P. L., and Biemont, E., to be published in Phys. Scr. (1977).

Mn II: Allowed transitions

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$a\ ^5S$–$z\ ^7P°$ (1)											
		3438.98	9473	38543	5	7	0.0041	0.0010	0.058	—2.29	D	1
2.	$a\ ^5S$–$z\ ^5P°$ (uv 5)	*2942.7*	9473	*43446*	5	15	1.7	0.68	33	0.53	C	2
		2949.20	9473	43370	5	7	1.7	0.30	15	0.18	C	2
		2939.30	9473	43485	5	5	1.8	0.23	11	0.06	C	2
		2933.05	9473	43557	5	3	1.7	0.14	6.5	—0.17	C	2

Mn II: Allowed transitions—Continued

No.	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^{8}s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
3.	$a\,^5D$–$z\,^5P°$ (3)	*3464.0*	*14586*	*43446*	25	15	0.55	0.060	17	0.17	C	2
		3441.98	14326	43370	9	7	0.43	0.060	6.1	—0.27	C	2
		3460.31	14594	43485	7	5	0.32	0.041	3.3	—0.54	C	2
		3474.12	14781	43557	5	3	0.15	0.017	0.95	—1.08	C	2
		3474.04	14594	43370	7	7	0.079	0.014	1.1	—1.00	C	2
		3482.91	14781	43485	5	5	0.20	0.036	2.1	—0.74	C	2
		3488.68	14901	43557	3	3	0.25	0.046	1.6	—0.86	C	2
		3496.81	14781	43370	5	7	0.016	0.0041	0.24	—1.69	C—	2
		3497.54	14901	43485	3	5	0.051	0.016	0.54	—1.33	C—	2
		3495.83	14960	43557	1	3	0.11	0.063	0.73	—1.20	C—	2

Mn VI

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2\ ^3F_2$

Ionization Potential [97] eV = [782000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
307.11	3	310.06	2	320.68	8	327.13	7
307.84	3	310.18	2	320.87	8	328.23	6
308.00	3	310.91	2	320.98	8	328.43	4
308.56	3	311.75	5	321.18	8	328.56	6
308.85	3	312.69	1	321.54	8	329.04	6
309.44	3	314.98	9	325.15	10	329.18	6
309.58	3	320.60	8	326.57	7	329.32	6

Warner and Kirkpatrick [1], using a scaled Thomas-Fermi single configuration method, have calculated a large number of transitions in the arrays $3d^2$–$3d4p$ and $3d4s$–$3d4p$. Of these data, we have selected a small number for inclusion here, using as a criterion for selection that the transition has been experimentally observed. For this selection procedure, we have used the wavelength list of Cady [2].

It is expected that for the relatively simple, essentially two-electron spectrum of Mn VI Warner and Kirkpatrick's data should be fairly reliable (except when configuration interaction effects become appreciable). This conjecture seems to be supported by the good consistency between their calculated data for the isoelectronic ion Ti III and lifetime data available for that ion [3].

References

[1] Warner, B., and Kirkpatrick, R., Publications of the Department of Astronomy, University of Texas at Austin, Vol. 3, No. 2 (1969).
[2] Cady, W. M., Phys. Rev. **43**, 322 (1933).
[3] Wiese, W. L., and Fuhr, J. R., J. Phys. Chem. Ref. Data **4**, 263 (1975).

Mn VI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki}(10^{8}s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3d^2$–$3d4p$	^3F–$^1D°$											
			312.69	0	319811	5	5	10	0.015	0.078	—1.12	D	1
2.		^3F–$^3D°$											
			310.91	1669	323283	9	7	45	0.051	0.47	—0.34	D	1
			310.06	746	323283	7	7	34	0.048	0.35	—0.47	D	1
			310.18	0	322409	5	5	28	0.040	0.20	—0.70	D	1

Mn VI: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
3.		^3F–$^3F^\circ$	*308.37*	*964*	*325249*	21	21	53	0.075	1.6	0.20	D	1
			308.00	1669	326369	9	9	37	0.052	0.47	—0.33	D	1
			308.56	746	324848	7	7	7.3	0.010	0.074	—1.14	E	1
			308.85	0	323795	5	5	7.5	0.011	0.055	—1.27	E	1
			309.44	1669	324848	9	7	57	0.064	0.59	—0.24	D	1
			309.58	746	323795	7	5	44	0.045	0.32	—0.50	D	1
			307.11	746	326369	7	9	2.5	0.0045	0.032	—1.50	E	1
			307.84	0	324848	5	7	1.2	0.0023	0.012	—1.93	E	1
4.		^1D–$^1D^\circ$	328.43	15336	319811	5	5	44	0.071	0.38	—0.45	D	1
5.		^1D–$^1P^\circ$	311.75	15336	336126	5	3	57	0.050	0.26	—0.60	D	1
6.		^3P–$^3D^\circ$											
			328.23	18628	323283	5	7	8.1	0.018	0.099	—1.04	D	1
			328.56	18057	322409	3	5	12	0.032	0.10	—1.02	D	1
			329.04	17782	321695	1	3	11	0.054	0.058	—1.27	D	1
			329.18	18628	322409	5	5	0.91	0.0015	0.0080	—2.13	E	1
			329.32	18057	321695	3	3	4.0	0.0065	0.021	—1.71	D	1
7.		^3P–$^3F^\circ$											
			326.57	18628	324848	5	7	5.4	0.012	0.065	—1.22	E	1
			327.13	18057	323795	3	5	3.0	0.0080	0.026	—1.62	E	1
8.		^3P–$^3P^\circ$	*321.03*	*18344*	*329846*	9	9	75	0.12	1.1	0.02	D	1
			321.18	18628	329995	5	5	60	0.094	0.49	—0.33	D	1
			320.98	18057	329635	3	3	22	0.033	0.11	—1.00	D	1
			321.54	18628	329635	5	3	27	0.025	0.13	—0.90	D	1
			320.87	18057	329732	3	1	78	0.040	0.13	—0.92	D	1
			320.60	18057	329995	3	5	15	0.039	0.12	—0.93	D	1
			320.68	17782	329635	1	3	22	0.10	0.11	—1.00	D	1
9.		^3P–$^1P^\circ$											
			314.98	18628	336126	5	3	7.1	0.0063	0.033	—1.50	E	1
10.		^1G–$^1F^\circ$	325.15	25511	333063	9	7	130	0.16	1.5	0.15	D	1

Mn VII

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d\ ^2D_{3/2}$

Ionization Potential 119.27 eV = 962001 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
115.38	1	133.66	2	134.22	5	139.65	6
115.39	1	133.67	5	134.35	3	140.38	7
115.57	1	133.68	2	135.93	3	141.17	7
133.40	4	133.90	2	136.21	3	141.81	8
133.43	2	133.98	5	138.49	6	142.08	8
133.65	4	134.21	4	138.74	6	142.68	8

Oscillator strengths for eight multiplets of Mn VII are taken from Cowan's Hartree-Fock calculations with intermediate coupling [1].

Biemont [2] has calculated multiplet oscillator strengths for transitions of the type ns–$n'p$ and np–$n'd$, where n, $n'=4$, 5, 6, 7, 8, using a single configuration Hartree-Fock approximation. We have not tabulated this material, however, since appreciable configuration interaction is expected with the $3d$ states, which makes Biemont's results unreliable. (The transitions considered by Cowan involve low level excitations from the ground state, and should not be seriously affected by configuration interaction until further into the isoelectronic sequence.)

References

[1] Cowan, R. D., Astrophys. J. **147**, 377 (1967).
[2] Biemont, E., Physica C **81**, 158 (1976).

Mn VII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3p^6 3d$–$3p^5 3d(^1P^\circ)4s$	^2D–$^2P^\circ$	*115.5*	*813*	[*866600*]	10	6	180	0.022	0.082	—0.67	D	1
			[115.57]	1355	[866600]	6	4	150	0.020	0.046	—0.92	D	1
			[115.38]	0	[866700]	4	2	190	0.019	0.029	—1.12	D	1
			[115.39]	0	[866600]	4	4	23	0.0045	0.0068	—1.74	D	1
2.	$3p^6 3d$–$3p^5 3d(^3D^\circ)4s$	^2D–$^2D^\circ$	*133.67*	*813*	*748940*	10	10	320	0.086	0.38	—0.06	D	1
			133.68	1355	749460	6	6	280	0.076	0.20	—0.34	D	1
			133.66	0	748170	4	4	250	0.067	0.12	—0.57	D	1
			133.90	1355	748170	6	4	61	0.011	0.029	—1.18	D	1
			133.43	0	749460	4	6	50	0.020	0.035	—1.10	D	1
3.		^2D–$^4D^\circ$											
			136.21	1355	735520	6	8	16	0.0060	0.016	—1.44	D	1
			135.93	1355	737030	6	6	28	0.0078	0.021	—1.33	D	1
			[134.35]	0	[744300]	4	4	20	0.0053	0.0094	—1.67	D	1
4.	$3p^6 3d$–$3p^5 3d(^1F^\circ)4s$	^2D–$^2F^\circ$	*133.9*	*813*	[*747800*]	10	14	140	0.054	0.24	—0.26	D	1
			134.21	1355	746460	6	8	150	0.055	0.15	—0.48	D	1
			[133.40]	0	[749600]	4	6	7.5	0.0030	0.0053	—1.92	D	1
			[133.65]	1355	[749600]	6	6	120	0.031	0.082	—0.73	D	1
5.	$3p^6 3d$–$3p^5 3d(^1D^\circ)4s$	^2D–$^2D^\circ$											
			[134.22]	1355	[746400]	6	6	8.1	0.0022	0.0058	—1.88	D	1
			[133.67]	0	[748100]	4	4	120	0.032	0.056	—0.89	D	1
			[133.98]	0	[746400]	4	6	54	0.022	0.039	—1.06	D	1
6.	$3p^6 3d$–$3p^5 3d(^3F^\circ)4s$	^2D–$^2F^\circ$	*139.16*	*813*	*719420*	10	14	270	0.11	0.50	0.04	D	1
			139.65	1355	717430	6	8	240	0.092	0.25	—0.26	D	1
			138.49	0	722070	4	6	300	0.13	0.24	—0.28	D	1
			138.74	1355	722070	6	6	16	0.0047	0.013	—1.55	D	1
7.		^2D–$^4F^\circ$											
			141.17	1355	709720	6	8	14	0.0055	0.015	—1.48	D	1
			140.38	0	712350	4	6	19	0.0083	0.015	—1.48	D	1
8.	$3p^6 3d$–$3p^5 3d(^3P^\circ)4s$	^2D–$^2P^\circ$	*142.26*	*813*	*703740*	10	6	270	0.049	0.23	—0.31	D	1
			142.08	1355	705170	6	4	240	0.048	0.13	—0.54	D	1
			142.68	0	700870	4	2	280	0.042	0.079	—0.77	D	1
			141.81	0	705170	4	4	36	0.011	0.021	—1.36	D	1

Mn VIII

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6\ {}^1S_0$

Ionization Potential [196.2] eV = [1582500] cm^{-1}

Allowed Transitions

Oscillator strengths for two transitions were obtained by interpolating the results of Cowan's configuration interaction calculation [1] (which was done in intermediate coupling) from neighboring ions of the Ar isoelectronic sequence.

Reference

[1] Cowan, R. D., J. Phys. (Paris), Colloq. C4 **31**, 191 (1970).

Mn VIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3p^6$–$3p^5 3d$	${}^1S$–${}^3D^\circ$											
			[240.05]	0	416574	1	3	1.9	0.0049	0.0039	−2.31	E	*interp.*
2.		${}^1S$–${}^1P^\circ$	185.46	0	539200	1	3	2700	4.1	2.5	0.61	E	*interp.*

Mn X

Ground State $1s^2 2s^2 2p^6 3s^2 3p^4\ {}^3P_2$

Ionization Potential [248.5] eV = [2004300] cm^{-1}

Allowed Transitions

The single multiplet oscillator strength presented was derived by graphical interpolation from the systematic trend along the sulfur isoelectronic sequence. The lines within the multiplet are analyzed according to *LS* coupling.

Mn X: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2 3p^4$–$3s 3p^5$	${}^3P$–${}^3P^\circ$	*383.9*	*4630*	[*265100*]	9	9	42	0.092	1.0	−0.08	E	*interp.*
			383.00	0	261100	5	5	30	0.067	0.42	−0.48	E	*ls*
			386.27	10000	268900	3	3	9.7	0.022	0.083	−1.19	E	*ls*
			371.88	0	268900	5	3	18	0.023	0.14	−0.94	E	*ls*
			[379.4]	10000	[273600]	3	1	41	0.029	0.11	−1.06	E	*ls*
			398.28	10000	261100	3	5	9.0	0.036	0.14	−0.97	E	*ls*
			388.91	11700	268900	1	3	13	0.086	0.11	−1.07	E	*ls*

Mn XI

Ground State $1s^2 2s^2 2p^6 3s^2 3p^3\ {}^4S^\circ_{3/2}$

Ionization Potential [283] eV = [228300] cm^{-1}

Allowed Transitions

The multiplet oscillator strength for the first multiplet was derived by graphical interpolation from a systematic trend along the phosphorus isoelectronic sequence.

The data for the second multiplet are the result of calculations by Ali and Joy, done in a single configuration Hartree-Fock approximation [1]. Thus, configuration in-

teraction was not taken into account, which may be important for this transition. However, a comparison of the transition integral calculated by Ali with the nuclear charge expansion method (unpublished result), which includes limited configuration interaction, shows good agreement. We calculated our f-values from the "free" form of Ali's transition integral instead of using his published gf-value directly, in order to take advantage of better energy level data now available.

We estimate that all listed data are outside the ±50% accuracy range, but the first multiplet should not be uncertain by more than a factor of two.

Reference

[1] Ali, M. A., and Joy, H. W., J. Phys. B **3**, 1552 (1970).

Mn XI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p^3$–$3s3p^4$	$^4S°$–^4P	*386.88*	0	*258480*	4	12	34	0.23	1.2	—0.04	E	*interp.*
			393.69	0	254010	4	6	33	0.12	0.60	—0.33	E	*ls*
			382.07	0	261730	4	4	36	0.080	0.40	—0.50	E	*ls*
			376.81	0	265390	4	2	38	0.040	0.20	—0.79	E	*ls*
2.	$3p^3$–$3p^2(^3P)3d$	$^4S°$–^4P	*208.62*	0	*479330*	4	12	760	1.5	4.1	0.78	E	1
			209.57	0	477170	4	6	770	0.76	2.1	0.48	E	*ls*
			208.02	0	480720	4	4	790	0.51	1.4	0.31	E	*ls*
			207.02	0	483050	4	2	780	0.25	0.68	—0.00	E	*ls*

Mn XII

Ground State $1s^22s^22p^63s^23p^2\ ^3P_0$

Ionization Potential [313.0] eV = [2524600] cm^{-1}

Allowed Transitions

The multiplet oscillator strengths were derived by graphical interpolation from systematic trends along the silicon isoelectronic sequence. The lines within the multiplets are analyzed according to LS coupling.

Mn XII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^23p^2$–$3s3p^3$	^3P–$^3D°$	*398.38*	*10746*	*264310*	9	15	12	0.046	0.54	—0.38	D	*interp.*
			397.46	15010	266610	5	7	12	0.038	0.25	—0.72	D	*ls*
			388.91	7222.3	264350	3	5	9.6	0.036	0.14	—0.96	D	*ls*
			386.27	0	258890	1	3	7.0	0.047	0.060	—1.33	D	*ls*
			[401.06]	15010	264350	5	5	2.8	0.0068	0.045	—1.47	D	*ls*
			[397.35]	7222.3	258890	3	3	4.8	0.011	0.045	—1.46	D	*ls*
			[410.04]	15010	258890	5	3	0.29	4.4(—4)[a]	0.0030	—2.65	D	*ls*
2.		^3P–$^3P°$				9	9		0.063		—0.25	D	*interp.*
3.		^1D–$^1D°$	342.67	42136	333960	5	5	48	0.085	0.48	—0.37	D	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XIII

Ground State $1s^2 2s^2 2p^6 3s^2 3p\ ^2P^\circ_{1/2}$

Ionization Potential [342.0] eV = [2758500] cm^{-1}

Allowed Transitions

The oscillator strengths for the first two multiplets are taken from the superposition-of-configurations calculations of Froese Fischer [1,2]. The calculation of Ref. [2] is an improvement over that of Ref. [1] in that more configurations are included. While the full effect of electron correlation has not been included in these calculations, comparisons with experiment for a few lower ions of the Al sequence suggest that the results should be accurate to within 50 percent.

Data for the third multiplet were obtained by interpolation from graphs of systematic trends along the Al isoelectronic sequence.

References

[1] Froese Fischer, C., J. Quant. Spectrosc. Radiat. Transfer **8**, 755 (1968).

[2] Froese Fischer, C., Fourth International Conference on Atomic Physics, Abstracts of Contributed Papers, Ed. Kowalski, J., and Weber, H. G., Heidelberg (1974).

Mn XIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2 3p$–$3s 3p^2$	$^2P^\circ$–^2D	*374.07*	*10207*	*277540*	6	10	15	0.051	0.38	—0.51	D	1
			380.42	15310	278180	4	6	14	0.046	0.23	—0.74	D	*ls*
			361.57	0	276570	2	4	14	0.055	0.13	—0.96	D	*ls*
			382.76	15310	276570	4	4	2.3	0.0050	0.025	—1.70	E	*ls*
2.	$3p$–$3d$	$^2P^\circ$–^2D	*231.80*	*10207*	*441620*	6	10	380	0.51	2.3	0.49	D	2
			234.24	15310	442230	4	6	370	0.45	1.4	0.26	D	*ls*
			226.91	0	440700	2	4	330	0.52	0.77	0.01	D	*ls*
			235.08	15310	440700	4	4	58	0.048	0.15	—0.71	E	*ls*
3.	$3p$–$4s$	$^2P^\circ$–^2S				6	2		0.066		—0.40	D	*interp.*

Mn XIV

Ground State $1s^2 2s^2 2p^6 3s^2\ ^1S_0$

Ionization Potential 404 eV = 3260000 cm^{-1}

Allowed Transitions

Oscillator strengths for this ion of the Mg isoelectronic sequence were derived by interpolation from graphs of systematic trends along isoelectronic sequences. The low accuracies reflect the general scarcity of data for high ions. Furthermore, for some transitions a level crossing occurs at Cl VI, which greatly complicates the extrapolation of lower Z data. It is expected that data marked "E" are accurate to within a factor of two.

Victor, Stewart and Laughlin [1] have recently presented data for a large number of transitions in the ions Mg I to Cl VI, which may be useful in the construction of additional systematic trends for transitions not presented here. Caution must be exercised when constructing such trends, however, for the reasons mentioned above.

Reference

[1] Victor, G. A., Stewart, R. F., and Laughlin, C., Astrophys. J. **31**, 237 (1976).

Mn XIV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3s^2$–$3s3p$	^1S–$^1P^o$	304.85	0	328030	1	3	200	0.84	0.84	—0.08	C+	*interp.*
2.	$3s3p$–$3p^2$	$^3P^o$–^3P	*329.34*	[*229490*]	[*533130*]	9	9	180	0.30	2.9	0.43	D	*interp.*
			327.84	[235080]	[540200]	5	5	140	0.22	1.2	0.05	D	*ls*
			330.49	[223700]	[526230]	3	3	45	0.074	0.24	—0.66	D	*ls*
			343.60	[235080]	[526230]	5	3	67	0.071	0.40	—0.45	D	*ls*
			339.19	[223700]	[518520]	3	1	170	0.096	0.32	—0.54	D	*ls*
			315.88	[223700]	[540200]	3	5	51	0.13	0.40	—0.41	D	*ls*
			325.34	[218910]	[526230]	1	3	63	0.30	0.32	—0.52	D	*ls*
3.		$^1P^o$–^1D				3	5		0.095		—0.55	D	*interp.*
4.		$^1P^o$–^1S	349.64	328030	614040	3	1	180	0.11	0.38	—0.48	D	*interp.*
5.	$3s3p$–$3s3d$	$^3P^o$–^3D	*246.68*	[*229490*]	[*634880*]	9	15	240	0.36	2.6	0.51	D	*interp.*
			249.64	[235080]	[635660]	5	7	220	0.29	1.2	0.16	D	*ls*
			243.45	[223700]	[634460]	3	5	180	0.27	0.65	—0.09	D	*ls*
			241.07	[218910]	[633740]	1	3	140	0.37	0.29	—0.44	D	*ls*
			[250.4]	[235080]	[634460]	5	5	57	0.053	0.22	—0.57	D	*ls*
			243.88	[223700]	[633740]	3	3	100	0.091	0.22	—0.56	D	*ls*
			[250.8]	[235080]	[633740]	5	3	6.0	0.0034	0.014	—1.77	D	*ls*
6.		$^1P^o$–^1D	518.16	328030	521020	3	5	100	0.68	3.5	0.31	E	*interp.*
7.	$3s3p$–$3s4s$	$^1P^o$–^1S				3	1		0.068		—0.69	E	*interp.*
8.		$^3P^o$–^3S	*74.649*	[*229490*]	[1569100]	9	3	2300	0.063	0.14	—0.25	E	*interp.*
			74.961	[235080]	[1569100]	5	3	1300	0.063	0.078	—0.50	E	*ls*
			74.327	[223700]	[1569100]	3	3	770	0.064	0.047	—0.72	E	*ls*
			74.063	[218910]	[1569100]	1	3	270	0.066	0.016	—1.18	E	*ls*

Mn XV

Ground State $1s^2 2s^2 2p^6 3s\ ^2S_{1/2}$

Ionization Potential 435.3 eV = 3511210 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
40.285	6	55.767	11	97.257	21	282.18	7
40.572	6	56.270	2	102.92	18	302.5	26
41.185	3	56.484	2	103.64	18	302.8	26
41.243	3	60.720	8	109.3	23	303.0	26
44.820	9	61.319	8	109.4	23	360.97	1
45.154	9	61.361	8	131.5	16	384.74	1
45.166	9	71.038	4	132.1	16	733.1	19
45.659	14	71.927	4	138.8	20	765.1	19
45.700	14	75.182	12	139.9	20	771.0	19
45.704	14	75.286	12	140.1	20	912.4	15
47.270	5	75.309	12	165.3	17	971.8	15
47.666	5	87.29	10	167.2	17	1506	25
52.977	13	87.47	10	191.8	22	1572	25
53.032	13	87.80	10	192.2	22	1587	25
53.040	13	96.628	21	193.1	22	1890	24
55.661	11	97.220	21	269.11	7	2020	24
55.708	11			280.35	7		

The data are taken primarily from the Hartree-Fock calculations of Biemont [1]. Data for several multiplets not given by Biemont were derived by interpolation from graphs of oscillator strengths along the Na isoelectronic sequence. Line strengths within multiplets are given according to *LS* coupling.

Reference

[1] Biemont, E., J. Quant. Spectrosc. Radiat. Transfer **15**, 531 (1975).

Mn XV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	3*s*–3*p*	^{2}S–^{2}P°	*368.55*	0	*271330*	2	6	68	0.416	1.01	—0.080	C	1
			360.97	0	277030	2	4	72	0.28	0.67	—0.25	C	*ls*
			384.74	0	259920	2	2	60	0.133	0.337	—0.58	C	*ls*
2.	3*s*–4*p*	^{2}S–^{2}P°	*56.341*	0	*1774900*	2	6	1550	0.221	0.082	—0.355	C	1
			56.270	0	1777100	2	4	1600	0.15	0.055	—0.53	C	*ls*
			56.484	0	1770400	2	2	1500	0.073	0.027	—0.84	C	*ls*
3.	3*s*–5*p*	^{2}S–^{2}P°	*41.203*	0	*2427000*	2	6	880	0.067	0.018	—0.87	C	1
			41.185	0	2428100	2	4	870	0.044	0.012	—1.05	C	*ls*
			41.243	0	2424700	2	2	870	0.022	0.0060	—1.35	C	*ls*
4.	3*p*–4*s*	^{2}P°–^{2}S	*71.625*	*271330*	1667500	6	2	2500	0.064	0.091	—0.42	C	1
			71.927	277030	1667500	4	2	1700	0.064	0.061	—0.59	C	*ls*
			71.038	259920	1667500	2	2	850	0.064	0.030	—0.89	C	*ls*
5.	3*p*–5*s*	^{2}P°–^{2}S	*47.531*	*271330*	2375200	6	2	1120	0.0126	0.0118	—1.121	C	1
			47.666	277030	2375200	4	2	740	0.013	0.0079	—1.30	C	*ls*
			47.270	259920	2375200	2	2	370	0.013	0.0039	—1.60	C	*ls*
6.	3*p*–6*s*	^{2}P°–^{2}S	*40.475*	*271330*	2742000	6	2	600	0.00490	0.00392	—1.53	C	*interp.*
			40.572	277030	2742000	4	2	396	0.00489	0.00261	—1.71	C	*ls*
			40.285	259920	2742000	2	2	203	0.00494	0.00131	—2.005	C	*ls*
7.	3*p*–3*d*	^{2}P°–^{2}D	*276.62*	*271330*	*632840*	6	10	160	0.305	1.67	0.262	C	1
			280.35	277030	633730	4	6	153	0.271	1.00	0.035	C	*ls*
			269.11	259920	631510	2	4	150	0.32	0.56	—0.20	C	*ls*
			282.18	277030	631510	4	4	25.0	0.0299	0.111	—0.92	C—	*ls*
8.	3*p*–4*d*	^{2}P°–^{2}D	*61.122*	*271330*	*1907400*	6	10	3220	0.301	0.363	0.257	C	1
			61.319	277030	1907800	4	6	3190	0.270	0.218	0.033	C	*ls*
			60.720	259920	1906800	2	4	2740	0.303	0.121	—0.218	C	*ls*
			61.361	277030	1906800	4	4	530	0.0299	0.0242	—0.92	C—	*ls*
9.	3*p*–5*d*	^{2}P°–^{2}D	*45.042*	*271330*	*2491500*	6	10	1900	0.097	0.086	—0.24	C	1
			45.154	277030	2491700	4	6	1900	0.087	0.052	—0.46	C	*ls*
			44.820	259920	2491100	2	4	1600	0.098	0.029	—0.71	C	*ls*
			[45.166]	277030	2491100	4	4	310	0.0096	0.0057	—1.42	C—	*ls*
10.	3*d*–4*p*	^{2}D–^{2}P°	*87.56*	*632840*	*1774900*	10	6	590	0.0409	0.118	—0.388	C	1
			87.47	633730	1777100	6	4	540	0.041	0.071	—0.61	C	*ls*
			87.80	631510	1770400	4	2	590	0.0340	0.0393	—0.87	C	*ls*
			[87.29]	631510	1777100	4	4	60	0.0069	0.0079	—1.56	C—	*ls*
11.	3*d*–5*p*	^{2}D–^{2}P°	*55.736*	*632840*	*2427000*	10	6	230	0.0065	0.012	—1.19	C	1
			55.708	633730	2428100	6	4	210	0.0065	0.0072	—1.41	C	*ls*
			[55.767]	631510	2424700	4	2	230	0.0054	0.0040	—1.66	C	*ls*
			[55.661]	631510	2428100	4	4	23	0.0011	8.0(—4)[a]	—2.36	C—	*ls*
12.	3*d*–4*f*	^{2}D–^{2}F°	*75.247*	*632840*	*1961800*	10	14	7800	0.93	2.3	0.97	C	*interp.*
			75.286	633730	1962000	6	8	7700	0.87	1.3	0.72	C	*ls*
			75.182	631510	1961600	4	6	7300	0.93	0.92	0.57	C	*ls*
			[75.309]	633730	1961600	6	6	520	0.044	0.066	—0.57	C—	*ls*

Mn XV: Allowed transitions—Continued

No.	Transition array	Mutliplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
13.	3*d*–5*f*	^{2}D–^{2}F°	*53.009*	*632840*	*2519300*	10	14	2880	0.170	0.297	0.230	C	*interp.*
			53.032	633730	2519400	6	8	2890	0.162	0.170	—0.012	C	*ls*
			52.977	631510	2519100	4	6	2700	0.171	0.119	—0.166	C	*ls*
			[53.040]	633730	2519100	6	6	190	0.0081	0.0085	—1.31	C—	*ls*
14.	3*d*–6*f*	^{2}D–^{2}F°	*45.684*	*632840*	*2821800*	10	14	1500	0.064	0.096	—0.19	C	1
			45.700	633730	2821900	6	8	1500	0.061	0.055	—0.44	C	*ls*
			45.659	631510	2821700	4	6	1300	0.063	0.038	—0.60	C	*ls*
			[45.704]	633730	2821700	6	6	96	0.0030	0.0027	—1.75	C—	*ls*
15.	4*s*–4*p*	^{2}S–^{2}P°	*931.1*	1667500	*1774900*	2	6	16	0.61	3.7	0.09	C	1
			[912.4]	1667500	1777100	2	4	17	0.42	2.5	—0.08	C	*ls*
			[971.8]	1667500	1770400	2	2	13	0.19	1.2	—0.43	C	*ls*
16.	4*s*–5*p*	^{2}S–^{2}P°	*131.7*	1667500	*2427000*	2	6	296	0.231	0.200	—0.335	C	1
			[131.5]	1667500	2428100	2	4	296	0.154	0.133	—0.51	C	*ls*
			[132.1]	1667500	2424700	2	2	290	0.077	0.067	—0.81	C	*ls*
17.	4*p*–5*s*	^{2}P°–^{2}S	*166.6*	*1774900*	2375200	6	2	790	0.110	0.362	—0.180	C	1
			[167.2]	1777100	2375200	4	2	520	0.109	0.241	—0.359	C	*ls*
			[165.3]	1770400	2375200	2	2	271	0.111	0.121	—0.65	C	*ls*
18.	4*p*–6*s*	^{2}P°–^{2}S	*103.40*	*1774900*	2742000	6	2	404	0.0216	0.0441	—0.89	C	*interp.*
			[103.64]	1777100	2742000	4	2	268	0.0215	0.0294	—1.065	C	*ls*
			[102.92]	1770400	2742000	2	2	137	0.0217	0.0147	—1.363	C	*ls*
19.	4*p*–4*d*	^{2}P°–^{2}D	*754.7*	*1774900*	*1907400*	6	10	33.6	0.478	7.1	0.458	C	1
			[765.1]	1777100	1907800	4	6	32	0.43	4.3	0.23	C	*ls*
			[733.1]	1770400	1906800	2	4	31	0.50	2.4	—0.00	C	*ls*
			[771.0]	1777100	1906800	4	4	5.2	0.046	0.47	—0.73	C—	*ls*
20.	4*p*–5*d*	^{2}P°–^{2}D	*139.5*	*1774900*	*2491500*	6	10	530	0.258	0.71	0.190	C	1
			[139.9]	1777100	2491700	4	6	530	0.23	0.43	—0.03	C	*ls*
			[138.8]	1770400	2491100	2	4	450	0.26	0.24	—0.28	C	*ls*
			[140.1]	1777100	2491100	4	4	87	0.025	0.047	—0.99	C—	*ls*
21.	4*p*–6*d*	^{2}P°–^{2}D	*97.031*	*1774900*	*2805500*	6	10	360	0.085	0.16	—0.29	D	*interp.*
			[97.220]	1777100	2805700	4	6	350	0.075	0.096	—0.52	D	*ls*
			[96.628]	1770400	2805300	2	4	300	0.083	0.053	—0.78	D	*ls*
			[97.257]	1777100	2805300	4	4	61	0.0086	0.011	—1.46	D—	*ls*
22.	4*d*–5*p*	^{2}D–^{2}P°	*192.5*	*1907400*	*2427000*	10	6	280	0.092	0.58	—0.04	C	1
			[192.2]	1907800	2428100	6	4	250	0.092	0.35	—0.26	C	*ls*
			[193.1]	1906800	2424700	4	2	270	0.075	0.19	—0.52	C	*ls*
			[191.8]	1906800	2428100	4	4	28	0.015	0.039	—1.21	C—	*ls*
23.	4*d*–6*f*	^{2}D–^{2}F°	*109.4*	*1907400*	*2821800*	10	14	710	0.179	0.64	0.253	C	1
			[109.4]	1907800	2821900	6	8	720	0.17	0.37	0.01	C	*ls*
			[109.3]	1906800	2821700	4	6	670	0.18	0.26	—0.14	C	*ls*
			[109.4]	1907800	2821700	6	6	46	0.0083	0.018	—1.30	C—	*ls*
24.	5*s*–5*p*	^{2}S–^{2}P°	*1931*	2375200	*2427000*	2	6	4.4	0.74	9.4	0.17	C	1
			[1890]	2375200	2428100	2	4	4.7	0.51	6.3	0.01	C	*ls*
			[2020]	2375200	2424700	2	2	3.8	0.23	3.1	—0.33	C	*ls*
25.	5*p*–5*d*	^{2}P°–^{2}D	*1550*	*2427000*	*2491500*	6	10	10	0.62	19	0.57	C	1
			[1572]	2428100	2491700	4	6	9.6	0.53	11	0.33	C	*ls*
			[1506]	2424700	2491100	2	4	9.3	0.64	6.3	0.10	C	*ls*
			[1587]	2428100	2491100	4	4	1.6	0.062	1.3	—0.60	C—	*ls*

Mn XV: Allowed transitions—Continued

No.	Transition array	Mutliplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
26.	$5d$–$6f$	^2D–$^2F°$	*302.8*	*2491500*	*2821800*	10	14	330	0.64	6.4	0.81	C	1
			[302.8]	2491700	2821900	6	8	340	0.62	3.7	0.57	C	*ls*
			[302.5]	2491100	2821700	4	6	320	0.65	2.6	0.42	C	*ls*
			[303.0]	2491700	2821700	6	6	22	0.030	0.18	−0.74	C—	*ls*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XVI

Ground State $1s^2 2s^2 2p^6\ ^1S_0$

Ionization Potential 1136.2 eV = 9164300 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
11.853	17	17.095	9	322.8	21	398.3	19
11.971	16	18.654	2	347.2	21	408.5	25
12.373	15	18.935	1	363.5	20, 21	426.1	19
12.510	14	209.1	23	368.5	27	427.9	18
13.46	12	250.9	28	372.0	26	434.4	26
13.61	13	269.2	22	373.8	21	469.0	18
13.927	4	271.1	21	375.7	19	532.2	26
14.098	3	284.9	22	391.9	19	714.8	18
16.616	10	308.3	19	392.8	20	748.5	24
16.882	11						

Two theoretical studies are available for this ion of the Ne sequence, the parametric-potential method of Crance [1] and the self-consistent field calculations by Kastner et al. [2]. Both authors obtain very similar results for the oscillator strengths, with agreement of 25 percent or better in every case.

Since the two sources use rather equivalent approaches, but Crance's calculations are more complete, we have applied his work exclusively for this compilation. Some transitions are represented in *jl*-coupling notation, as given by Crance.

Both calculations have been done in a single-configuration approximation only, but this should not lead to significant uncertainties for this highly ionized species. However, the weaker lines are expected to be affected by uncertainties in the calculated intermediate coupling coefficients more than the stronger lines, and the accuracy ratings have been correspondingly lowered. Also, a configuration interaction calculation for Fe XVII by Loulergue [3] indicates that some of Crance's data could be too low by as much as a factor of two. Systematic trends along the sequence have not yet been definitively established, since sufficient data are only available for the first few ions.

References

[1] Crance, M., At. Data **5**, 185 (1973).
[2] Kastner, S. O., Omidvar, K., and Underwood, J. H., Astrophys. J. **148**, 269 (1967).
[3] Loulergue, M., Astron. Astrophys. **15**, 216 (1971).

Mn XVI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2p^6$–$2p^5 3s$	^1S–[1½]°	18.935	0	5281200	1	3	4100	0.066	0.0041	−1.18	D—	1
2.		^1S–[½]°	18.654	0	5360800	1	3	3800	0.059	0.0036	−1.23	D—	1
3.	$2p^6$–$2p^5 4s$	^1S–[1½]°	14.098	0	7093200	1	3	1800	0.016	7.4 (−4)[a]	−1.80	D—	1
4.		^1S–[½]°	[13.927]	0	[7180100]	1	3	1100	0.0099	4.5 (−4)	−2.00	D—	1

Mn XVI: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
5.	$2p^6$–$2p^5 5s$	^{1}S–[1½]°				1	3		0.0066		—2.18	E	1
6.		^{1}S–[½]°				1	3		0.0036		—2.44	E	1
7.	$2p^6$–$2p^5 6s$	^{1}S–[1½]°				1	3		0.0034		—2.47	E	1
8.		^{1}S–[½]°				1	3		0.0018		—2.74	E	1
9.	$2p^6$–$2p^5 3d$	^{1}S–^{3}P°											
			17.095	0	5849700	1	3	760	0.010	5.6 (—4)	—2.00	E	1
10.		^{1}S–^{3}D°											
			16.616	0	6018300	1	3	4.6 (+4)	0.57	0.031	—0.24	D	1
11.		^{1}S–^{1}P°	16.882	0	5923500	1	3	1.9 (+5)	2.4	0.13	0.38	D	1
12.	$2p^6$–$2p^5 4d$	^{1}S–^{3}D°											
			13.46	0	7429000	1	3	4.2 (+4)	0.34	0.015	—0.47	D	1
13.		^{1}S–^{1}P°	13.61	0	7348000	1	3	4.8 (+4)	0.40	0.018	—0.40	D	1
14.	$2p^6$–$2p^5 5d$	^{1}S–^{3}D°											
			12.510	0	7993600	1	3	1.8 (+4)	0.13	0.0054	—0.89	D	1
15.		^{1}S–^{1}P°	12.373	0	8082100	1	3	2.5 (+4)	0.17	0.0069	—0.77	D	1
16.	$2p^6$–$2p^5 6d$	^{1}S–^{3}D°											
			11.971	0	8353500	1	3	9500	0.061	0.0024	—1.21	E	1
17.		^{1}S–^{1}P°	11.853	0	8436700	1	3	1.5 (+4)	0.096	0.0037	—1.02	E	1
18.	$2p^5 3s$–$2p^5 3p$	^{3}P°–^{3}S	*462.1*	[*5278000*]	[5494400]	9	3	31	0.034	0.46	—0.52	D	1
			[427.9]	[5260700]	[5494400]	5	3	38	0.063	0.44	—0.50	D	1
			[469.0]	5281200	[5494400]	3	3	1.0	0.0033	0.015	—2.00	E	1
			[714.8]	[5354500]	[5494400]	1	3	0.12	0.0028	0.0065	—2.56	E	1
19.		^{3}P°–^{3}D											
			[375.7]	[5260700]	[5526900]	5	7	60	0.18	1.1	—0.05	D	1
			[426.1]	5281200	[5515900]	3	5	22	0.10	0.42	—0.52	D	1
			[398.3]	[5354500]	[5605600]	1	3	20	0.14	0.19	—0.85	D	1
			[391.9]	[5260700]	[5515900]	5	5	25	0.058	0.37	—0.54	D	1
			[308.3]	5281200	[5605600]	3	3	0.17	2.4 (—4)	7.4 (—4)	—3.14	E	1
20.		^{3}P°–^{1}P											
			[363.5]	[5260700]	[5535800]	5	3	2.2	0.0026	0.016	—1.88	E	1
			[392.8]	5281200	[5535800]	3	3	50	0.12	0.45	—0.46	D	1
21.		^{3}P°–^{3}P											
			[347.2]	[5260700]	[5548700]	5	5	39	0.070	0.40	—0.45	D	1
			[271.1]	[5260700]	[5629600]	5	3	5.3	0.0035	0.016	—1.76	E	1
			[322.8]	5281200	[5591000]	3	1	63	0.033	0.10	—1.01	D	1
			[373.8]	5281200	[5548700]	3	5	28	0.098	0.36	—0.53	E	1
			[363.5]	[5354500]	[5629600]	1	3	38	0.23	0.27	—0.65	E	1
22.		^{3}P°–^{1}D											
			[269.2]	[5260700]	[5632200]	5	5	0.84	9.1 (—4)	0.0040	—2.34	E	1
			[284.9]	5281200	[5632200]	3	5	0.90	0.0018	0.0051	—2.26	E	1
23.		^{3}P°–^{1}S											
			[209.1]	5281200	[5759400]	3	1	110	0.024	0.050	—1.14	E	1
24.		^{1}P°–^{3}S											
			[748.5]	5360800	[5494400]	3	3	0.13	0.0011	0.0081	—2.48	E	1

Mn XVI: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
25.		$^1P°-^3D$											
			[408.5]	5360800	[5605600]	3	3	27	0.068	0.27	—0.69	D	1
26.		$^1P°-^3P$											
			[532.2]	5360800	[5548700]	3	5	0.24	0.0017	0.0089	—2.29	E	1
			[372.0]	5360800	[5629600]	3	3	24	0.050	0.18	—0.83	D	1
			[434.4]	5360800	[5591000]	3	1	13	0.012	0.053	—1.43	E	1
27.		$^1P°-^1D$	[368.5]	5360800	[5632200]	3	5	62	0.21	0.77	—0.20	D	1
28.		$^1P°-^1S$	[250.9]	5360800	[5759400]	3	1	140	0.044	0.11	—0.88	D	1

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XVII

Ground State $1s^2 2s^2 2p^5\ ^2P°_{3/2}$

Ionization Potential [1220] eV = [9840000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
15.365	16	15.926	11	16.179	10	17.465	3
15.404	16	15.946	12	16.20	9	17.541	3
15.570	16	15.958	10	16.278	8	17.550	4
15.615	15	15.98	9	16.315	8	17.716	2
15.670	15	15.987	8	16.346	6	17.729	3
15.676	14	16.041	7	16.880	5	17.794	2
15.732	12	16.054	8	17.131	5	17.807	3
15.826	15	16.090	8	17.291	4	100.00	1
15.871	10	16.121	6	17.301	4	109.35	1
15.889	14						

The multiplet strength for the first multiplet is taken from Safronova's many-body perturbation theory calculation [1]. At lower Z, this calculation is in excellent agreement with the non-closed shell many-electron theory of Sinanoglu [2]. As an expansion in Z^{-1}, Safronova's results should improve with increasing Z, and should be fairly accurate for Mn XVII. The data resulting from the expansion in Z^{-1} of the line strength by Cohen and Dalgarno [3] were found to lie above both Safronova's and Sinanoglu's values by about 20%.

The oscillator strengths of Cohen, Feldman, and Kastner [4], obtained with the Hartree-Fock method, should be used with caution, as similar calculations for Sc XIII, another ion of the F isoelectronic sequence, have shown discrepancies of more than a factor of 5 for some transitions when compared to more accurate material [5].

Additional data for this ion are available from the work of Ali [6,7], who has calculated multiplet strengths for the fairly strong $3s$–$3p$ and $3p$–$3d$ transitions, again using an expansion in Z^{-1}. We did not tabulate this material, however, since the relevant wavelengths and energy levels are not known.

References

[1] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 231 (1975).

[2] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).

[3] Cohen, M., and Dalgarno, A., Proc. R. Soc. London, Ser. A **280**, 258 (1964).

[4] Cohen, L., Feldman, U., and Kastner, S. O., J. Opt. Soc. Am. **58**, 331 (1968).

[5] Wiese, W. L., and Fuhr, J. R., J. Phys. Chem. Ref. Data **4**, 263 (1975).

[6] Ali, M. A., Int. J. Quantum Chem., Symp. **3**, 359 (1970).

[7] Ali, M. A., J. Quant. Spectrosc. Radiat. Transfer **11**, 503 (1971).

Mn XVII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^22p^5$–$2s2p^6$	$^2P^o$–^2S	*102.93*	*28500*	1000000	6	2	930	0.049	0.10	—0.53	D	1
			100.00	0	1000000	4	2	680	0.051	0.067	—0.69	D	*ls*
			109.35	85500	1000000	2	2	260	0.046	0.033	—1.04	D	*ls*
2.	$2p^5$–$2p^4(^3P)3s$	$^2P^o$–^4P											
			17.794	0	5619900	4	6	340	0.0024	5.6(—4) [a]	—2.02	E	4
			17.716	0	5644600	4	4	150	7.2(—4)	1.7(—4)	—2.54	E	4
						2	2		6.2(—4)		—2.91	E	4
						4	2		6.0(—4)		—2.62	E	4
3.		$^2P^o$–^2P	*17.603*	*28500*	*5709200*	6	6	1.5(+4)	0.069	0.024	—0.38	E	4
			17.541	0	5700900	4	4	1.4(+4)	0.065	0.015	—0.59	E	4
			17.729	85500	5725700	2	2	8300	0.039	0.0046	—1.11	E	4
			17.465	0	5725700	4	2	7400	0.017	0.0039	—1.17	E	4
			17.807	85500	5700900	2	4	650	0.0062	7.3(—4)	—1.91	E	4
4.	$2p^5$–$2p^4(^1D)3s$	$^2P^o$–^2D	*17.383*	*28500*	*5781400*	6	10	5800	0.044	0.015	—0.58	E	4
			17.301	0	5780000	4	6	5100	0.034	0.0077	—0.87	E	4
			17.550	85500	5783500	2	4	6400	0.059	0.0068	—0.93	E	4
			[17.291]	0	5783500	4	4	190	8.5(—4)	1.9(—4)	—2.47	E	4
5.	$2p^5$–$2p^4(^1S)3s$	$^2P^o$–^2S	*16.965*	*28500*	5922900	6	2	5800	0.0084	0.0028	—1.30	E	4
			16.880	0	5922900	4	2	1700	0.0036	8.0(—4)	—1.84	E	4
			17.131	85500	5922900	2	2	4100	0.018	0.0020	—1.44	E	4
6.	$2p^5$–$2p^4(^3P)3d$	$^2P^o$–^4D											
						4	6		0.044		—0.75	E	4
			[16.346]	85500	6203100	2	4	5600	0.045	0.0048	—1.05	E	4
			16.121	0	6203100	4	4	2.5(+4)	0.097	0.021	—0.41	E	4
						2	2		0.055		—0.96	E	4
						4	2		0.019		—1.12	E	4
7.		$^2P^o$–^4F											
			16.041	0	6234000	4	6	1.2(+4)	0.068	0.014	—0.57	E	4
						2	4		0.12		—0.62	E	4
						4	4		0.12		—0.32	E	4
8.		$^2P^o$–^4P											
			15.987	0	6255100	4	6	2100	0.012	0.0025	—1.32	E	4
			16.278	85500	6229000	2	4	2800	0.022	0.0024	—1.36	E	4
			16.054	0	6229000	4	4	5400	0.021	0.0044	—1.08	E	4
			[16.315]	85500	6215000	2	2	65	2.6(—4)	2.8(—5)	—3.28	E	4
			16.090	0	6215000	4	2	3500	0.0067	0.0014	—1.57	E	4
9.		$^2P^o$–^2P											
			[15.98]	0	6258000	4	4	7.1(+4)	0.27	0.057	0.03	E	4
						2	2		0.10		—0.70	E	4
						4	2		0.048		—0.72	E	4
			16.20	85500	6258000	2	4	3.0(+4)	0.24	0.026	—0.32	E	4
10.		$^2P^o$–^2D	*15.978*	*28500*	*6287000*	6	10	1.3(+5)	0.82	0.26	0.69	E	4
			15.871	0	6300800	4	6	8.7(+4)	0.49	0.10	0.29	E	4
			[16.179]	85500	6266400	2	4	1.5(+5)	1.2	0.13	0.38	E	4
			15.958	0	6266400	4	4	4.2(+4)	0.16	0.034	—0.19	E	4
11.		$^2P^o$–^2F											
			15.926	0	6279000	4	6	530	0.0030	6.3(—4)	—1.92	E	4

Mn XVII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
12.	$2p^5$–$2p^4$(^{1}D)$3d$	^{2}P°–^{2}S	*15.803*	*28500*	6356500	6	2	1.4(+5)	0.18	0.056	0.032	E	4
			15.732	0	6356500	4	2	7.5(+4)	0.14	0.029	—0.25	E	4
			15.946	85500	6356500	2	2	6.8(+4)	0.26	0.027	—0.28	E	4
13.		^{2}P°–^{2}F											
						4	6		0.14		—0.25	E	4
14.		^{2}P°–^{2}P											
			[15.676]	0	6379200	4	4	5.2(+4)	0.19	0.039	—0.12	E	4
						2	2		0.32		—0.19	E	4
						4	2		0.11		—0.36	E	4
			15.889	85500	6379200	2	4	100	7.6(—4)	8.0(—5)	—2.82	E	4
15.		^{2}P°–^{2}D	*15.718*	*28500*	*6390600*	6	10	8.3(+4)	0.52	0.16	0.49	E	4
			15.670	0	6381600	4	6	1.4(+5)	0.79	0.16	0.50	E	4
			15.826	85500	6404100	2	4	590	0.0044	4.6(—4)	—2.06	E	4
			15.615	0	6404100	4	4	520	0.0019	3.9(—4)	—2.12	E	4
16.	$2p^5$–$2p^4$(^{1}S)$3d$	^{2}P°–^{2}D	*15.456*	*28500*	*6498300*	6	10	7.7(+4)	0.46	0.14	0.44	E	4
			15.404	0	6491800	4	6	8.8(+4)	0.47	0.095	0.27	E	4
			15.570	85500	6508100	2	4	5.6(+4)	0.41	0.042	—0.09	E	4
			[15.365]	0	6508100	4	4	4500	0.016	0.0032	—1.19	E	4

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XVIII

Ground State $1s^2 2s^2 2p^4\ ^3P_2$

Ionization Potential [1313] eV = [10590000] cm^{-1}

Allowed Transitions

The oscillator strengths for five multiplets of this oxygen-like ion are the results of Sinanoglu's many-electron theory [1]. The transition probabilities for lines of three other multiplets are from Safronova's Z-expansion calculation [2], which includes relativistic effects and agrees well with the more advanced many-electron theory of Sinanoglu for those cases where the data overlap.

References

[1] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).
[2] Safronova, U. I., J. Quant. Spectrosc. Radiat. Transfer **15**, 223 (1975).

Mn XVIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p^4$–$2s2p^5$	^{3}P–^{3}P°	*115.93*	*32060*	*894650*	9	9	380	0.076	0.26	—0.16	D	1
			115.33	0	867080	5	5	290	0.058	0.11	—0.54	D	*ls*
			118.2	73940	919960	3	3	90	0.019	0.022	—1.25	D	*ls*
			108.70	0	919960	5	3	190	0.020	0.036	—1.00	D	*ls*
			113.3	73940	956550	3	1	400	0.026	0.029	—1.11	D	*ls*
			126.0	73940	867080	3	5	73	0.029	0.036	—1.06	D	*ls*
			117.2	66720	919960	1	3	120	0.075	0.029	—1.12	D	*ls*
2.		^{3}P–^{1}P°											
			[84.0]			5	3	260	0.017	0.023	—1.08	D	2
			[89.0]			3	3	65	0.0077	0.0068	—1.64	D	2
3.		^{1}D–^{3}P°											
			[129]			5	3	47	0.0070	0.015	—1.45	D	2

Mn XVIII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
4.		^1D–$^1P^\circ$	96.22			5	3	1200	0.10	0.16	—0.30	D	1
5.		^1S–$^1P^\circ$	[111.93]?			1	3	76	0.043	0.016	—1.37	D	1
6.	$2s2p^5$–$2p^6$	$^1P^\circ$–^1S	[121]			3	1	1300	0.095	0.11	—0.55	D	1
7.		$^3P^\circ$–^1S	[91.6]			3	1	76	0.0032	0.0029	—2.02	D	1
8.	$2p^3(^4S^\circ)3s$–$2p^3(^4S^\circ)3p$	$^3S^\circ$–^3P				3	9		0.35		0.021	D	*interp.*
9.		$^5S^\circ$–^5P				5	15		0.18		—0.05	D	*interp.*

Mn XIX

Ground State $1s^2 2s^2 2p^3\ ^4S^\circ_{3/2}$

Ionization Potential [1431] eV = [11542000] cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
89.26	3	113.03	5	122	2	141.03	1
96.24	3	113.75	6	123.85	8	142.68	4
99.01	6	115	7	127.28	1	144	4
99.16	3	117.40	7	130.58	1	146.59	9
104.13	6	117.72	2	131.00	9	148.54	9
104.90	7	118.41	5	135.30	4	168.90	9
107.67	6	120.45	2	139.41	8		

Transition probabilities for lines of the first nine multiplets are the results of the many-body perturbation theory calculations by Safronova and Bolotin [1]. These results are in good agreement with extrapolations from lower charged ions, based mainly on the non-closed shell many-electron theory of Sinanoglu [2].

Oscillator strengths for the last five multiplets were obtained by graphical interpolation of systematic trends along the nitrogen isoelectronic sequence.

References

[1] Safronova, U. I., and Bolotin, A. B., Czech. J. Phys., Sect. B **26**, 945 (1976).

[2] Sinanoglu, O, Nucl. Instrum. Methods **110**, 193 (1973).

Mn XIX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p^3$–$2s2p^4$	$^4S^\circ$–^4P	*136.73*	0	*731380*	4	12	130	0.11	0.19	—0.37	C+	1
			141.03	0	690320	4	6	110	0.049	0.091	—0.71	C+	1
			130.58	0	765810	4	4	150	0.038	0.066	—0.81	C+	1
			127.28	0	785670	4	2	170	0.021	0.035	—1.08	C+	1
2.		$^2D^\circ$–^2D	*121*			10	10	290	0.063	0.25	—0.20	C	1
			120.45			6	6	270	0.059	0.14	—0.45	C+	1
			117.72			4	4	350	0.073	0.11	—0.54	C+	1
			[122]			6	4	1.2	1.8(—4)[a]	4.3(—4)	—2.97	D	1

Mn XIX: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
3.		$^2D°-^2P$	*97.6*			10	6	800	0.068	0.22	—0.16	C+	1
			99.16			6	4	870	0.085	0.17	—0.29	C+	1
			89.26			4	2	290	0.017	0.020	—1.16	C	1
			96.24			4	4	140	0.019	0.025	—1.11	C	1
4.		$^2P°-^2D$	*139*			6	10	47	0.023	0.062	—0.87	C	1
			142.68			4	6	54	0.025	0.046	—1.00	C+	1
			[135.30]			2	4	27	0.015	0.013	—1.53	C+	1
			[144]			4	4	4.6	0.0014	0.0027	—2.24	D	1
5.		$^2P°-^2S$	*114*			6	2	340	0.022	0.050	—0.88	C	1
			[118.41]?			4	2	34	0.0036	0.0056	—1.84	D	1
			113.03			2	2	310	0.059	0.044	—0.93	C+	1
6.		$^2P°-^2P$	*109*			6	6	340	0.060	0.13	—0.44	C+	1
			113.75			4	4	89	0.017	0.026	—1.16	C+	1
			99.01			2	2	38	0.0056	0.0036	—1.95	C+	1
			104.13			4	2	790	0.064	0.088	—0.59	C+	1
			107.67			2	4	71	0.025	0.017	—1.31	C+	1
7.	$2s2p^4-2p^5$	$^2D-^2P°$											
			[117.40]			6	4	370	0.051	0.12	—0.51	C+	1
			[104.90]			4	2	400	0.033	0.046	—0.88	C+	1
			[115]			4	4	130	0.026	0.039	—0.99	C+	1
8.		$^2S-^2P°$											
			[139.41]			2	4	77	0.045	0.041	—1.05	C+	1
			[123.85]			2	2	14	0.0032	0.0026	—2.19	D	1
9.		$^2P-^2P°$											
			[148.54]			4	4	270	0.089	0.17	—0.45	C+	1
			[146.59]			2	2	280	0.090	0.087	—0.74	C+	1
			[131.00]			4	2	180	0.023	0.040	—1.03	C+	1
			[168.90]			2	4	15	0.013	0.014	—1.59	C	1
10.	$2p^2(^3P)3s-2p^2(^3P)3p$	$^4P-^4D°$				12	20		0.14		0.23	E	*interp.*
11.		$^4P-^4P°$				12	12		0.10		0.08	E	*interp.*
12.		$^2P-^2D°$				6	10		0.15		—0.05	E	*interp.*
13.	$2p^2(^1D)3s-2p^2(^1D)3p$	$^2D-^2F°$				10	14		0.10		0.00	E	*interp.*
14.	$2p^2(^1D)3p-2p^2(^1D)3d$	$^2F°-^2G$				14	18		0.14		0.29	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XX

Ground State $1s^2 2s^2 2p^2\ ^3P_0$

Ionization Potential [1536] eV = [12389000] cm^{-1}

Allowed Transitions

The data have been obtained by the generation and analysis of systematic trends along the carbon isoelectronic sequence and the subsequent determination of interpolated oscillator strengths. For many transitions our final recommended data agree well with the interpolated values given by Smith and Wiese [1]. However, in some cases

the dependence of the oscillator strength on the inverse nuclear charge, $1/Z$, has been reinterpreted as a result of the availability of new f-value data (or, in some cases, of wavelength data which enabled us to convert previously published line strengths to oscillator strengths).

To single out some of the principal contributing sources, the nuclear charge expansion method has been used by Safronova [2], Laughlin and Dalgarno [3], and Cohen and Dalgarno [4] to calculate line strengths for the entire isoelectronic sequence, so that f-values could be derived whenever wavelength data existed. In addition, the extrapolated values given by Sinanoglu [5] for the higher ions of the sequence, which were based on data calculated according to his many-electron theory for the lower ions, were helpful in establishing some systematic trends, as were the self-consistent field (SCF) calculations in intermediate coupling by Fawcett et al. [6] for Fe XXI.

It should be noted that uncertainties in the interpolated data are expected to be fairly large, mainly since relativistic effects should become significant at about this point and have either not at all, or only roughly, been accounted for in the existing calculated data.

References

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Mn XX: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^22p^2$–$2s2p^3$	^3P–$^3D^\circ$				9	15		0.044		—0.40	C	*interp.*
2.		^3P–$^3P^\circ$				9	9		0.044		—0.40	C	*interp.*
3.		^3P–$^3S^\circ$	*105.1*	*74600*	*1026000*	9	3	920	0.051	0.16	—0.34	C	*interp.*
			107.88	98500	1026000	5	3	480	0.050	0.089	—0.60	C—	*ls*
			103.53	59600	1026000	3	3	320	0.052	0.053	—0.81	C—	*ls*
			97.51	0	1026000	1	3	130	0.056	0.018	—1.25	C—	*ls*
4.		^1D–$^1D^\circ$	119.54			5	5	270	0.058	0.11	—0.54	C	*interp.*
5.		^1D–$^1P^\circ$	104.1			5	3	610	0.059	0.10	—0.53	C	*interp.*
6.		^1S–$^1P^\circ$				1	3		0.11		—0.96	C	*interp.*
7.	$2p^2$–$2p3s$	^3P–$^3P^\circ$				9	9		0.044		—0.40	C	*interp.*
8.		^1D–$^1P^\circ$				5	3		0.040		—0.70	C	*interp.*
9.		^1S–$^1P^\circ$				1	3		0.043		—1.37	C	*interp.*
10.	$2p^2$–$2p3d$	^1D–$^1F^\circ$	13.46?			5	7	2.5(+5)[a]	0.95	0.21	0.68	C	*interp.*
11.		^1S–$^1P^\circ$				1	3		1.23		0.090	C	*interp.*
12.	$2p^2$–$2p4s$	^3P–$^3P^\circ$				9	9		0.010		—1.05	D	*interp.*
13.	$2s2p^3$–$2p^4$	$^3D^\circ$–^3P				15	9		0.050		—0.12	D—	*interp.*
14.		$^3P^\circ$–^3P				9	9		0.031		—0.55	D	*interp.*
15.	$2p3s$–$2p3p$	$^3P^\circ$–^3D				9	15		0.093		—0.08	D	*interp.*
16.		$^3P^\circ$–^3S				9	3		0.021		—0.72	D	*interp.*
17.		$^3P^\circ$–^3P				9	9		0.075		—0.17	D	*interp.*
18.		$^1P^\circ$–^1P				3	3		0.052		—0.81	D	*interp.*
19.		$^1P^\circ$–^1D				3	5		0.15		—0.35	D	*interp.*
20.	$2p3p$–$2p3d$	^1P–$^1D^\circ$				3	5		0.097		—0.54	D	*interp.*
21.		^1P–$^1P^\circ$				3	3		0.032		—1.02	D	*interp.*
22.		^3D–$^3P^\circ$				15	9		0.0016		—1.62	D	*interp.*
23.		^3D–$^3F^\circ$				15	21		0.037		—0.26	D—	*interp.*
24.		^3D–$^3D^\circ$				15	15		0.035		—0.28	D	*interp.*

Mn XX: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
25.		^{3}S–^{3}P°				3	9		0.080		—0.62	D	*interp.*
26.		^{3}P–^{3}D°				9	15		0.053		—0.32	D	*interp.*
27.		^{3}P–^{3}P°				9	9		0.037		—0.48	D	*interp.*
28.		^{1}D–^{1}D°				5	5		0.0031		—1.81	D	*interp.*
29.		^{1}D–^{1}F°				5	7		0.11		—0.26	D	*interp.*
30.		^{1}D–^{1}P°				5	3		6.1(—4)		—2.52	D	*interp.*
31.		^{1}S–^{1}P°				1	3		0.070		—1.15	D	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XXI

Ground State $1s^2 2s^2 2p\ ^2P^\circ_{1/2}$

Ionization Potential [1640] eV = [13228000] cm^{-1}

Allowed Transitions

Oscillator strengths for lines corresponding to the first three multiplets were obtained by Sinanoglu and Luken [1], who use a simple extrapolation procedure and only approximately account for the major relativistic effects.

The remainder of the data were derived by interpolation from graphs of systematic trends along the boron isoelectronic sequence. Although in most cases these trends are fairly well established for low Z, Mn XXI lies at a point in the sequence where significant relativistic changes on line strengths and energy levels are expected to occur. Mainly for this reason, it is estimated that the values presented are uncertain within a factor of two.

Reference

[1] Sinanoglu, O., and Luken, W., J. Chem. Phys. **64**, 4197 (1976).

Mn XXI: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2 2p$–$2s2p$	^{2}P°–^{2}D											
						4	6		0.036		—0.84	E	1
						2	4		0.060		—0.92	E	1
						4	4		3.1(—4)[a]		—2.91	E	1
2.		^{2}P°–^{2}S											
						4	2		3.4(—4)		—2.87	E	1
						2	2		0.081		—0.79	E	1
3.		^{2}P°–^{2}P											
						2	2		0.012		—1.62	E	1
						4	2		0.039		—0.81	E	1
4.	$2s2p^2$–$2p^3$	^{4}P–^{4}S°				12	4		0.040		—0.32	E	*interp.*
5.		^{2}D–^{2}D°				10	10		0.046		—0.34	E	*interp.*
6.		^{2}D–^{2}P°				10	6		0.028		—0.55	E	*interp.*
7.		^{2}P–^{2}D°				6	10		0.048		—0.54	E	*interp.*
8.		^{2}P–^{2}P°				6	6		0.055		—0.48	E	*interp.*
9.	$2p$–$3s$	^{2}P°–^{2}S				6	2		0.020		—0.92	E	*interp.*

Mn XXI: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
10.	$2p$–$3d$	$^2P°$–^2D				6	10		0.66		0.60	E	*interp.*
11.	$3s$–$3p$	^2S–$^2P°$				2	6		0.15		—0.52	E	*interp.*
12.	$3p$–$3d$	$^2P°$–^2D				6	10		0.050		—0.52	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XXII

Ground State $1s^2 2s^2\ ^1S_0$

Ionization Potential [1780] eV = [14357000] cm^{-1}

Allowed Transitions

Oscillator strengths were derived by interpolation from graphs of systematic trends along the Be isoelectronic sequence.

The data marked "E" are estimated to be accurate within a factor of two.

Mn XXII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s^2$–$2s2p$	^1S–$^1P°$	[141.09]	0	[708770]	1	3	170	0.15	0.070	—0.82	C	*interp.*
2.	$2s^2$–$2s3p$	^1S–$^1P°$	[12.010]	0	[8326400]	1	3	9.7(+4)[a]	0.63	0.025	—0.20	C	*interp.*
3.	$2s^2$–$2s4p$	^1S–$^1P°$				1	3		0.16		—0.80	E	*interp.*
4.	$2s2p$–$2p^2$	$^3P°$–^3P				9	9		0.060		—0.27	D	*interp.*
5.		$^1P°$–^1D				3	5		0.070		—0.68	D	*interp.*
6.		$^1P°$–^1S				3	1		0.038		—0.94	D	*interp.*
7.	$2s2p$–$2s3s$	$^3P°$–^3S				9	3		0.030		—0.57	E	*interp.*
8.		$^1P°$–^1S				3	1		0.0050		—1.82	E	*interp.*
9.	$2s2p$–$2s3d$	$^3P°$–^3D				9	15		0.75		0.83	D	*interp.*
10.		$^1P°$–^1D	[12.8]	[708770]	[8515000]	3	5	1.3(+5)	0.54	0.068	0.21	D	*interp.*
11.	$2s3s$–$2s3p$	^3S–$^3P°$				3	9		0.18		—0.27	E	*interp.*
12.		^1S–$^1P°$				1	3		0.055		—1.26	E	*interp.*
13.	$2s3p$–$2s3d$	$^1P°$–^1D				3	5		0.050		—0.82	E	*interp.*
14.		$^3P°$–^3D				9	15		0.030		—0.57	E	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XXIII

Ground State $1s^2 2s\ ^2S_{1/2}$

Ionization Potential [1880.6] eV = [15168300] cm^{-1}

Allowed Transitions

The data are taken from the theoretical analysis of Martin and Wiese [1], which was based on a generalized study of systematic trends for several spectral series of the lithium isoelectronic sequence. For the $3d$–$4f$ transition, the f-value was taken from an earlier study of systematic trends along isoelectronic sequences by Smith and Wiese [2].

Results of the relativistic calculations of Kim and Desclaux [3] were incorporated into the data for the $2s$–$2p$ and $2s$–$3p$ transitions. More recently, Armstrong et al. [4] have reported results of relativistic calculations of f-values for the $2s$–$2p$, $2s$–$3p$, and $2p$–$3d$ transitions which agree well with the final recommended data of ref. [1]. For all other transitions, no relativistic calculations were available. However, the relativistic calculations of Younger and Weiss [5] for the hydrogen isoelectronic sequence provide a means of assessing the magnitude of relativistic corrections since the Li sequence is very similar in structure to the H sequence. For those transitions for which relativistic effects were estimated to be significant (specifically, whenever the ratio of the weighted relativistic hydrogenic f-values $g_i f_{ik}$ of any two lines within a multiplet was found to deviate from the corresponding LS-coupling line strength ratio by more than 5% for the appropriate value of the nuclear charge Z), the f-values were excluded from the compilation. A more detailed discussion of this comparison is given in ref. [1].

References

[1] Martin, G. A., and Wiese, W. L., J. Phys. Chem. Ref. Data **5**, 537 (1976).

[2] Smith, M. W., and Wiese, W. L., Astrophys. J. Suppl. Ser. **23**, No. 196, 103 (1971).

[3] Kim, Y. K., and Desclaux, J. P., private communication (1975).

[4] Armstrong, L., Jr., Fielder, W. R., and Lin, D. L., Phys. Rev. A **14**, 1114 (1976).

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Mn XXIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$2s$–$2p$	^2S–$^2P^o$	*223.65*	0	*447120*	2	6	30	0.067	0.099	—0.87	B	1
			206.90	0	483330	2	4	37	0.048	0.065	—1.02	B	1
			266.88	0	374700	2	2	18	0.019	0.033	—1.42	B	1
2.	$2s$–$3p$	^2S–$^2P^o$	*11.57*	0	[*8646000*]	2	6	6.21(+4)[a]	0.374	0.0285	—0.126	B+	1
			[11.55]	0	[8658000]	2	4	6.15(+4)	0.246	0.0187	—0.308	B+	1
			[11.60]	0	[8621000]	2	2	6.35(+4)	0.128	0.00978	—0.592	B+	1
3.	$2s$–$4p$	^2S–$^2P^o$	[8.68]	0	[11500000]	2	6	3.0(+4)	0.10	0.0057	—0.70	C+	1
4.	$2s$–$5p$	^2S–$^2P^o$	[7.79]	0	[12800000]	2	6	1.5(+4)	0.040	0.0021	—1.10	C+	1
5.	$2s$–$6p$	^2S–$^2P^o$				2	6		0.0212		—1.373	C+	1
6.	$2s$–$7p$	^2S–$^2P^o$				2	6		0.0125		—1.602	C+	1
7.	$2p$–$3d$	$^2P^o$–^2D	*12.12*	*447120*	[*8700000*]	6	10	1.9(+5)	0.68	0.16	0.61	B	1
			12.158	483330	**8708400**	4	6	1.8(+5)	0.60	0.096	0.38	B	*ls*
			[12.03]	374700	[8687000]	2	4	1.5(+5)	0.67	0.053	0.13	B	*ls*
			[12.18]	483330	[8687000]	4	4	3.1(+4)	0.069	0.011	—0.56	C+	*ls*
8.	$2p$–$4d$	$^2P^o$–^2D				6	10		0.12		—0.14	B	1
9.	$2p$–$5d$	$^2P^o$–^2D				6	10		0.0450		—0.569	C+	1
10.	$2p$–$6d$	$^2P^o$–^2D				6	10		0.0220		—0.879	C+	1
11.	$2p$–$7d$	$^2P^o$–^2D				6	10		0.0126		—1.121	C+	1
12.	$3s$–$4p$	^2S–$^2P^o$				2	6		0.44		—0.06	C	1
13.	$3s$–$5p$	^2S–$^2P^o$				2	6		0.108		—0.67	C	1
14.	$3s$–$6p$	^2S–$^2P^o$				2	6		0.047		—1.03	C	1

Mn XXIII: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
15.	3s–7p	^{2}S–^{2}P°				2	6		0.0249		—1.303	C	1
16.	3p–4d	^{2}P°–^{2}D				6	10		0.59		0.55	B	1
17.	3p–5d	^{2}P°–^{2}D				6	10		0.138		—0.082	C+	1
18.	3p–6d	^{2}P°–^{2}D				6	10		0.0558		—0.475	C+	1
19.	3p–7d	^{2}P°–^{2}D				6	10		0.0289		—0.761	C+	1
20.	3d–4f	^{2}D–^{2}F°				10	14		1.00		1.000	B	2
21.	4s–5p	^{2}S–^{2}P°				2	6		0.475		—0.022	C	1
22.	4s–6p	^{2}S–^{2}P°				2	6		0.128		—0.59	C	1
23.	4s–7p	^{2}S–^{2}P°				2	6		0.056		—0.95	C	1
24.	4p–5d	^{2}P°–^{2}D				6	10		0.584		0.545	C+	1
25.	4p–6d	^{2}P°–^{2}D				6	10		0.142		—0.070	C+	1
26.	4p–7d	^{2}P°–^{2}D				6	10		0.0616		—0.432	C+	1

[a] The number in parentheses following the tabulated value indicate s the power of ten by which this value has to be multiplied.

Mn XXIV

Ground State $1s^2\ ^1S_0$

Ionization Potential [8141] eV = [65663000] cm^{-1}

Allowed Transitions

For this high ion of the He isoelectronic sequence the data were mainly derived by interpolation from well established systematic trends for the lower ions.

Data used in the interpolation of oscillator strengths for the first eight transitions are taken from the relativistic random phase approximation calculation of Johnson and Lin [1]. Their results exhibit a dramatic drop in the oscillator strengths for $Z>18$, indicating significant relativistic effects on line strengths. The reduced accuracy of the intercombination lines reflects a sudden change in the systematic trend curve, making precise interpolation difficult. For other transitions, not involving the ground state, it is expected that relativistic effects play a much smaller role.

The Z-expansion calculation of Laughlin [2] has been used for four transitions, where it was found to be in good agreement with the accurate variational calculations of Schiff, Pekeris, and Accad [3] for lower Z.

The remaining multiplets were analyzed by extrapolating the variational calculations of Weiss [4] for $Z\leq 10$, which are expected to be quite accurate. Although these extrapolations do not include relativistic effects, they involve relatively highly excited states where such effects are small.

Data for transitions involving highly excited states not tabulated here may be found in the papers of Ali and Schaad [5] and Brown and Cortez [6].

References

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[3] Schiff, B., Pekeris, C. L., and Accad, Y., Phys. Rev. A **4**, 885 (1971).
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Mn XXIV: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} (10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$1s^2$–1s2p	^{1}S–^{3}P°											
			2.02	0	49500000	1	3	4.3(+5)[a]	0.078	5.2(—4)	—1.11	E	*interp.*
2.		^{1}S–^{1}P°	[2.01]	0	[49800000]	1	3	4.0(+6)	0.72	0.0048	—0.14	B	*interp.*

Mn XXIV: Allowed transitions—Continued

No.	Transition array	Multiplet	λ(Å)	E_i (cm^{-1})	E_k (cm^{-1})	g_i	g_k	A_{ki} ($10^8 s^{-1}$)	f_{ik}	S(at.u.)	log gf	Accuracy	Source
3.	$1s^2$–$1s3p$	^1S–$^3P^o$											
			1.72	0	58100000	1	3	1.1(+5)	0.015	8.5(—5)	—1.82	E	*interp.*
4.		^1S–$^1P^o$				1	3		0.14		—0.85	B	*interp.*
5.	$1s^2$–$1s4p$	^1S–$^3P^o$											
						1	3		0.0040		—2.40	E	*interp.*
6.		^1S–$^1P^o$				1	3		0.052		—1.28	B	*interp.*
7.	$1s^2$–$1s5p$	^1S–$^3P^o$											
						1	3		0.0028		—2.55	E	*interp.*
8.		^1S–$^1P^o$				1	3		0.025		—1.60	B	*interp.*
9.	$1s2s$–$1s2p$	^1S–$^1P^o$				1	3		0.016		—1.80	E	*interp.*
10.		^3S–$^3P^o$				3	9		0.029		—1.06	E	*interp.*
11.	$1s2s$–$1s3p$	^1S–$^1P^o$				1	3		0.42		—0.38	B	*interp.*
12.		^3S–$^3P^o$				3	9		0.40		0.08	B	*interp.*
13.	$1s2p$–$1s3s$	$^1P^o$–^1S				3	1		0.015		—1.35	C	2
14.		$^3P^o$–^3S				9	3		0.015		—0.87	C	2
15.	$1s2p$–$1s3d$	$^1P^o$–^1D				3	5		0.70		0.32	B	*interp.*
16.		$^3P^o$–^3D				9	15		0.69		0.79	B	*interp.*
17.	$1s3s$–$1s3p$	^1S–$^1P^o$				1	3		0.035		—1.46	C	2
18.		^3S–$^3P^o$				3	9		0.046		—0.86	C	2
19.	$1s3p$–$1s3d$	$^3P^o$–^3D				9	15		0.012		—0.97	C	*interp.*

[a] The number in parentheses following the tabulated value indicates the power of ten by which this value has to be multiplied.

Mn XXV

Ground State $1s\ ^2S_{1/2}$

Ionization Potential [8575.5] eV = [69166000] cm^{-1}

Allowed Transitions

The transition probability data for this hydrogen-like ion may be obtained by scaling the data available for the hydrogen spectrum (see NSRDS-NBS 4 [1]) according to

$$f_{\text{Mn XXV}} = f_{\text{Hydrogen}},$$
$$A_{\text{Mn XXV}} = (25)^4 A_{\text{Hydrogen}},$$
$$S_{\text{Mn XXV}} = (25)^{-2} S_{\text{Hydrogen}}.$$

An uncertainty of a few percent arises from the neglect of relativistic effects. Recent theoretical studies [2, 3] indicate that relativistic effects on line strengths for this ion are generally in this range, with the relativistic value usually slightly below the non-relativistic one, although in certain transitions where n increases and l decreases the line strength increases. Younger and Weiss [3] have calculated exact Dirac relativistic hydrogenic line strengths for a number of transitions of interest along the hydrogen isoelectronic sequence.

References

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[2] Garstang, R. H., *Topics in Modern Physics (A Tribute to Edward U. Condon)*, 153–167, Ed. Brittin, W. E., and Odabasi, H., Colorado Associated Univ. Press, Boulder, Colorado (1971).

[3] Younger, S. M., and Weiss, A. W., J. Res. Nat. Bur. Stand., Sect. A **79**, 629 (1975).