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Atomic Transition Probabilities for Scandium and Titanium

(A Critical Data Compilation of Allowed Lines)

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Atomic transition probabilities for about 1500 allowed spectral lines of the elements scandium and titanium through all stages of ionization have been critically evaluated and compiled. All available literature sources have been utilized. 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 is 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; line strengths; oscillator strengths; scandium; titanium; transition probabilities.

Contents

1. Introductory Remarks

This compilation is another part of a continuing effort to critically evaluate and tabulate atomic transition probabilities available from the general literature. In these tables, we closely maintain the format of our previous compilations on the first twenty elements [1, 2][1] and on the forbidden lines of the iron group [3].

The literature sources are the bibliographies on atomic transition probabilities [4], which have been published in regular intervals by this NBS data center. In addition, the most recent literature until April 1974 has been utilized for this compilation. As before, we have aimed

[1] Numbers in brackets indicate the literature references.

at presenting data for at least the more prominent lines of each spectrum, even if these data are of low accuracy. Furthermore, we have presented data for weaker multiplets if their accuracy is estimated to be better than 50 percent.

For some highly ionized spectra, atomic transition probabilities,[2] but no wavelength or energy level data, are available. In such cases, we list the f-values of strong, prominent lines if they are estimated to be fairly accurate, and we have identified these transitions by quantum numbers and multiplet notations. However, if such line strength data are available only for weaker lines, we quote the relevant literature reference rather than tabulating all this material.

During our first survey of the scandium and titanium spectra three years ago, we found many gaps in the data base as well as many rather unreliable data. Several research groups, especially the Plasma Spectroscopy Section at NBS, then mounted a concerted effort to eliminate these gaps. This recent work has indeed substantially improved and enlarged the body of data, so that at this point we would like to express our special thanks to Drs. Sørensen and Andersen [5] of the beam-foil spectroscopy group at Aarhus, Denmark, as well as Drs. J. R. Roberts and P. A. Voigt [6] of NBS for their extensive work on the spectra of Ti I, II, and III. Dr. A. Czernichowski [6] of Wroclaw University, Poland, has also cooperated in this work. Further thanks are due to Dr. A. W. Weiss [7] of NBS for his many superposition of configurations (SOC) calculations including intermediate coupling on Sc I, II, and III. Furthermore, we could make extensive use of the venerable Coulomb approximation [8] for the potassium-like ions Sc III and Ti IV, and could apply the recently found regularities of f-values along isolectronic sequences for many highly ionized spectra [9, 10]. Thanks to these new efforts and available methods, and the timely recent work of Sinanoglu and coworkers [11, 12], the f-value data situation for most stages of ionization in scandium and titanium is now quite encouraging. We have thus been able to compile a substantial amount of data, of which the large majority is estimated to be accurate within 50 percent, with some material of even significantly better quality.

However, one should not as yet conclude that the transition probability situation for these two elements is satisfactory. Needs for further improvement are quite evident. For example, for Ti II substantial discrepancies between the stabilized arc results and atomic lifetime work remain unresolved. Similar discrepancies, of the order of a factor of two, exist for Sc I between recent calculations and lifetime experiments. Furthermore, relativistic effects may cause significant uncertainties, but have remained largely unexplored. Thus, the multiplet component intensities, which had to be listed here mostly in LS-coupling, need to be checked and probably in many cases replaced by intermediate coupling data because of significant spin-orbit interaction. Also, other relativistic effects, such as orbital corrections, may become significant for very high stages of ionization, and need to be investigated.

[2] Or the equivalent quantities atomic oscillator strengths (f-values) or line strengths (S).

2. Method of Evaluation

The central tasks in a critical compilation are the critical evaluation of the accuracy of the data and, subsequently, the choice of the material.

This most crucial aspect of critical compilations has been covered in considerable detail in the general introductions to our previous tabulations, especially NSRDS–NBS 22 [2]. We shall discuss this problem briefly again and shall emphasize those criteria which are particularly relevant to the present compilation.

First, we want to state the principal factors which were applied to each paper containing original data, in order to judge its merit for this compilation. These factors are:

2.1. Our general evaluation of the applied methods.

2.2. The authors' consideration of the major critical factors that enter into the results.

2.3. The authors' estimate of their uncertainties.

2.4. The extent of the agreement between the authors' results and other reliable material.

2.5. The degree of fit of the data into established regularities and, if deviations exist, the reasons for this disagreement.

We shall now make some comments on each of these five points.

2.1. General Evaluation

The material of this compilation is based on rather few theoretical and experimental methods. Almost all papers are of a very recent nature, and the methods used have proved to be quite successful as demonstrated by many satisfactory intercomparisons. Most of the comparisons are available for lighter atoms of relatively simple structure, and some deterioration in the theoretical data may be expected for the more complex spectra of Sc and Ti in the low stages of ionization. We have, therefore, been conservative with our error estimates for such theoretical material. (A table which contains some interesting comparison data is presented in the introduction to Sc III.)

All experimental material is confined to neutral Sc and Ti and the first three stages of ionization. Most prominent among this material are data from emission experiments and lifetime determinations by the beam-foil technique. The emission experiments, performed with stabilized arcs, or, in one case, with a shock tube, provide the bulk of the data and are used by us strictly on a relative basis. Most authors have, in fact, produced these data on a relative scale only

and thus did not need to make the somewhat risky assumption of the existence of complete local thermodynamic equilibrium (LTE). The much less restrictive assumption of partial LTE (among the excited atomic states) is, however, still necessary. Various checks for the existence of partial LTE have been carried out by the experimental investigators, and in all cases it is confirmed within the experimental uncertainties. Other critical factors in the emission experiments are distortions of line intensities by self-absorption effects or spatial variations and inhomogeneities in the sources, which appear to have also been adequately taken into account in the papers that were selected. The uncertainties originate principally in the temperature and line intensity measurements and stay within 25 percent.

The normalization of these relative values to an absolute scale is accomplished with data from lifetime experiments. The lifetime data have been produced mostly with the beam-foil and Hanle-effect techniques. Both are very successful techniques, which have produced many accurate atomic lifetimes. However, the beam-foil technique suffers from cascading effects, which are difficult to detect unless they are fairly large, and are also difficult to correct. These effects tend to make the lifetimes too long and the derived transition probabilities too small. From comparisons with the best theoretical data and studies of systematic trends, uncertainties in the 10–30 percent range due to cascading are indicated.

A few of the experimental data have been obtained with other methods, such as the absorption method and anomalous dispersion technique. Details on the evaluation of these methods as well as further details on the critical factors of the above discussed methods are given in our earlier compilation, ref. [2]. Recent reviews of all the experimental methods for the determination of atomic transition probabilities may be found in several books, e.g. [13, 14].

Turning now to the theoretical side, it is most important to note that in practically all the recent treatments which have been selected the important role of configuration interaction effects is recognized. Thus, configuration interaction is taken into account in many different ways—from simplified treatments, limited to the one or two major interacting configurations, to very extensive treatments, including numerous interacting states. The most complete treatments are the various superposition-of-configuration calculations. Next to these most advanced calculations comes the nuclear charge expansion method. At its present level of refinement the configuration interaction treatment is confined to configurations within the same complex, i.e., to all possible combinations of electrons within the same set of principal quantum numbers. This method is expected to increase in accuracy for more highly ionized species (as long as relativistic effects remain small), where the atomic states regroup according to principal quantum numbers and where, therefore, interactions between states with different principal quantum numbers become small. Still lower in the order of configuration interaction treatments are semiempirical methods, where part of the configuration interaction should be included through the use of experimental energies. The Coulomb approximation by Bates and Damgaard [8] falls into this category. Since this method has proved to be very successful for simple spectra, we have made use of this approximation in cases where we estimated that configuration interaction effects would be of only minor importance and where we encountered simple spectra, as in alkali-like Sc III. However, in the analogous case of Ti IV, we expect some configuration interaction to come into play and have thus been quite conservative in our error estimates (see also the Ti IV introduction).

The theoretical methods for the calculation of atomic transition probabilities have recently been reviewed by Weiss [15] and Crossley [16], and some additional comments may be found in ref. [2].

For all spectra of Sc and Ti, especially for the very high stages of ionization, relativistic effects should become noticeable. Unfortunately, these have normally not been considered in the theoretical work. Relativistic effects should be felt mainly in two ways: (a) by configurational changes due to increased spin-orbit interaction, i.e., intermediate coupling, and (b) by orbital changes, mainly contraction, due to the variation of electron mass with velocity.

(a) For this general tabulation, the presentation of individual line strengths is very important since individual lines are the features seen in experimental applications. At present, individual line strengths are available for only a few spectra of Sc and Ti from measurements or suitable calculations, and thus for all other cases we had to take recourse to tabulated "*LS*-coupling" line strengths to obtain the line data. We are aware that this procedure is questionable for Sc and Ti since it assumes that spin-orbit interaction is very small compared to electrostatic interactions, which is not the case. Many indications of significant spin-orbit interactions are observed in the Sc and Ti spectra, such as deviations of multiplet splittings from the Landé interval rule and substantial energy splittings between components of "*LS*-multiplets," which are largest for the highest stages of ionization. A fair idea of the uncertainties due to the application of *LS*-line strengths may be obtained from comparisons between these *LS*-data with the above mentioned data from experiments and intermediate coupling calculations. Some representative comparisons are listed in table 1 and show that deviations from *LS*-coupling strengths appear to be much more severe for highly ionized spectra than for the lower stages of ionization. Also, deviations from *LS*-coupling are smallest for the strongest lines in a multiplet, while weak lines are much more affected. Thus, we have tried to account for these uncertainties in the individual line data by lowering the accuracy ratings for the lines compared to the multiplet values

TABLE 1. Comparisons of relative line strengths within multiplets. A selection of the rather few line strength data for Ti and Sc, which are available from experiments for Ti I, or intermediate coupling calculations, for Sc II and Sc XIII, is compared with *LS*-coupling data. The data are normalized by setting the strongest *LS*-coupled line equal to unity in each multiplet.

Ti I

Transition [a]	Multiplet (No.)	Line [b] (*J*-values)	Line strength	
			Experiment [c]	*LS*-coupling
$3d^24s^2-3d^24s4p$	$a\ ^3F-z\ ^3F^\circ$ (4)	4–4	1.00	1.00
		3–3	0.83	0.70
		2–2	0.86	0.53
		4–3	0.020	0.067
		3–2	0.097	0.066
		3–4	0.10	0.067
		2–3	0.10	0.066
	$a\ ^3P-y\ ^3D^\circ$ (72)	2–3	1.00	1.00
		1–2	0.54	0.54
		0–1	0.19	0.24
		2–2	0.094	0.18
		1–1	0.15	0.18
	$a\ ^3P-z\ ^3S^\circ$ (69)	2–1	1.00	1.00
		1–1	0.82	0.60
		0–1	0.38	0.20
$3d^34s-3d^34p$	$a\ ^5F-y\ ^5F^\circ$ (42)	5–5	1.00	1.00
		4–4	0.68	0.64
		3–3	0.38	0.40
		2–2	0.25	0.25
		1–1	0.18	0.20
		5–4	0.12	0.11
		4–3	0.19	0.16
		3–2	0.15	0.15
		2–1	0.098	0.014
		4–5	0.12	0.11
		3–4	0.15	0.16
		2–3	0.17	0.15
		1–2	0.10	0.014
	$a\ ^5P-w\ ^5D^\circ$ (145)	3–4	1.00	1.00
		2–3	0.58	0.52
		1–2	0.25	0.19
		2–1	0.12	0.083
		1–0	0.14	0.11
$3d^24s^2-3d^34p$	$a\ ^3F-x\ ^3D^\circ$ (18)	4–3	1.00	1.00
		3–2	1.00	0.69
		2–1	0.96	0.47
		3–3	0.73	0.087
		2–2	0.57	0.087
		2–3	0.27	0.0024
	$a\ ^3F-y\ ^3G^\circ$ (19)	4–5	1.00	1.00
		3–4	0.87	0.77
		2–3	0.80	0.58
		4–4	0.093	0.051
		3–3	0.093	0.051
		4–3	0.014	0.00078

TABLE 1. Comparisons of relative line strengths within multiplets. A selection of the rather few line strength data for Ti and Sc, which are available from experiments for Ti I, or intermediate coupling calculations, for Sc II and Sc XIII, is compared with *LS*-coupling data. The data are normalized by setting the strongest *LS*-coupled line equal to unity in each multiplet – Continued

Transition [a]	Multiplet (No.)	Line [b] (*J*-values)	Line strength	
			Intermediate coupling [c]	*LS*-coupling
		Sc II		
$3d4s$–$3d4p$	$a\,^3D$–$z\,^3F^\circ$ (2)	3–4	1.00	1.00
		2–3	0.66	0.69
		1–2	0.45	0.47
		3–3	0.061	0.087
		2–2	0.076	0.087
		3–2	0.0016	0.0024
	$a\,^3D$–$z\,^3D^\circ$ (3)	3–3	1.00	1.00
		2–2	0.56	0.56
		1–1	0.35	0.36
		3–2	0.13	0.13
		2–1	0.12	0.12
		2–3	0.16	0.13
		1–2	0.13	0.12
	$a\,^3D$–$z\,^3P^\circ$ (4)	3–2	1.00	1.00
		2–1	0.52	0.54
		1–0	0.24	0.24
		2–2	0.17	0.18
		1–1	0.17	0.18
		1–2	0.011	0.012
$3d^2$–$3d4p$	$a\,^3P$–$z\,^3D^\circ$ (28)	2–3	1.00	1.00
		1–2	0.59	0.54
		0–1	0.25	0.24
		2–2	0.14	0.18
		1–1	0.16	0.18
		2–1	0.0082	0.012
	$a\,^3P$–$z\,^3P^\circ$ (29)	2–2	1.00	1.00
		1–1	0.20	0.20
		2–1	0.31	0.33
		1–0	0.26	0.27
		1–2	0.31	0.33
		0–1	0.24	0.27
		Sc XIII		
$2s^22p^5$–$2s^22p^4(^3P)3s$	$^2P^\circ$–^2P	3/2–3/2	1.00	1.00
		1/2–1/2	25	0.40
		3/2–1/2	31	0.20
		1/2–3/2	6.0	0.20
$2s^22p^5$–$2s^22p^4(^1D)3s$	$^2P^\circ$–^2D	3/2–5/2	1.00	1.00
		1/2–3/2	610	0.56
		3/2–3/2	65	0.11
$2s^22p^5$–$2s^22p^4(^1S)3s$	$^2P^\circ$–^2S	3/2–1/2	1.00	1.00
		1/2–1/2	0.77	0.50
$2s^22p^5$–$2s^22p^4(^1D)3d$	$^2P^\circ$–^2P	3/2–3/2	1.00	1.00
		1/2–1/2	19	0.40
		3/2–1/2	2.8	0.20
		1/2–3/2	4.4	0.20

[a] Upper and lower states are usually composed of several *LS*-terms, of which only the principal one is listed.

[b] *J* is the total angular momentum quantum number.

[c] As listed in the tables for this spectrum.

and by lowering the ratings for the weak lines in each multiplet substantially more than the stronger ones.

At this point, we should note that the listed multiplet values (insofar as they are of acceptable accuracy) should be a good starting point for normalizing any future individual line strength data should they become available either from experiments or intermediate coupling calculations.

(b) Another relativistic effect may become noticeable for transitions of the most tightly bound electrons in the highly ionized Sc and Ti spectra. This is due to the relativistic electron speeds and the accompanying increase in mass, which is usually manifested by a shrinkage of the atomic orbitals compared to the nonrelativistic case. Only a few studies [7, 17, 18] of this effect have been made, and they suggest that it is very small for elements lighter than Fe ($Z=26$). Therefore, we do not expect this to cause more than a few percent changes for any of the listed data for Sc and Ti, but further quantitative studies of this effect are very desirable.

The material obtained from the various experiments and calculations may be complemented by data derived by interpolation from systematic trends of oscillator strengths within isoelectronic sequences. These trends have been discussed in detail by one of us (see, e.g. refs. [2, 9]). Such regularities also permit additional tests of the accuracy of f-value data by checking their consistency and fit with well-established systematic trends. One example of a systematic trend, showing the dependence of the f-value of the $2s^22p^2\ {}^3P-2s^22p3s\ {}^3P^\circ$ transition of the carbon sequence versus the inverse nuclear charge, is shown in figure 1. The positions of a few selected spectra are marked on the abscissa, including the Sc XVI and Ti XVII spectra of interest. We have taken most of the interpolated data from a compilation of graphs by Smith and Wiese [9], but have updated these systematic trends whenever we became aware of new input data.

2.2. Critical Factors

In the comments in section 2.1, we mentioned several critical factors that come up in the various methods. For example, in the discussion of the emission methods we noted the importance of experimental or theoretical checks on the existence of partial LTE, freedom of line intensities from self-absorption, and the condition of a good spatial definition of the source. These and other critical factors are listed in more detail in our earlier data compilation, NSRDS–NBS 22 [2], to which we hereby refer. Generally speaking, the authors seem to have adequately taken care of the critical factors. If an important factor was not taken into account by an author or not mentioned in his paper, we note this in the introduction of that spectrum.

2.3. Error Estimates

One must first note that the theoretical papers, which constitute the great majority of the data sources, contain no error estimates. This is the typical situation for theoretical work where no assessment of the uncertainties introduced by the various approximations is feasible. (However, recent work by Weinhold and coworkers [19, 20] and Sims and Whitten [21] on upper and lower bounds for calculated f-values constitutes a breakthrough on error estimates for theoretical papers. Applications of this scheme have so far been confined to lines of the helium and beryllium sequences.)

With respect to experimental papers, we have carefully looked at all the error estimates, and found often that the authors' statements are too brief to be very useful. Sometimes, only the statistical measurement uncertainties are considered, and no allowance for systematic errors is made.

2.4. Data Comparisons

Whenever possible we have made comparisons between different experiments or theories. In a few cases especially interesting comparisons exist, and we have then presented special tables, such as in the introductions to Sc III and Ti I.

2.5. Systematic Trends and Regularities

These have been very helpful to assess the accuracy of calculated data, especially for the highly ionized spectra. For example, we found that in some cases theoretical data did not fit into established regularities, which could be traced with a high likelihood to numerical errors in these calculations. An example is discussed in the introductions to Sc XVI and Ti XVII.

3. General Arrangement of the Tables

We have continued to use the same general arrangement which we adopted in our first volume [1]. However, for neutral Sc and Ti and the lowest stages of ionization, the columns for the spectroscopic notation were changed in order to follow the usual conventions. In these cases, we have abolished the transition array column, since this becomes much less meaningful with the numerous transition arrays involving various $3d$ electrons. But lower case letters (a, b, c, . . . x, y, z) before the multiplet notation easily permit the identification of the upper and lower levels involved, as found in the tables of "Atomic Energy Levels" by C. E. Moore [22]. In a few other special cases, we have adapted our notation to the special coupling situation encountered in those spectra. For example, jl-coupling is used in the neon-like spectra Sc XII and Ti XIII.

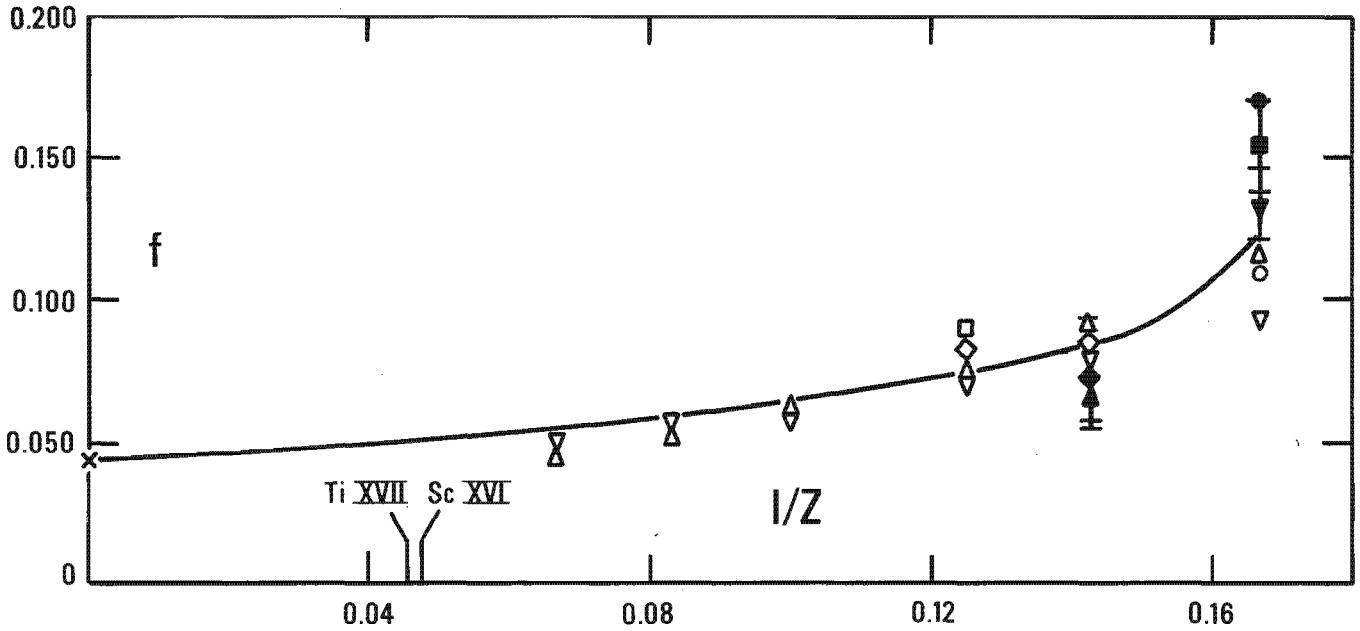

Figure 1. C-sequence: $2s^2 2p^2\ ^3P\text{-}2s^2 2p3s\ ^3P^\circ$ transition.

○ Weiss, A. W., Phys. Rev. 162, 71 (1967) (superposition of configurations calculations);

□ Nussbaumer, H., Astrophys. Lett. 4, 183 (1969) (scaled Thomas-Fermi potential with conf. int.);

△ Odabasi, H., JILA Report No. 97, AD680470 (1968) (self-consistent field-Slater calculations);

▽ Warner, B., and Kirkpatrick, R. C., Mon. Not. R. Astron. Soc. 142, 265 (1969) (calculations with a scaled Thomas-Fermi potential);

◇ Kelly, P. S., Astrophys. J. 140, 1247 (1964) (self-consistent field calculations);

✕ Weiss, A. W., private communication (1970) (superposition of configurations calculations);

● Boldt, G., Z. Naturforsch. A 18, 1107 (1963) (emission measurements);

■ Bromander, J., Buchta, R., and Lundin, L., Phys. Lett. A 29, 523 (1969) (beam-foil lifetimes);

▼ Lawrence, G. M., and Savage, B. D., Phys. Rev. 141, 67 (1966) (phase-shift lifetimes);

▲ Heroux, L., Phys. Rev. 153, 156 (1967) (beam-foil lifetimes);

◆ Hesser, J. E., and Lutz, B. L., J. Opt. Soc. Am. 58, 1513 (1968) (phase-shift lifetimes).

The wavelength and energy level data have been taken—whenever available—from the tables by C. E. Moore [22, 23, 24], and R. L. Kelly and L. J. Palumbo [25]. But these compilations contain little material for the higher ions. We, therefore, had to find these energy level and wavelength data from the recent original literature, a task which proved to be difficult and time consuming. We have mainly obtained the data through the recent bibliographies on atomic energy levels and spectra [26, 27], and Dr. L. Hagan of the NBS Data Center on Atomic Energy Levels has assisted us on numerous occasions, for which we would like to express our appreciation. The literature sources used for this new material are compiled in table 2. For several very highly ionized spectra, we have not been successful in finding either wavelength data or energy levels, while atomic oscillator strengths could be derived by interpolation from systematic trends along isoelectronic sequences.

A number of the energy level data are from calculations and are not expected to be nearly as accurate as those derived from experimental term analysis. These data are given in square brackets to distinguish them from the more accurate experimental material. The same notation has been applied when wavelengths are calculated from energy level differences rather than derived from observations.

TABLE 2. Special source material for wavelength and energy level data (references for energy levels are marked EL; those for wavelengths are marked λ).

Spectrum	Reference	Spectrum	Reference
Sc II	28 (EL)	Ti III	43 (EL)
Sc III	29 (EL)	Ti V	32 (EL)
	29, 30 (λ)	Ti VIII	33 (EL)
Sc IV	31 (EL, λ)	Ti X	33 (EL)
Sc VII	33 (EL)	Ti XI	39 (EL, λ)
Sc IX	33 (EL)	Ti XIII	40 (EL)
Sc X	31 (EL, λ)	Ti XIV	34 (EL)
Sc XII	40 (EL)	Ti XV	36 (EL)
Sc XIII	34, 35 (EL, λ)	Ti XVII	38 (EL)
Sc XIV	36 (EL)	Ti XIX	42 (EL, λ)
Sc XV	37 (λ)	Ti XX	41 (EL)
Sc XVI	38 (EL)		
Sc XIX	41 (EL)		

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,
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.

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. We have also included there for convenience the relations between line and multiplet values for the case of *LS*-coupling. In table 3, we provide a table of conversion factors, which we have used to convert from transition probabilities to oscillator strengths and line strengths and vice versa.

TABLE 3. 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	$\frac{6.670_2\times10^{15}}{\lambda^2}\frac{g_i}{g_k}$	$\frac{2.026_1\times10^{18}}{g_k\lambda^3}$
f_{ik}	$1.4992\times10^{-16}\lambda^2\frac{g_k}{g_i}$	1	$\frac{303.7_5}{g_i\lambda}$
S	$4.935_6\times10^{-19}g_k\lambda^3$	$3.292_1\times10^{-3}g_i\lambda$	1

The line strength is given in atomic units, which are $a_0^2e^2 = 7.187_3\times10^{-59}m^2C^2$ for electric dipole transitions. The transition probability is in units s^{-1}, and the f-value is dimensionless. The wavelength λ is given in Angstrom 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 National Academy of Sciences adopted by the National Bureau of Standards (NBS Handbook 102(1967)). There has been a recent revision of the values of these constants (J. Phys. Chem. Ref. Data **2**, 663 (1973)). These slightly revised constants, however, do not change the values of our tabulated data.

4. Key to Abbreviations and Symbols Used in the Tables[3]

1. Symbols for indication of accuracy:

A . . . . uncertainties within 3 percent,
B . . . . uncertainties within 10 percent,
C . . . . uncertainties within 25 percent,
D . . . . uncertainties within 50 percent,
E . . . . uncertainties larger than 50 percent.

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

ls = *LS*-coupling
ca = Coulomb approximation
n = normalized to a scale different from the author

[3] 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}.

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

Number in parenthesis under multiplet notation refers to running number of ref. [23] (Revised Multiplet Table). If letters "uv" are added, we refer to running number of ref. [24] (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.

Useful Relations

(A) Statistical Weights:

The statistical weights are related to the inner quantum number J_L (in one-electron spectra j) of a level (initial and final states of a *line*) by

$$g_L = 2J_L + 1,$$

and to the quantum numbers of a term (initial and final states 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:

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

$$\text{or } S(\text{Multiplet}) = \sum S(\text{line})$$

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

2. Absorption oscillator strength:

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

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 probabilities

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

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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5. 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] Wiese, W. L., Smith, M. W., and Miles, B. M., *Atomic Transition Probabilities—Sodium through Calcium (A Critical Data Compilation)*, Vol. II, 306 pp., Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 22 (Oct. 1969).

[3] Smith, M. W., and Wiese, W. L., J. Phys. Chem. Ref. Data **2**, 85 (1973).

[4] Miles, B. M., and Wiese, W. L., *Bibliography on Atomic Transition Probabilities (January 1916 through June 1969)*, 111 pp., Nat. Bur. Stand. (U.S.), Spec. Publ. 320 (Feb. 1970); Fuhr, J. R., and Wiese, W. L., *Bibliography on Atomic Transition Probabilities (July 1969 through June 1971)*, 67 pp., Nat. Bur. Stand. (U.S.), Spec. Publ. 320, Suppl. 1 (Sept. 1971); Fuhr, J. R., and Wiese, W. L., *Bibliography on Atomic Transition Probabilities (July 1971 through June 1973)*, 63 pp., Nat. Bur. Stand. (U.S.), Spec. Publ. 320, Suppl. 2 (Nov. 1973).

[5] Sørensen, G., and Andersen, T., private communication (1973); Roberts, J. R., Andersen, T., and Sørensen, G., Astrophys. J. **181**, 567 (1973).

[6] Roberts, J. R., Voigt, P. A., and Czernichowski, A., to be published (1974).

[7] Weiss, A. W., private communication.

[8] Bates, D. R., and Damgaard, A., Philos. Trans. R. Soc. Lond. A **242**, 101 (1949).

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

[10] Martin, G. A., and Wiese, W. L., to be published (1975).

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

[12] Nicolaides, C. A., and Sinanoglu, O., private communication (1973).

[13] Wiese, W. L., *Methods of Experimental Physics*, Vol. 7, Part A, Ch. 2.1, pp. 117–141, Eds., Bederson, B., and Fite, W. L., Academic Press, New York (1968).

[14] Huber, M. C. E., *Modern Optical Methods in Gas Dynamic Research*, pp. 85–112, Ed., Dosanjh, D. S., Plenum Press, New York (1971).

[15] Weiss, A. W., Nucl. Instrum. Methods **90**, 121 (1970); *Advances in Atomic and Molecular Physics*, Vol. 9, pp. 1–46, Ed., Bates D. R., and Estermann, I., Academic Press, New York (1973).

[16] Crossley, R. J. S., *Advances in Atomic and Molecular Physics*, Vol. 5, pp. 237–296, Academic Press Inc., New York (1969).

[17] Sinanoglu, O., and Luken, W., Chem. Phys. Lett. **20**, 407 (1973).

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

[19] Weinhold, F., J. Chem. Phys. **54**, 1874 (1971).
[20] Anderson, M. T., and Weinhold, F., Phys. Rev. A **9**, 118 (1974).
[21] Sims, J. S., and Whitten, R. C., Phys. Rev. A **8**, 2220 (1973).
[22] Moore, C. E., *Atomic Energy Levels* (As *Derived from the Analyses of Optical Spectra*), Vol. I, Nat. Bur. Stand. (U.S.), Circ. 467, (June 1949).
[23] Moore, C. E., *A Multiplet Table of Astrophysical Interest, Revised Edition*, 253 pp., Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 40 (Feb. 1972).
[24] Moore, C. E., *An Ultraviolet Multiplet Table*, Sect. 1, Nat. Bur. Stand. (U.S.), Circ. 488 (Apr. 1950).
[25] Kelly, R. L., and Palumbo, L. J., *Atomic and Ionic Emission Lines Below 2000 Angstroms—Hydrogen through Krypton*, Naval Research Laboratory Report 7599 (June 1973).
[26] Moore, C. E., *Bibliography on the Analyses of Optical Atomic Spectra*, Sect. 1, Nat. Bur. Stand. (U.S.), Spec. Publ. 306 (Sept. 1968).
[27] Hagan, L., and Martin, W. C., *Bibliography on Atomic Energy Levels and Spectra (July 1968 through June 1971)*, 103 pp., Nat. Bur. Stand. (U.S.), Spec. Publ. 363 (June 1972).
[28] Neufeld, L. W., Thesis, 1970.
[29] Van Deurzen, C. H. H., Conway, J. G., and Davis, S. P., J. Opt. Soc. Am. **63**, 158 (1973).
[30] Holmström, J. E., Phys. Scr. **5**, 249 (1972).
[31] Smitt, R., Phys. Scr. **8**, 292 (1973).
[32] Svensson, L. A., and Ekberg, J. O., Ark. Fys. **37**, 65 (1968).
[33] Ekberg, J. O., and Svensson, L. A., Phys. Scr. **2**, 283 (1970).
[34] Feldman, U., Doschek, G. A., Cowan, R. D., and Cohen, L., J. Opt. Soc. Am. **63**, 1445 (1973).
[35] Chapman, R. D., and Shadmi, Y., J. Opt. Soc. Am. **63**, 1440 (1973).
[36] Edlén, B., Sol. Phys. **24**, 356 (1972).
[37] Fawcett, B. C., J. Phys. B **4**, 981 (1971).
[38] Goldsmith, S., Feldman, U., Crooker, A., and Cohen, L., J. Opt. Soc. Am. **62**, 260 (1972).
[39] Ekberg, J. O., Phys. Scr. **4**, 101 (1971).
[40] Crance, M., At. Data **5**, 185 (1973).
[41] Goldsmith, S., Feldman, U., Oren (Katz), L., and Cohen, L., Astrophys. J. **174**, 209 (1972).
[42] Goldsmith, S., Oren (Katz), L., Crooker, A. M., and Cohen, L., Astrophys. J. **184**, 1021 (1973).
[43] Shadmi, Y., Caspi, E., and Oreg, J., J. Res. Nat. Bur. Stand. (U.S.), **73A**, 173 (1969).

6. Tables of Spectra

Scandium

Sc I

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

Ionization Potential 6.54 eV = 52750 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
2965.86	5	4729.3	9	5356.10	12	5988.5	13
2974.01	5	4734.10	9	5447.2	11	5992.8	13
2980.75	5	4737.65	9	5481.99	11	6021.7	13
2988.95	5	4741.02	9	5484.62	11	6026.1	13
3015.36	4	4743.81	9	5514.22	10	6210.68	1
3019.35	4	5064.32	8	5519.7	11	6239.41	1
3030.77	4	5070.25	8	5520.50	10	6276.31	1
3907.49	3	5075.81	8	5549.68	10	6305.67	1
3911.81	3	5081.55	8	5671.81	7	21486	6
3933.38	3	5083.71	8	5686.83	7	21634	6
3996.61	2	5085.55	8	5700.14	7	21728	6
4020.40	2	5086.95	8	5708.60	7	21814	6
4023.69	2	5096.72	8	5711.75	7	22049	6
4047.79	2	5099.23	8	5717.30	7	22064	6
4717.03	9	5101.12	8	5724.07	7	22206	6
4720.83	9	5323.1	12	5739.30	7	22266	6
4728.77	9	5349.29	12	5741.36	7	22395	6

The data selected for this spectrum are taken from recent theoretical work by Weiss [1]. He has performed superposition-of-configurations (SOC) calculations which are limited, however, to the principal interacting configurations. His results are given in the dipole length as well as dipole velocity approximations, which agree fairly well, especially for the stronger transitions. We have chosen the dipole length results for this compilation since they should be less sensitive to the remaining corrections to the wave functions.

Some of his data may be compared with the results of two lifetime experiments, namely, measurements with the beam-foil technique by Buchta et al. [2], and measurements with the Hanle effect technique by Birkhahn et al. [3]. The experimental data, especially the beam-foil results, are found to yield generally longer lifetimes than the calculations. Judged mainly on the basis of many available comparisons with other experimental and theoretical data for the lighter elements, it is likely that the beam-foil data are significantly affected by cascading effects. However, since a smaller difference in the same direction, of the order of 25 percent, also exists between the calculations and the Hanle effect measurements, it appears that other experimental or theoretical deficiencies may be present in this case, too, with a likely candidate being the limited treatment of configuration interaction in the calculations by Weiss, which may not include some of the significant contributions; we have, consequently, been quite conservative in our error assignments.

We have used *LS* coupling to obtain data for the individual lines within multiplets. For a number of multiplets, we have compared the *LS* coupling data to Corliss and Bozman's [4], and L'vov's [5] experimental values, which should be fairly reliable when comparing individual lines within the same multiplet. For the stronger lines the agreement is usually within 25 percent, while—not unexpectedly—much larger discrepancies are observed for the weaker lines.

References

[1] Weiss, A. W., private communication (1973).
[2] Buchta, R., Curtis, L. J., Martinson, I., and Brzozowski, J., Phys. Scr. **4**, 55 (1971).
[3] Birkhahn, R., Ney, J., and Tuszynski, W., *Third Conference on Atomic Spectroscopy* No. 15 (University of Reading, Reading, England, 1971).
[4] Corliss, C. H. and Bozman, W. R., Nat. Bur. Stand. (U.S.), Monogr. 53 (July 1962).
[5] L'vov, B. V., Method. Phys. Anal. **8**, 3 (1972); J. Quant. Spectrosc. Radiat. Transfer **12**, 651 (1972).

Sc 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.	$a\,^2$D–$z\,^2$D° (2)	*6267.1*	*101*	*16053*	10	10	0.027	0.016	3.3	−0.80	E	1
		6305.67	168	16023	6	6	0.024	0.014	1.8	−1.08	E	*ls*
		6210.68	0	16097	4	4	0.025	0.015	1.2	−1.22	E	*ls*
		6276.31	168	16097	6	4	0.0027	0.0010	0.13	−2.22	E	*ls*
		6239.41	0	16023	4	6	0.0018	0.0016	0.13	−2.19	E	*ls*
2.	$a\,^2$D–$y\,^2$D° (7)	*4022.4*	*101*	*24955*	10	10	2.5	0.60	79	0.78	D	1
		4023.69	168	25014	6	6	2.3	0.56	44	0.53	D	*ls*
		4020.40	0	24866	4	4	2.2	0.54	28	0.33	D	*ls*
		4047.79	168	24866	6	4	0.24	0.040	3.2	−0.62	D−	*ls*
		3996.61	0	25014	4	6	0.17	0.061	3.2	−0.61	D−	*ls*
3.	$a\,^2$D–$y\,^2$F° (8)	*3910.6*	*101*	*25665*	10	14	2.2	0.71	91	0.85	D	1
		3911.81	168	25725	6	8	2.2	0.67	52	0.60	D	*ls*
		3907.49	0	25585	4	6	2.1	0.71	36	0.45	D	*ls*
		3933.38	168	25585	6	6	0.14	0.033	2.6	−0.70	D−	*ls*
4.	$a\,^2$D–$x\,^2$F° (10)	*3018.1*	*101*	*33225*	10	14	2.5	0.47	47	0.67	D	1
		3019.35	168	33279	6	8	2.5	0.45	27	0.43	D	*ls*
		3015.36	0	33154	4	6	2.3	0.47	19	0.27	D	*ls*
		3030.77	168	33154	6	6	0.16	0.022	1.3	−0.88	E	*ls*
5.	$a\,^2$D–$x\,^2$D° (11)	*2978.1*	*101*	*33670*	10	10	2.5	0.33	33	0.52	D	1
		2980.75	168	33707	6	6	2.3	0.31	18	0.27	D	*ls*
		2974.01	0	33615	4	4	2.3	0.30	12	0.08	D	*ls*
		2988.95	168	33615	6	4	0.25	0.022	1.3	−0.88	E	*ls*
		2965.86	0	33707	4	6	0.17	0.033	1.3	−0.88	E	*ls*
6.	$a\,^4$F–$z\,^4$D°	*22108*	*11610*	*16132*	28	20	0.0034	0.018	37	−0.30	E	1
		[22049]	11677	16211	10	8	0.0031	0.018	13	−0.74	E	*ls*
		[22064]	11610	16141	8	6	0.0029	0.016	9.1	−0.89	E	*ls*
		[22395]	11558	16022	6	4	0.0027	0.013	5.9	−1.11	E	*ls*
		[22266]	11520	16010	4	2	0.0034	0.013	3.7	−1.28	E	*ls*
		[21728]	11610	16211	8	8	3.7(−4) [a]	0.0026	1.5	−1.68	E	*ls*
		[21814]	11558	16141	6	6	6.2(−4)	0.0044	1.9	−1.58	E	*ls*
		[22206]	11520	16022	4	4	6.9(−4)	0.0051	1.5	−1.69	E	*ls*
		[21486]	11558	16211	6	8	2.0(−5)	1.8(−4)	0.077	−2.97	E	*ls*
		[21634]	11520	16141	4	6	3.7(−5)	3.9(−4)	0.11	−2.81	E	*ls*
7.	$a\,^4$F–$z\,^4$G° (12)	*5690.3*	*11610*	*29179*	28	36	0.75	0.47	250	1.12	D	1
		5671.81	11677	29304	10	12	0.76	0.44	82	0.64	D	*ls*
		5686.83	11610	29190	8	10	0.69	0.42	63	0.53	D	*ls*
		5700.14	11558	29096	6	8	0.65	0.42	47	0.40	D	*ls*
		5711.75	11520	29023	4	6	0.64	0.47	35	0.27	D	*ls*
		5708.60	11677	29190	10	10	0.062	0.030	5.7	−0.52	D−	*ls*
		5717.30	11610	29096	8	8	0.10	0.049	7.4	−0.41	D−	*ls*
		5724.07	11558	29023	6	6	0.10	0.050	5.7	−0.52	D−	*ls*
		5739.30	11677	29096	10	8	0.0023	9.0(−4)	0.17	−2.05	E	*ls*
		5741.36	11610	29023	8	6	0.0037	0.0014	0.21	−1.95	E	*ls*

Sc 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
8.	$a\,^4F$–$y\,^4F°$ (13)	*5083.8*	*11610*	*31275*	28	28	1.1	0.43	200	1.08	D	1
		5081.55	11677	31351	10	10	1.0	0.40	66	0.60	D	*ls*
		5083.71	11610	31275	8	8	0.84	0.33	44	0.42	D	*ls*
		5085.55	11558	31216	6	6	0.76	0.30	30	0.25	D	*ls*
		5086.95	11520	31173	4	4	0.88	0.34	23	0.14	D	*ls*
		5101.12	11677	31275	10	8	0.11	0.035	5.9	−0.46	D−	*ls*
		5099.23	11610	31216	8	6	0.20	0.057	7.7	−0.34	D−	*ls*
		5096.72	11558	31173	6	4	0.22	0.057	5.7	−0.47	D−	*ls*
		5064.32	11610	31351	8	10	0.092	0.044	5.9	−0.45	D−	*ls*
		5070.25	11558	31275	6	8	0.15	0.077	7.7	−0.34	D−	*ls*
		5075.81	11520	31216	4	6	0.15	0.085	5.7	−0.47	D−	*ls*
9.	$a\,^4F$–$y\,^4D°$ (14)	*4739.1*	*11610*	*32705*	28	20	1.4	0.34	150	0.97	D	1
		4743.81	11677	32752	10	8	1.3	0.34	53	0.53	D	*ls*
		4741.02	11610	32697	8	6	1.1	0.29	36	0.36	D	*ls*
		4737.65	11558	32659	6	4	1.1	0.25	24	0.18	D	*ls*
		4734.10	11520	32637	4	2	1.4	0.24	15	−0.03	D	*ls*
		4728.77	11610	32752	8	8	0.14	0.048	6.0	−0.42	D−	*ls*
		[4729.3]	11558	32697	6	6	0.25	0.082	7.7	−0.31	D−	*ls*
		[4729.3]	11520	32659	4	4	0.28	0.095	5.9	−0.42	D−	*ls*
		4717.03	11558	32752	6	8	0.0072	0.0032	0.30	−1.72	E	*ls*
		4720.83	11520	32697	4	6	0.013	0.0068	0.42	−1.57	E	*ls*
10.	$a\,^2F$–$z\,^2G°$ (15)	*5518.2*	*14992*	*33109*	14	18	0.57	0.33	85	0.67	D	1
		5520.50	15042	33151	8	10	0.57	0.33	47	0.42	D	*ls*
		5514.22	14926	33056	6	8	0.55	0.33	36	0.30	D	*ls*
		5549.68	15042	33056	8	8	0.019	0.0089	1.3	−1.15	E	*ls*
11.	$a\,^2F$–$x\,^2F°$ (16)	*5483.0*	*14992*	*33225*	14	14	0.46	0.21	53	0.47	D	1
		5481.99	15042	33279	8	8	0.45	0.20	29	0.21	D	*ls*
		5484.62	14926	33154	6	6	0.44	0.20	22	0.08	D	*ls*
		[5519.7]	15042	33154	8	6	0.022	0.0076	1.1	−1.22	D−	*ls*
		[5447.2]	14926	33279	6	8	0.017	0.010	1.1	−1.22	D−	*ls*
12.	$a\,^2F$–$x\,^2D°$ (17)	*5352.4*	*14992*	*33670*	14	10	0.54	0.17	41	0.36	D	1
		5356.10	15042	33707	8	6	0.51	0.17	23	0.12	D	*ls*
		5349.29	14926	33615	6	4	0.54	0.15	16	−0.03	D	*ls*
		[5323.1]	14926	33707	6	6	0.027	0.011	1.2	−1.18	D−	*ls*
13.	$b\,^2D$–$x\,^2D°$	*6003.6*	*17018*	*33670*	10	10	0.044	0.024	4.7	−0.62	E	1
		[5988.5]	17013	33707	6	6	0.041	0.022	2.6	−0.88	E	*ls*
		[6026.1]	17025	33615	4	4	0.039	0.021	1.7	−1.08	E	*ls*
		[6021.7]	17013	33615	6	4	0.0044	0.0016	0.19	−2.02	E	*ls*
		[5992.8]	17025	33707	4	6	0.0030	0.0024	0.19	−2.02	E	*ls*

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

Sc II

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d4s\ ^3D_1$

Ionization Potential 12.80 eV = 103240 cm^{-1}

Allowed Transitions

List of tabulated lines:

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
1880.6	14	3535.73	12	3843.00	1	4716.13	15
2232.9	23	3558.54	3	3859.36	1	5031.02	21
2273.10	26	3567.70	3	3902.09	10	5239.82	25
2290.7	31	3572.52	3	3923.51	10	5318.34	20
2294.9	31	3576.34	3	3939.51	10	5334.23	29
2540.9	7	3580.93	3	3989.06	9	5342.05	29
2545.24	7	3589.64	3	4014.49	9	5357.20	29
2552.38	7	3590.48	3	4246.83	8	5526.81	32
2555.84	7	3613.84	2	4279.93	17	5552.25	24
2560.26	7	3630.74	2	4294.77	17	5640.97	28
2563.23	7	3642.79	2	4305.72	17	5657.87	28
3096.77	6	3645.31	2	4314.08	17	5658.33	28
3107.39	6	3651.80	2	4320.75	17	5667.16	28
3244.17	5	3664.25	11	4325.01	17	5669.03	28
3251.32	5	3666.54	2	4354.61	16	5684.19	28
3352.05	4	3669.5	30	4374.46	16	5890.02	19
3353.73	13	3675.27	11	4384.81	16	6245.63	27
3359.68	4	3676.6	30	4400.36	16	6279.76	27
3361.27	4	3697.2	30	4415.56	16	6300.70	27
3361.94	4	3700.9	30	4420.67	16	6309.90	27
3368.95	4	3708.1	30	4431.37	16	6320.85	27
3372.15	4	3716.3	30	4670.40	22	6342.08	27
3502.1	34	3833.06	1	4698.28	15	6604.60	18
						27420	33

For this ion, we have used the results of superposition of configuration (SOC) calculations by Weiss [1], and the semi-empirical calculations by Kurucz [2], based on scaled Thomas-Fermi-Dirac wave functions. Both authors include (approximately) the effects of configuration interaction and furthermore calculate the individual line strengths in intermediate coupling. The two sets of data are, as might be expected, in very good agreement, usually within 10% for the stronger lines. Whenever available, Weiss's presumably somewhat more accurate data are used.

Similar to the case of Sc I, the theoretical data yield shorter lifetimes than those obtained from the beam-foil work of Buchta et al. [3]. However, the differences stay usually within 50 percent. Again, cascading from higher excited levels is likely to be responsible for a major part of the deviations.

References

[1] Weiss, A. W., private communication (1973).
[2] Kurucz, R. L., Smithsonian Astrophysical Observatory Special Report 351 (1973).
[3] Buchta, R., Curtis, L. J., Martinson, I., and Brzozowski, J., Phys. Scr. **4**, 55 (1971).

Sc 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.	$a\ ^3D$–$z\ ^1D^\circ$ (1)											
		3859.36	178	26081	7	5	1.2(−4)[a]	1.9(−5)[a]	0.0017	−3.88	E	2
		3843.00	68	26081	5	5	0.016	0.0035	0.22	−1.76	E	2
		3833.06	0	26081	3	5	0.0079	0.0029	0.11	−2.06	E	2
2.	$a\ ^3D$–$z\ ^3F^\circ$ (2)	*3627.3*	*106*	*27667*	15	21	1.80	0.497	89	0.87	C	1
		3613.84	178	27841	7	9	1.88	0.474	39.5	0.52	C	1
		3630.74	68	27602	5	7	1.58	0.438	26.2	0.340	C	1
		3642.79	0	27444	3	5	1.50	0.497	17.9	0.173	C	1
		3645.31	178	27602	7	7	0.15	0.029	2.4	−0.69	D	1
		3651.80	68	27444	5	5	0.25	0.050	3.0	−0.60	D	1
		3666.54	178	27444	7	5	0.0051	7.3(−4)	0.062	−2.29	E	1

Sc 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
3.	$a\,^3$D–$z\,^3$D° (3)	*3575.5*	*106*	*28066*	15	15	2.13	0.408	72	0.79	C	1
		3572.52	178	28161	7	7	1.86	0.356	29.3	0.397	C	1
		3576.34	68	28021	5	5	1.45	0.278	16.4	0.143	C	1
		3580.93	0	27918	3	3	1.52	0.292	10.3	−0.057	C	1
		3590.48	178	28021	7	5	0.33	0.045	3.7	−0.50	D	1
		3589.64	68	27918	5	3	0.51	0.059	3.5	−0.53	D	1
		3558.54	68	28161	5	7	0.30	0.080	4.7	−0.40	D	1
		3567.70	0	28021	3	5	0.35	0.11	3.9	−0.48	D	1
4.	$a\,^3$D–$z\,^3$P° (4)	*3368.2*	*106*	*29787*	15	9	1.35	0.138	23.0	0.316	C	1
		3372.15	178	29824	7	5	1.16	0.141	10.9	−0.006	C	1
		3368.95	68	29742	5	3	1.00	0.102	5.7	−0.292	C	1
		3361.94	0	29736	3	1	1.4	0.080	2.6	−0.62	D	1
		3359.68	68	29824	5	5	0.20	0.034	1.9	−0.77	D	1
		3361.27	0	29742	3	3	0.32	0.054	1.8	−0.79	D	1
		3352.05	0	29824	3	5	0.013	0.0037	0.12	−1.95	E	1
5.	$a\,^3$D–$z\,^1$P° (5)											
		3251.32	68	30816	5	3	0.033	0.0032	0.17	−1.80	D−	1
		3244.17	0	30816	3	3	0.023	0.0036	0.11	−1.97	D−	1
6.	$a\,^3$D–$z\,^1$F° (6)											
		3107.39	178	32350	7	7	0.0015	2.2(−4)	0.016	−2.81	E	1
		3096.77	68	32350	5	7	7.0(−4)	1.0(−4)	0.007	−3.16	E	1
7.	$a\,^3$D–$y\,^3$P° (uv 1)	*2555.2*	*106*	*39230*	15	9	2.8	0.17	21	0.41	C	2
		2552.38	178	39345	7	5	2.3	0.16	9.4	0.06	C	2
		2560.26	68	39114	5	3	2.2	0.13	5.5	−0.20	C	2
		2563.23	0	39002	3	1	2.9	0.094	2.4	−0.55	D	2
		2545.24	68	39345	5	5	0.43	0.042	1.8	−0.68	D	2
		2555.84	0	39114	3	3	0.71	0.070	1.8	−0.68	D	2
		[2540.9]	0	39345	3	5	0.029	0.0047	0.12	−1.85	E	2
8.	$a\,^1$D–$z\,^1$D° (7)	4246.83	2541	26081	5	5	1.55	0.420	29.4	0.322	C	1
9.	$a\,^1$D–$z\,^3$F° (8)											
		3989.06	2541	27602	5	7	0.0016	5.5(−4)	0.036	−2.56	E	2
		4014.49	2541	27444	5	5	0.017	0.0042	0.28	−1.68	D−	2
10.	$a\,^1$D–$z\,^3$D° (9)											
		3902.09	2541	28161	5	7	1.0(−4)	3.3(−5)	0.0021	−3.78	E	2
		3923.51	2541	28021	5	5	0.0026	6.0(−4)	0.039	−2.52	E	2
		3939.51	2541	27918	5	3	1.7(−4)	2.4(−5)	0.0016	−3.92	E	2
11.	$a\,^1$D–$z\,^3$P° (10)											
		3664.25	2541	29824	5	5	0.0035	7.1(−4)	0.043	−2.45	E	2
		3675.27	2541	29742	5	3	0.0072	8.7(−4)	0.053	−2.36	E	2

Sc 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
12.	$a\,^1$D–$z\,^1$P° (11)	3535.73	2541	30816	5	3	0.82	0.092	5.4	−0.34	D	1
13.	$a\,^1$D–$z\,^1$F° (12)	3353.73	2541	32350	5	7	1.98	0.467	25.8	0.368	C	1
14.	$a\,^1$D–$y\,^1$P°	[1880.6]	2541	55716	5	3	5.0	0.16	5.0	−0.10	D	1
15.	$a\,^3$F–$z\,^1$D° (13)											
		4716.13	4883	26081	7	5	7.1(−6)	1.7(−6)	1.8(−4)	−4.93	E	2
		4698.28	4802	26081	5	5	8.5(−4)	2.8(−4)	0.022	−2.85	E	2
16.	$a\,^3$F–$z\,^3$F° (14)	*4392.8*	*4909*	*27667*	21	21	0.17	0.049	15	0.01	D	2
		4374.46	4988	27841	9	9	0.16	0.045	5.8	−0.39	D	2
		4400.36	4883	27602	7	7	0.15	0.044	4.5	−0.51	D	2
		4415.56	4803	27444	5	5	0.16	0.046	3.3	−0.64	D	2
		4420.67	4988	27602	9	7	0.0035	8.0(−4)	0.10	−2.14	D−	2
		4431.37	4883	27444	7	5	0.0090	0.0019	0.19	−1.88	D−	2
		4354.61	4883	27841	7	9	0.011	0.0039	0.39	−1.56	D−	2
		4384.81	4803	27602	5	7	0.014	0.0055	0.40	−1.56	D−	2
17.	$a\,^3$F–$z\,^3$D° (15)	*4317.1*	*4909*	*28066*	21	15	0.47	0.094	28	0.30	D	2
		4314.08	4988	28161	9	7	0.46	0.10	13	−0.04	D	2
		4320.75	4883	28021	7	5	0.44	0.088	8.8	−0.21	D	2
		4325.01	4803	27918	5	3	0.48	0.081	5.8	−0.39	D	2
		4294.77	4883	28161	7	7	0.027	0.0075	0.74	−1.28	D−	2
		4305.72	4803	28021	5	5	0.0043	0.0012	0.085	−1.22	D−	2
		4279.93	4803	28161	5	7	5.5(−4)	2.1(−4)	0.015	−2.98	E	2
18.	$b\,^1$D–$z\,^1$D° (19)	6604.60	10945	26081	5	5	0.010	0.0066	0.72	−1.48	E	1
19.	$b\,^1$D–$z\,^3$D° (21)											
		5890.02	10945	27918	5	3	7.6(−4)	2.4(−4)	0.023	−2.92	E	1
20.	$b\,^1$D–$z\,^3$P° (22)											
		5318.34	10945	29742	5	3	0.0074	0.0019	0.16	−2.02	D−	1
21.	$b\,^1$D–$z\,^1$P° (23)	5031.02	10945	30816	5	3	0.490	0.111	9.2	−0.256	C	1
22.	$b\,^1$D–$z\,^1$F° (24)	4670.40	10945	32350	5	7	0.183	0.084	6.5	−0.377	C	1
23.	$b\,^1$D–$y\,^1$P°	[2232.9]	10945	55716	5	3	0.78	0.035	1.3	−0.76	D	1
24.	$a\,^1$S–$z\,^3$P° (25)											
		5552.25	11736	29742	1	3	0.0039	0.0054	0.099	−2.27	D−	2
25.	$a\,^1$S–$z\,^1$P° (26)	5239.82	11736	30816	1	3	0.14	0.17	2.9	−0.77	D	1
26.	$a\,^1$S–$y\,^1$P° (uv 2)	2273.10	11736	55716	1	3	7.7	1.80	13.5	0.255	C	1

Sc 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
27.	$a\,^3$P–$z\,^3$D° (28)	*6272.2*	*12127*	*28066*	9	15	0.026	0.025	4.7	−0.65	D	2
		6245.63	12154	28161	5	7	0.026	0.021	2.2	−0.98	D	2
		6279.76	12101	28021	3	5	0.021	0.021	1.3	−1.21	D	2
		6309.90	12074	27918	1	3	0.015	0.027	0.56	−1.57	D−	2
		6300.70	12154	28021	5	5	0.0049	0.0029	0.30	−1.84	D−	2
		6320.85	12101	27918	3	3	0.0095	0.0057	0.36	−1.77	D−	2
		6342.08	12154	27918	5	3	4.7(−4)	1.7(−4)	0.018	−3.08	E	2
28.	$a\,^3$P–$z\,^3$P° (29)	*5661.0*	*12127*	*29787*	9	9	0.16	0.078	13	−0.15	D+	2
		5657.87	12154	29824	5	5	0.12	0.058	5.4	−0.54	D+	2
		5667.16	12101	29742	3	3	0.039	0.019	1.1	−1.24	D	2
		5684.19	12154	29742	5	3	0.062	0.018	1.7	−1.05	D	2
		5669.03	12101	29736	3	1	0.16	0.025	1.4	−1.12	D	2
		5640.97	12101	29824	3	5	0.038	0.030	1.7	−1.04	D	2
		5658.33	12074	29742	1	3	0.047	0.068	1.3	−1.17	D	2
29.	$a\,^3$P–$z\,^1$P° (30)											
		5357.20	12154	30816	5	3	0.0046	0.0012	0.11	−2.21	D−	2
		5342.05	12101	30816	3	3	5.6(−4)	2.4(−4)	0.013	−3.14	E	2
		5334.23	12074	30816	1	3	0.0048	0.0062	0.11	−2.21	D−	2
30.	$a\,^3$P–$y\,^3$P°	*3688.6*	*12127*	*39230*	9	9	0.063	0.013	1.4	−0.93	E	2
		[3676.6]	12154	39345	5	5	0.046	0.0094	0.57	−1.33	E	2
		[3700.9]	12101	39114	3	3	0.016	0.0033	0.12	−2.01	E	2
		[3708.1]	12154	39114	5	3	0.026	0.0032	0.20	−1.79	E	2
		[3716.3]	12101	39002	3	1	0.064	0.0044	0.16	−1.88	E	2
		[3669.5]	12101	39345	3	5	0.015	0.0052	0.19	−1.81	E	2
		[3697.2]	12074	39114	1	3	0.021	0.013	0.16	−1.88	E	2
31.	$a\,^3$P–$y\,^1$P°											
		[2294.9]	12154	55716	5	3	0.0030	1.4(−4)	0.0053	−3.16	E	2
		[2290.7]	12074	55716	1	3	0.081	0.019	0.14	−1.71	D−	2
32.	$a\,^1$G–$z\,^1$F° (31)	5526.81	14261	32350	9	7	0.41	0.15	24	0.12	D	1
33.	$b\,^1$S–$z\,^1$P°	[27420]	27170	30816	1	3	4.1(−4)	0.014	1.3	−1.85	D	1
34.	$b\,^1$S–$y\,^1$P°	[3502.1]	27170	55716	1	3	0.069	0.038	0.44	−1.42	D	1

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

Sc III

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

Ionization Potential 24.76 eV = 119677 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
627.069	4	1168.608	8	2699.067	5	6307.595	9
627.846	4	1168.883	8	2734.048	5	7449.155	12
627.85	4	1598.002	1	4061.209	10	7548.148	12
730.600	3	1603.064	1	4068.661	10	8814.293	14
731.655	3	1610.194	1	4068.7	10	8829.785	14
731.66	3	1895.441	6	4992.886	13	8830.1	14
779.538	2	1912.620	6	5032.087	13	8865.6	11
780.597	2	1993.886	7	5037.176	13	8865.891	11
780.729	2	2011.070	7	6238.314	9	8881.585	11
1162.443	8	2012.906	7	6256.010	9		

For this spectrum the results of Hartree-Fock calculations by Weiss [1], a recent lifetime experiment using the beam-foil technique by Buchta et al. [2], and scaled Thomas-Fermi calculations by Warner [3], are available. Furthermore, for this relatively simple atomic system the Coulomb approximation by Bates and Damgaard [4] may be used with confidence. The four data sources may be conveniently compared by examining the lifetimes of several excited states. The data for the lifetime of the $4p\ ^2P^\circ$ state, obtained either directly by Buchta et al. [2], or by summing over all A-values originating downward from this state, produce an especially interesting comparison. The comparison table below shows for this transition good agreement between the experimental value and Weiss' dipole length result as well as the Coulomb approximation. The disagreement of Warner's results with the other data for the $4p\ ^2P^\circ$ level may be—with a high degree of probability—traced to a numerical error in his A-value. His value for the $3d$–$4p$ transition differs by about a factor of 10 from the other theoretical data.

Lifetimes (in ns) of various excited states of Sc III

Upper atomic level	τ_k	$(\Sigma_i A_{ki})^{-1}$		
	Buchta et al. [2]	Weiss [1]	Warner [3]	Bates and Damgaard [4]
$4p\ ^2P^\circ$	1.7	1.3	2.9 [a]	1.6
$4d\ ^2D$	1.2	–	0.90	0.88
$5s\ ^2S$	1.4	–	1.2	1.2
$5p\ ^2P^\circ$	3.5	–	3.5	3.6
$4f\ ^2F^\circ$	3.5	–	0.59	0.70
$5d\ ^2D$	2.4	–	2.4	2.3
$5f\ ^2F^\circ$	2.7	–	0.99	1.2
$5g\ ^2G$	–	–	2.8	2.7

[a] See comment in text.

The table reveals—with two exceptions to be discussed below—good agreement between Buchta's lifetimes on one hand and the Coulomb approximation and Warner's calculations on the other hand. The experimental lifetimes are often slightly longer than the calculated ones which seems to indicate the presence of small, unaccounted-for cascading effects. A remarkable result is that the Coulomb approximation appears to produce reliable results even for transitions going down to the $3d$ level where appreciable interaction with the core electrons must be expected. Because of its consistently good reliability, the Coulomb approximation has been used for all transitions tabulated here except for the $3d$–$4p$ and $4s$–$4p$ transitions. For these, the slightly more accurate Hartree-Fock calculations by Weiss are available, which have been used in their dipole length form as suggested by him.

Turning now to the two cases where the agreement between experiment and the calculations are not good, we note that Buchta et al. have stated in their paper that they had difficulties in measuring lifetimes shorter than 1 ns. They are speculating that the lifetime given for the $4f\ ^2F^\circ$ state could be actually the lifetime of the $5g\ ^2G$ state, which is the dominant cascade into the other state. The Coulomb approximation seems to support this hypothesis insofar as it yields a very short lifetime (0.70 ns) for the $4f\ ^2F^\circ$ state and a lifetime of 2.7 ns for the $5g\ ^2G$ state which does not differ appreciably from the observed lifetime. An analogous case may prevail for the $5f$ state where the other discrepancy with the theoretical data occurs.

The rather crude intensity estimates for individual lines, given by Kelly and Palumbo [5], indicate that LS coupling may not be too well approximated for Sc III. We have, therefore, within each multiplet assigned higher uncertainties to the weakest lines.

References

[1] Weiss, A. W., J. Res. Nat. Bur. Stand., Sect. A **71**, 157 (1967) and private communication.

[2] Buchta, R., Curtis, L. J., Martinson, I., and Brzozowski, J., Phys. Scr. **4**, 55 (1971).

[3] Warner, B., Observatory **92**, 50 (1972).

[4] Bates, D. R., and Damgaard, A., Phil. Trans. Roy. Soc. London, Ser. A **242**, 101 (1949).

[5] Kelly, R. L., and Palumbo, L. J., *Atomic and Ionic Emission Lines Below 2000 Angstroms—Hydrogen through Krypton*, Naval Research Laboratory Report 7599 (June 1973).

Sc III: 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*d*–4*p*	^{2}D–^{2}P° (uv 1)	*1605.1*	*119*	*62420*	10	6	4.5	0.10	5.5	0.00	D +	1
			1603.064	198	62578	6	4	4.1	0.10	3.3	− 0.22	D +	*ls*
			1610.194	0	62104	4	2	4.4	0.085	1.8	− 0.47	D +	*ls*
			1598.002	0	62578	4	4	0.46	0.018	0.37	− 1.14	D	*ls*
2.	3*d*–5*p*	^{2}D–^{2}P°	*780.61*	*119*	*128224*	10	6	1.4	0.0079	0.20	− 1.10	D −	*ca*
			780.729	198	128283	6	4	1.3	0.0079	0.12	− 1.32	D −	*ls*
			780.597	0	128107	4	2	1.5	0.0066	0.068	− 1.58	D −	*ls*
			779.538	0	128283	4	4	0.15	0.0014	0.014	− 2.26	E	*ls*
3.	3*d*–4*f*	^{2}D–^{2}F° (uv 2)	*731.24*	*119*	*136874*	10	14	11	0.13	3.0	0.10	D	*ca*
			731.655	198	136874	6	8	11	0.12	1.7	− 0.14	D	*ls*
			730.600	0	136874	4	6	11	0.13	1.2	− 0.30	D	*ls*
			[731.66]	198	136874	6	6	0.78	0.0062	0.090	− 1.43	E	*ls*
4.	3*d*–5*f*	^{2}D–^{2}F°	*627.54*	*119*	*159472*	10	14	7.1	0.059	1.2	− 0.23	D	*ca*
			627.846	198	159472	6	8	7.1	0.056	0.70	− 0.47	D	*ls*
			627.069	0	159472	4	6	6.7	0.059	0.49	− 0.63	D	*ls*
			[627.85]	198	159472	6	6	0.48	0.0028	0.035	− 1.77	E	*ls*
5.	4*s*–4*p*	^{2}S–^{2}P° (uv 3)	*2710.6*	25539	*62420*	2	6	3.4	1.1	20	0.34	D +	1
			2699.067	25539	62578	2	4	3.3	0.73	13	0.16	D +	*ls*
			2734.048	25539	62104	2	2	3.3	0.37	6.7	− 0.13	D	*ls*
6.	4*p*–5*s*	^{2}P°–^{2}S (uv 5)	*1906.9*	*62420*	114862	6	2	8.2	0.15	5.6	− 0.05	D	*ca*
			1912.620	62578	114862	4	2	5.4	0.15	3.7	− 0.23	D	*ls*
			1895.441	62104	114862	2	2	2.8	0.15	1.9	− 0.53	D	*ls*
7.	4*p*–4*d*	^{2}P°–^{2}D (uv 4)	*2004.8*	*62420*	*112285*	6	10	11	1.1	45	0.84	D	*ca*
			2011.070	62578	112303	4	6	11	1.0	27	0.61	D	*ls*
			1993.886	62104	112258	2	4	9.6	1.1	15	0.36	D	*ls*
			2012.906	62578	112258	4	4	1.9	0.11	3.0	− 0.34	E	*ls*
8.	4*p*–5*d*	^{2}P°–^{2}D	*1166.6*	*62420*	*148142*	6	10	2.0	0.066	1.5	− 0.40	D	*ca*
			1168.608	62578	148150	4	6	1.9	0.060	0.92	− 0.62	D	*ls*
			1162.443	62104	148130	2	4	1.6	0.067	0.51	− 0.88	D	*ls*
			1168.883	62578	148130	4	4	0.32	0.0066	0.10	− 1.58	E	*ls*
9.	4*d*–5*p*	^{2}D–^{2}P°	*6271.9*	*112285*	*128224*	10	6	0.71	0.25	52	0.40	D	*ca*
			6256.010	112303	128283	6	4	0.65	0.25	31	0.18	D	*ls*
			6307.595	112258	128107	4	2	0.70	0.21	17	− 0.08	D	*ls*
			6238.314	112258	128283	4	4	0.072	0.042	3.5	− 0.77	E	*ls*

Sc III: 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
10.	4*d*–4*f*	^{2}D–^{2}F° (1)	*4065.7*	*112285*	136874	10	14	3.2	1.1	150	1.04	D	*ca*
			4068.661	112303	136874	6	8	3.1	1.0	83	0.80	D	*ls*
			4061.209	112258	136874	4	6	2.9	1.1	58	0.64	D	*ls*
			[4068.7]	112303	136874	6	6	0.21	0.052	4.2	−0.51	E	*ls*
11.	4*f*–5*d*	^{2}F°–^{2}D	*8872.1*	136874	*148142*	14	10	0.21	0.18	71	0.39	D	*ca*
			8865.891	136874	148150	8	6	0.20	0.18	41	0.15	D	*ls*
			8881.585	136874	148130	6	4	0.21	0.16	29	−0.01	D	*ls*
			[8865.6]	136874	148150	6	6	0.0099	0.012	2.0	−1.16	E	*ls*
12.	5*s*–5*p*	^{2}S–^{2}P°	*7481.8*	114862	*128224*	2	6	0.56	1.4	69	0.45	D	*ca*
			7449.155	114862	128283	2	4	0.57	0.94	46	0.27	D	*ls*
			7548.148	114862	128107	2	2	0.54	0.47	23	−0.03	D	*ls*
13.	5*p*–5*d*	^{2}P°–^{2}D	*5019.3*	*128224*	*148142*	6	10	2.2	1.4	140	0.91	D	*ca*
			5032.087	128283	148150	4	6	2.2	1.2	81	0.69	D	*ls*
			4992.886	128107	148130	2	4	1.8	1.4	45	0.44	D	*ls*
			5037.176	128283	148130	4	4	0.36	0.14	9.0	−0.26	E	*ls*
14.	5*d*–5*f*	^{2}D–^{2}F°	*8823.6*	*148142*	*159472*	10	14	0.91	1.5	430	1.17	D	*ca*
			8829.785	148150	159472	6	8	0.91	1.4	250	0.93	D	*ls*
			8814.293	148130	159472	4	6	0.85	1.5	170	0.77	D	*ls*
			[8830.1]	148150	159472	6	6	0.060	0.071	12	−0.37	E	*ls*

Sc IV

Ground State $1s^22s^22p^63s^23p^6\ ^1S_0$

Ionization Potential 73.47 eV = 592600 cm^{-1}

Allowed Transitions

Cowan's calculations [1], done in a multiconfiguration approximation based on self-consistent field wave functions, provide all the listed data. The two very weak intercombination lines are estimated to be of rather low accuracy.

Reference

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

Sc IV: 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.	$3p^6$–$3p^53d$	^{1}S–^{3}P°											
			415.968	0	240403	1	3	0.024	1.9(−4) [a]	2.6(−4) [a]	−3.72	E	1
2.		^{1}S–^{3}D°											
			371.160	0	269427	1	3	0.30	0.0019	0.0023	−2.72	E	1
3.		^{1}S–^{1}P°	289.851	0	345005	1	3	1500	5.6	5.3	0.75	D	1

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

Sc VII

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

Ionization Potential [137] eV = [1105000] cm^{-1}

Allowed Transitions

The data for this ion are the result of calculations by Ali and Joy [1], done in a single-configuration Hartree-Fock approximation. Thus, configuration interaction was not taken into account, which may be important for the one listed transition. However, a comparison with a transition integral calculated by Ali with the nuclear charge expansion method (unpublished result), which presumably 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.

Reference

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

Sc 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.	$3p^3$–$3p^2(^3P)3d$	$^4S^\circ$–^4P	*297.79*	0	*335808*	4	12	520	2.1	8.1	0.92	E	1
			298.557	0	334944	4	6	520	1.0	4.1	0.60	E	*ls*
			297.269	0	336396	4	4	520	0.69	2.7	0.44	E	*ls*
			296.539	0	337224	4	2	540	0.36	1.4	0.16	E	*ls*

Sc IX

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

Ionization Potential 180.02 eV = 1452000 cm^{-1}

Allowed Transitions

All data for this ion of the aluminum isoelectronic sequence are taken from the superposition of configurations calculations by Froese-Fischer [1]. While the configuration interaction treatment is limited to a few, presumably dominant, interactions, comparisons with experiment for a few lower ions of the Al sequence suggest that the results should be accurate within 50 percent.

Reference

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

Sc 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.	$3s^2(^1S)3p$–$3s3p^2$	$^2P^\circ$–^2D	*531.89*	*3841*	*191851*	6	10	6.9	0.049	0.51	−0.53	D	1
			536.901	5761	192012	4	6	6.8	0.044	0.31	−0.75	D	*ls*
			521.896	0	191609	2	4	6.1	0.049	0.17	−1.01	D	*ls*
			[538.07]	5761	191609	4	4	1.1	0.0048	0.034	−1.72	E	*ls*
2.	$3s^2(^1S)3p$–$3s^2(^1S)3d$	$^2P^\circ$–^2D	*322.34*	*3841*	*314072*	6	10	320	0.84	5.3	0.70	D	1
			324.199	5761	314214	4	6	320	0.75	3.2	0.48	D	*ls*
			318.615	0	313859	2	4	280	0.86	1.8	0.24	D	*ls*
			324.570	5761	313859	4	4	52	0.082	0.35	−0.48	E	*ls*

Sc X

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

Ionization Potential 225.32 eV = 1817400 cm^{-1}

Allowed Transitions

The chosen values represent data obtained from studies of the f-value dependence on the nuclear charge [1]. For Sc X, an ion of the Mg isoelectronic sequence, the material available for the neutral end of the sequence is particularly reliable and plentiful, and for some transitions the nuclear charge expansion calculations by Crossley and Dalgarno [2] yield data up to very high nuclear charges. In addition, other calculated data for some very highly charged ions of the sequence have made possible reliable interpolations. The graphically derived f-values from such regularities have been chosen over the directly calculated ones, since they represent "best" values incorporating all results.

References

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

[2] Crossley, R. J. S., and Dalgarno, A., Proc. Roy. Soc., Ser. A **286**, 510 (1965).

Sc 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.	$3s^2$–$3s3p$	^{1}S–^{1}P°	422.850	0	236490	1	3	126	1.01	1.41	0.004	B	1
2.	$3s3p$–$3p^2$	^{3}P°–^{3}P	*458.86*	*160562*	*378495*	9	9	110	0.36	4.9	0.51	C+	1
			458.132	162699	380977	5	5	84	0.27	2.0	0.13	C+	*ls*
			459.38	158392	376042	3	3	29	0.090	0.41	−0.57	C	*ls*
			468.74	162699	376042	5	3	45	0.088	0.68	−0.36	C	*ls*
			465.01	158392	373441	3	1	110	0.12	0.54	−0.44	C	*ls*
			449.28	158392	380977	3	5	30	0.15	0.68	−0.35	C	*ls*
			455.32	156386	376042	1	3	39	0.36	0.54	−0.44	C	*ls*
3.		^{1}P°–^{1}D	[735.79]	236490	372398	3	5	10	0.14	1.0	−0.38	D	1
4.		^{1}P°–^{1}S	[490.23]	236490	[440476]	3	1	110	0.13	0.63	−0.41	D	1
5.	$3s3p$–$3s3d$	^{3}P°–^{3}D	*340.26*	*160562*	*454457*	9	15	160	0.45	4.5	0.61	C+	1
			342.509	162699	454662	5	7	150	0.37	2.1	0.27	C+	*ls*
			337.888	158392	454348	3	5	120	0.33	1.1	0.00	C	*ls*
			335.815	156386	454161	1	3	89	0.45	0.50	−0.35	C	*ls*
			342.877	162699	454348	5	5	38	0.067	0.38	−0.47	C	*ls*
			338.115	158392	454161	3	3	66	0.11	0.38	−0.48	C	*ls*
			343.100	162699	454161	5	3	4.2	0.0044	0.025	−1.66	D	*ls*
6.		^{1}P°–^{1}D	357.490	236490	516218	3	5	266	0.85	3.00	0.407	C	1
7.	$3s4s$–$3s4p$	^{1}S–^{1}P°	[1528.1]	915165	980604	1	3	3.6	0.38	1.9	−0.42	D+	1
8.		^{3}S–^{3}P°				3	9		0.75		0.35	D+	1

Sc XI

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

Ionization Potential 249.832 eV = 2015080 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
70.445	3	104.435	8	168.942	9	372.507	7
70.509	3	105.140	8	186.06	16	381.151	7
71.543	6	105.170	8	186.94	16	382.13	7
71.887	6	127.156	4	226.20	14	505.117	1
83.958	5	128.247	4	226.86	14	522.810	1
84.433	5	138.283	10	241.88	18	1028.6	17
94.888	2	138.380	10	243.31	18	1053.1	17
95.117	2	138.40	10	243.37	18	1056.1	17
97.777	11	168.22	9	302.32	15	1308.9	13
97.830	11	168.396	9	304.66	15	1353.7	13
97.835	11						

The *f*-value data chosen for this ion of the Na isoelectronic sequence have been derived by interpolation from studies of systematic trends in this sequence. The interpolated values are primarily based on theoretical data and have been modified for some transitions from Smith and Wiese's [1] original values where more recent data sources have become available. The additional sources are the nuclear charge expansion calculations by Ali [2], and Laughlin et al. [3], and a Coulomb approximation calculation by Kunze and Datla [4]. The interpolated *f*-values are expected to be quite accurate, since most regularities are based on fairly extensive and reliable material for the lower end of the Na isoelectronic sequence.

References

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

[2] Ali, M. A., J. Phys. B **4**, 748 (1971).

[3] Laughlin, C., Lewis, M. N., and Horak, Z. J., J. Opt. Soc. Am. **63**, 736 (1973).

[4] Kunze, H.-J., and Datla, R. U., Astrophys. J. **169**, 425 (1971).

Sc 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.	3*s*–3*p*	^2S–$^2P^\circ$	*511.54*	0	*195490*	2	6	42.5	0.50	1.68	0.000	B	1
			505.117	0	197720	2	4	44.0	0.337	1.12	−0.171	B	*ls*
			522.810	0	191030	2	2	39.7	0.163	0.56	−0.487	B	*ls*
2.	3*s*–4*p*	^2S–$^2P^\circ$	*94.964*	0	*1053027*	2	6	402	0.163	0.102	−0.487	C+	1, 4
			94.888	0	1053870	2	4	403	0.109	0.0679	−0.662	C+	*ls*
			95.117	0	1051340	2	2	400	0.0543	0.0340	−0.964	C+	*ls*
3.	3*s*–5*p*	^2S–$^2P^\circ$	*70.466*	0	*1419127*	2	6	230	0.051	0.024	−0.99	D+	1
			70.445	0	1419550	2	4	230	0.034	0.016	−1.17	D+	*ls*
			70.509	0	1418280	2	2	230	0.017	0.0079	−1.47	D+	*ls*
4.	3*p*–4*s*	$^2P^\circ$–^2S	*127.88*	*195490*	977470	6	2	1100	0.087	0.22	−0.28	D+	1
			128.247	197720	977470	4	2	720	0.089	0.15	−0.45	D+	*ls*
			127.156	191030	977470	2	2	360	0.087	0.073	−0.76	D+	*ls*
5.	3*p*–5*s*	$^2P^\circ$–^2S	*84.273*	*195490*	1382110	6	2	420	0.015	0.025	−1.05	D+	1
			84.433	197720	1382110	4	2	290	0.015	0.017	−1.22	D+	*ls*
			83.958	191030	1382110	2	2	140	0.015	0.0083	−1.52	D+	*ls*

Sc XI: 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–6s	^{2}P°–^{2}S	*71.772*	*195490*	1588790	6	2	210	0.0054	0.0077	−1.49	D+	1
			71.887	197720	1588790	4	2	140	0.0054	0.0051	−1.67	D+	*ls*
			[71.543]	191030	1588790	2	2	71	0.0055	0.0026	−1.96	D+	*ls*
7.	3p–3d	^{2}P°–^{2}D	*378.37*	*195490*	*459782*	6	10	110	0.40	3.0	0.38	C+	1
			381.151	197720	460030	4	6	110	0.36	1.8	0.16	C+	*ls*
			372.507	191030	459410	2	4	98	0.41	1.0	−0.09	C+	*ls*
			[382.13]	197720	459410	4	4	18	0.040	0.20	−0.80	D	*ls*
8.	3p–4d	^{2}P°–^{2}D	*104.91*	*195490*	*1148722*	6	10	760	0.21	0.44	0.10	D	1
			105.140	197720	1148830	4	6	760	0.19	0.26	−0.12	D	*ls*
			104.435	191030	1148560	2	4	670	0.22	0.15	−0.36	D	*ls*
			105.170	197720	1148560	4	4	130	0.021	0.029	−1.08	E	*ls*
9.	3d–4p	^{2}D–^{2}P°	*168.56*	*459782*	*1053027*	10	6	254	0.065	0.361	−0.187	C	1, 3
			168.396	460030	1053870	6	4	229	0.065	0.216	−0.409	C	*ls*
			168.942	459410	1051340	4	2	252	0.054	0.120	−0.67	C	*ls*
			[168.22]	459410	1053870	4	4	26	0.011	0.024	−1.36	D	*ls*
10.	3d–4f	^{2}D–^{2}F°	*138.34*	*459782*	*1182633*	10	14	2360	0.95	4.33	0.98	C	1
			138.380	460030	1182680	6	8	2360	0.90	2.47	0.73	C	*ls*
			138.283	459410	1182570	4	6	2210	0.95	1.73	0.58	C	*ls*
			[138.40]	460030	1182570	6	6	150	0.044	0.12	−0.58	D	*ls*
11.	3d–5f	^{2}D–^{2}F°	*97.808*	*459782*	*1482189*	10	14	800	0.16	0.52	0.20	D+	1
			97.830	460030	1482210	6	8	810	0.16	0.30	−0.02	D+	*ls*
			97.777	459410	1482160	4	6	760	0.16	0.21	−0.19	D+	*ls*
			[97.835]	460030	1482160	6	6	54	0.0078	0.015	−1.33	E	*ls*
12.	3d–6f	^{2}D–^{2}F°				10	14		0.059		−0.229	D	1
13.	4s–4p	^{2}S–^{2}P°	*1323.5*	977470	*1053027*	2	6	9.0	0.71	6.2	0.152	C	1, 2
			[1308.9]	977470	1053870	2	4	9.3	0.479	4.13	−0.019	C	*ls*
			[1353.7]	977470	1051340	2	2	8.5	0.232	2.07	−0.333	C	*ls*
14.	4s–5p	^{2}S–^{2}P°	*226.42*	977470	*1419127*	2	6	87	0.20	0.30	−0.40	D	1
			[226.20]	977470	1419550	2	4	88	0.13	0.20	−0.59	D	*ls*
			[226.86]	977470	1418280	2	2	87	0.067	0.10	−0.87	D	*ls*
15.	4p–5s	^{2}P°–^{2}S	*303.87*	*1053027*	1382110	6	2	300	0.14	0.84	−0.08	D+	1
			[304.66]	1053870	1382110	4	2	200	0.14	0.56	−0.25	D+	*ls*
			[302.32]	1051340	1382110	2	2	100	0.14	0.28	−0.55	D+	*ls*
16.	4p–6s	^{2}P°–^{2}S	*186.65*	*1053027*	1588790	6	2	140	0.025	0.092	−0.82	D	1
			[186.94]	1053870	1588790	4	2	95	0.025	0.061	−1.00	D	*ls*
			[186.06]	1051340	1588790	2	2	49	0.025	0.031	−1.30	D	*ls*
17.	4p–4d	^{2}P°–^{2}D	*1045.0*	*1053027*	*1148722*	6	10	23.3	0.63	13.1	0.58	C	1, 2
			[1053.1]	1053870	1148830	4	6	22.8	0.60	7.9	0.380	C	*ls*
			[1028.6]	1051340	1148560	2	4	20.3	0.65	4.37	0.114	C	*ls*
			[1056.1]	1053870	1148560	4	4	3.7	0.063	0.87	−0.60	D	*ls*

Sc XI: 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
18.	4*p*–5*d*	^{2}P°–^{2}D	*242.83*	*1053027*	*1464830*	6	10	130	0.19	0.91	0.06	D	1
			[243.31]	1053870	1464870	4	6	130	0.17	0.55	−0.17	D	*ls*
			[241.88]	1051340	1464770	2	4	110	0.19	0.30	−0.42	D	*ls*
			[243.37]	1053870	1464770	4	4	21	0.019	0.061	−1.12	E	*ls*
19.	4*p*–6*d*	^{2}P°–^{2}D				6	10		0.046		−0.56	D	1

Sc XII

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

Ionization Potential 685.89 eV = 5532200 cm^{-1}

Allowed Transitions

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 agreements 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 more affected by uncertainties in the calculated intermediate coupling coefficients than the stronger lines, and the accuracy ratings have been correspondingly lowered.

References

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

Sc XII: Allowed transitions

No.	Transition array	Multiplet or transition	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.	$2p^6$–$2p^5 3s$	^{1}S–^{3}P°											
			[30.816]	0	3245100	1	3	1400	0.060	0.0061	−1.22	D−	1
2.		^{1}S–^{1}P°	[30.480]	0	3280800	1	3	1900	0.081	0.0081	−1.09	D−	1
3.	$2p^6$–$2p^5 4s$	^{1}S–[1½]°	[23.045]	0	4339300	1	3	710	0.017	0.0013	−1.77	D−	1
4.		^{1}S–[1/2]°	[22.837]	0	4378800	1	3	510	0.012	9.0(−4)[a]	−1.92	D−	1
5.	$2p^6$–$2p^5 5s$	^{1}S–[1½]°				1	3		0.0071		−2.15	E	1
6.		^{1}S–[1/2]°				1	3		0.0041		−2.39	E	1
7.	$2p^6$–$2p^5 6s$	^{1}S–[1½]°				1	3		0.0035		−2.46	E	1
8.		^{1}S–[1/2]°				1	3		0.0019		−2.72	E	1
9.	$2p^6$–$2p^5 3d$	^{1}S–^{3}D°											
			[26.920]	0	3714700	1	3	8600	0.28	0.025	−0.55	D	1
10.		^{1}S–^{1}P°	[26.544]	0	3767300	1	3	7.3(+4)	2.3	0.20	0.36	D	1
11.	$2p^6$–$2p^5 4d$	^{1}S–^{3}D°											
			[22.119]	0	4521000	1	3	1.1(+4)	0.25	0.018	−0.60	D	1
12.		^{1}S–^{1}P°	[21.940]	0	4557900	1	3	2.1(+4)	0.46	0.033	−0.34	D	1
13.	$2p^6$–$2p^5 5d$	^{1}S–^{3}D°											
			20.438			1	3	8000	0.15	0.010	−0.82	D	1
14.		^{1}S–^{1}P°	20.298			1	3	8600	0.16	0.011	−0.80	D	1
15.	$2p^6$–$2p^5 6d$	^{1}S–^{3}P°											
						1	3		0.0012		−2.92	E	1

Sc XII: Allowed transitions—Continued

No.	Transition array	Multiplet or Transition	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki}(10^{8}sec^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
16.		^{1}S–^{3}D°											
						1	3		0.067		−1.17	E	1
17.		^{1}S–^{1}P°				1	3		0.092		−1.04	E	1
18.	$2p^53s$–$2p^53p$	^{3}P°–^{3}S	616.14	[3240800]	[3403100]	9	3	22	0.041	0.75	−0.43	D	1
			[583.43]	[3231700]	[3403100]	5	3	22	0.067	0.65	−0.47	D	1
			[632.91]	3245100	[3403100]	3	3	2.1	0.013	0.079	−1.42	E	1
			[722.20]	[3273600]	[3403100]	1	3	0.32	0.0086	0.022	−2.07	E	1
19.		^{3}P°–^{3}D											
			[517.33]	[3231700]	[3425000]	5	7	37	0.21	1.8	0.02	D	1
			[561.48]	3245100	[3423200]	3	5	16	0.13	0.70	−0.42	D	1
			[527.43]	[3273600]	[3463200]	1	3	17	0.21	0.37	−0.67	D	1
			[522.19]	[3231700]	[3423200]	5	5	17	0.069	0.60	−0.46	D	1
			[458.51]	3245100	[3463200]	3	3	0.22	6.9(−4)	0.0031	−2.68	E	1
20.		^{3}P°–^{1}P											
			[495.29]	[3231700]	[3433600]	5	3	3.8	0.0084	0.068	−1.38	E	1
			[530.50]	3245100	[3433600]	3	3	31	0.13	0.69	−0.41	D	1
			[625.00]	[3273600]	[3433600]	1	3	0.40	0.0070	0.014	−2.15	E	1
21.		^{3}P°–^{3}P	466.42	[3240800]	[3455200]	9	9	40	0.13	1.8	0.07	D	1
			[476.64]	[3231700]	[3441500]	5	5	25	0.085	0.67	−0.37	D	1
			[434.03]	3245100	[3475500]	3	3	0.13	3.7(−4)	0.0016	−2.96	E	1
			[410.17]	[3231700]	[3475500]	5	3	5.2	0.0079	0.053	−1.41	E	1
			[459.98]	3245100	[3462500]	3	1	37	0.039	0.18	−0.93	D	1
			[509.16]	3245100	[3441500]	3	5	17	0.11	0.55	−0.48	D	1
			[495.29]	[3273600]	[3475500]	1	3	21	0.23	0.38	−0.64	D	1
22.		^{3}P°–^{1}D											
			[409.17]	[3231700]	[3476100]	5	5	1.1	0.0028	0.019	−1.86	E	1
			[432.90]	3245100	[3476100]	3	5	1.4	0.0066	0.028	−1.71	E	1
23.		^{3}P°–^{1}S											
			[287.27]	3245100	[3593200]	3	1	67	0.028	0.078	−1.08	E	1
24.		^{1}P°–^{3}S											
			[817.66]	3280800	[3403100]	3	3	0.25	0.0025	0.020	−2.12	E	1
25.		^{1}P°–^{3}D											
			[548.25]	3280800	[3463200]	3	3	16	0.072	0.39	−0.66	D	1
26.		^{1}P°–^{3}P											
			[622.28]	3280800	[3441500]	3	5	0.75	0.0073	0.045	−1.66	E	1
			[513.61]	3280800	[3475500]	3	3	17	0.067	0.34	−0.70	D	1
			[550.36]	3280800	[3462500]	3	1	9.3	0.014	0.077	−1.37	E	1
27.		^{1}P°–^{1}D	[512.03]	3280800	[3476100]	3	5	36	0.24	1.2	−0.15	D	1
28.		^{1}P°–^{1}S	[320.10]	3280800	[3593200]	3	1	110	0.056	0.18	−0.77	D	1

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

Sc XIII

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

Ionization Potential 755.47 eV = 6093400 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
18.574	26	24.135	19	24.666	12	25.635	6
18.579	26	24.167	20	24.715	15	25.667	6
18.711	26	24.205	19	24.720	14	25.690	6
22.663	25	24.234	21	24.764	17	25.887	6
22.802	23	24.249	18	24.815	14	25.919	6
22.830	23	24.284	16	24.899	12	26.893	5
22.859	25	24.306	18	24.970	10	27.170	5
22.860	24	24.308	20	24.998	9	27.618	4
22.912	24	24.333	19	25.079	11	27.628	4
23.001	23	24.353	18	25.099	10	27.911	4
23.029	23	24.358	19	24.133	8	27.979	3
23.112	24	24.391	20	25.163	9	28.131	3
23.808	22	24.474	18	25.200	7, 8	28.191	2
24.013	21	24.484	15	25.242	8, 9	28.280	3
24.025	22	24.491	14	25.329	7	28.324	2
24.061	16	24.532	18	25.341	10	28.434	3
24.086	20	24.534	17	25.405	9	28.497	2
24.097	16	24.560	15	25.440	8	28.633	2
24.111	19	24.584	14	25.485	8	130.96	1
24.130	21	24.648	13	25.574	7	137.80	1

Sinanoglu's configuration interaction calculations [1] should provide a reliable value for the first multiplet.

All other data are taken from the comprehensive calculations of Chapman and Shadmi [2], who employed Hartree-Fock wave functions, including the principal configuration mixing, and calculated individual oscillator strengths in intermediate coupling. We have been quite conservative in the assignment of error estimates, since—especially for the weaker lines—many large discrepancies exist with the presumably somewhat less accurate calculations of Cohen et al. [3].

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 using the nuclear charge expansion method. We did not tabulate this material, however, since the relevant wavelengths and energy levels are not known.

References

[1] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).
[2] Chapman, R. D., and Shadmi, Y., J. Opt. Soc. Am. **63**, 1440 (1973).
[3] Cohen, L., Feldman, U., and Kastner, S. O., J. Opt. Soc. Am. **58**, 331 (1968).
[4] Ali, M. A., Int. J. Quantum Chem. IIIS, 359 (1970).
[5] Ali, M. A., J. Quant. Spectrosc. Radiat. Transfer **11**, 503 (1971).

Sc 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.	$2s^2 2p^5$–$2s2p^6$	$^2P^\circ$–^2S	*133.16*	*12633*	763590	6	2	580	0.051	0.13	−0.51	C	1
			130.96	0	763590	4	2	400	0.052	0.089	−0.68	D	*ls*
			137.80	37900	763590	2	2	170	0.049	0.045	−1.01	D	*ls*
2.	$2s^2 2p^5$–$2s^2 2p^4(^3P)3s$	$^2P^\circ$–^4P											
			28.633	37900	3530600	2	4	85	0.0021	3.9(−4)[a]	−2.38	E	2
			28.324	0	3530600	4	4	62	7.5(−4)	2.7(−4)	−2.52	E	2
			28.497	37900	3547200	2	2	99	0.0012	2.2(−4)	−2.62	E	2
			[28.191]	0	3547200	4	2	150	9.0(−4)	3.3(−4)	−2.44	E	2

Sc 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
3.		^{2}P°–^{2}P	*28.180*	*12633*	*3561233*	6	6	3300	0.040	0.022	−0.62	D	2
			28.131	0	3554800	4	4	81	9.6(−4)	3.5(−4)	−2.42	E	2
			28.280	37900	3574100	2	2	4000	0.048	0.0089	−1.02	D	2
			27.979	0	3574100	4	2	4900	0.029	0.011	−0.94	D	2
			28.434	37900	3554800	2	4	450	0.011	0.0021	−1.66	E	2
4.	$2s^22p^5$–$2s^22p^4(^1D)3s$	^{2}P°–^{2}D	*27.721*	*12633*	*3620020*	6	10	1500	0.029	0.016	−0.76	D	2
			27.628	0	3619500	4	6	3.7	6.3(−5)	2.3(−5)	−3.60	E	2
			27.911	37900	3620800	2	4	3200	0.075	0.014	−0.82	D	2
			[27.618]	0	3620800	4	4	350	0.0040	0.0015	−1.80	E	2
5.	$2s^22p^5$–$2s^22p^4(^1S)3s$	^{2}P°–^{2}S	*26.985*	*12633*	3718400	6	2	4800	0.018	0.0094	−0.97	D	2
			26.893	0	3718400	4	2	2800	0.015	0.0053	−1.22	D	2
			27.170	37900	3718400	2	2	2100	0.023	0.0041	−1.34	D	2
6.	$2s^22p^5$–$2s^22p^4(^3P)3d$	^{2}P°–^{4}D											
			[25.690]	0	[3892500]	4	6	300	0.0044	0.0015	−1.75	E	2
			[25.919]	37900	[3896100]	2	4	16	3.2(−4)	5.5(−5)	−3.19	E	2
			[25.667]	0	[3896100]	4	4	650	0.0064	0.0022	−1.59	E	2
			[25.887]	37900	[3900900]	2	2	9.0	9.0(−5)	1.5(−5)	−3.74	E	2
			[25.635]	0	[3900900]	4	2	390	0.0019	6.4(−4)	−2.12	E	2
7.		^{2}P°–^{4}F											
			25.200	0	3968300	4	6	36	5.1(−4)	1.7(−4)	−2.69	E	2
			[25.574]	37900	[3948100]	2	4	150	0.0029	4.9(−4)	−2.24	E	2
			[25.329]	0	[3948100]	4	4	86	8.3(−4)	2.8(−4)	−2.48	E	2
8.		^{2}P°–^{4}P											
			25.133	0	3978800	4	6	92	0.0013	4.3(−4)	−2.28	E	2
			25.440	37900	3968300	2	4	150	0.0030	5.0(−4)	−2.22	E	2
			25.200	0	3968300	4	4	1700	0.016	0.0053	−1.19	D	2
			[25.485]	37900	3961700	2	2	28	2.7(−4)	4.5(−5)	−3.27	E	2
			25.242	0	3961700	4	2	0.73	3.5(−6)	1.2(−6)	−4.85	E	2
9.		^{2}P°–^{2}P	*25.132*	*12633*	*3991567*	*6*	6	2600	0.024	0.012	−0.84	D	2
			24.998	0	4000300	4	4	46	4.3(−4)	1.4(−4)	−2.76	E	2
			[25.405]	37900	3974100	2	2	170	0.0016	2.7(−4)	−2.49	E	2
			25.163	0	3974100	4	2	4400	0.021	0.0070	−1.08	D	2
			25.242	37900	4000300	2	4	1500	0.029	0.0048	−1.24	D	2
10.		^{2}P°–^{2}D	*25.101*	*12633*	*3996560*	6	10	6500	0.10	0.051	−0.22	D	2
			24.970	0	4004800	4	6	6800	0.095	0.031	−0.42	D	2
			25.341	37900	3984200	2	4	3400	0.066	0.011	−0.88	D	2
			25.099	0	3984200	4	4	2800	0.026	0.0086	−0.98	D	2
11.		^{2}P°–^{2}F											
			25.079	0	3987400	4	6	990	0.014	0.0046	−1.25	E	2

Sc 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
12.	$2s^22p^5$–$2s^22p^4(^1D)3d$	$^2P^o$–^2S	*24.743*	*12633*	4054200	6	2	9400	0.029	0.014	−0.76	D	2
			24.666	0	4054200	4	2	5.3	2.4(−5)	7.8(−6)	−4.02	E	2
			24.899	37900	4054200	2	2	9500	0.088	0.014	−0.75	D	2
13.		$^2P^o$–^2F											
			24.648	0	4057100	4	6	1300	0.018	0.0058	−1.14	E	2
14.		$^2P^o$–^2P	*24.629*	*12633*	[4072867]	6	6	2.3(+4)	0.21	0.10	0.10	D	2
			[24.584]	0	[4067700]	4	4	1200	0.011	0.0036	−1.36	D	2
			[24.720]	37900	[4083200]	2	2	4.7(+4)	0.433	0.070	−0.06	D	2
			[24.491]	0	[4083200]	4	2	6900	0.031	0.010	−0.91	D	2
			[24.815]	37900	[4067700]	2	4	5100	0.095	0.016	−0.72	D	2
15.		$^2P^o$–^2D	*24.606*	*12633*	*4076940*	6	10	1.5(+4)	0.23	0.11	0.14	D	2
			24.560	0	4071700	4	6	4000	0.054	0.017	−0.67	D	2
			24.715	37900	4084300	2	4	2.8(+4)	0.52	0.085	0.02	D	2
			24.484	0	4084300	4	4	2100	0.019	0.0061	−1.12	D	2
16.	$2s^22p^5$–$2s^22p^4(^1S)3d$	$^2P^o$–^2D	*24.156*	*12633*	*4152380*	6	10	1.1(+4)	0.17	0.079	0.01	D	2
			24.097	0	4149900	4	6	2300	0.030	0.0095	−0.92	D	2
			24.284	37900	4156100	2	4	1.5(+4)	0.26	0.042	−0.28	D	2
			24.061	0	4156100	4	4	9800	0.085	0.027	−0.47	D	2
17.	$2s^22p^5$–$2s2p^5(^3P)3p$	$^2P^o$–^4S											
			[24.764]	37900	[4076000]	2	4	1500	0.027	0.0044	−1.27	E	2
			[24.534]	0	[4076000]	4	4	1.6	1.4(−5)	4.5(−6)	−4.25	E	2
18.		$^2P^o$–^4D											
			[24.353]	0	[4106300]	4	6	2600	0.035	0.011	−0.85	D	2
			[24.532]	37900	[4114200]	2	4	1.6	2.8(−5)	4.5(−6)	−4.25	E	2
			[24.306]	0	[4114200]	4	4	10	9.3(−5)	3.0(−5)	−3.43	E	2
			[24.474]	37900	[4123900]	2	2	310	0.0028	4.5(−4)	−2.25	E	2
			[24.249]	0	[4123900]	4	2	77	3.4(−4)	1.1(−4)	−2.87	E	2
19.		$^2P^o$–^4P											
			[24.205]	0	[4131300]	4	6	5100	0.067	0.021	−0.57	D	2
			[24.333]	37900	[4147500]	2	4	7900	0.14	0.022	−0.55	D	2
			[24.111]	0	[4147500]	4	4	6400	0.056	0.018	−0.65	D	2
			[24.358]	37900	[4143400]	2	2	1700	0.015	0.0024	−1.52	E	2
			[24.135]	0	[4143400]	4	2	480	0.0021	6.7(−4)	−2.08	E	2
20.		$^2P^o$–^2P	*24.21*	*12633*	*[4142467]*	6	6	1.0(+4)	0.090	0.043	−0.27	D	2
			[24.167]	0	[4137800]	4	4	4100	0.036	0.011	−0.84	D	2
			[24.308]	37900	[4151800]	2	2	9700	0.086	0.014	−0.76	D	2
			[24.086]	0	[4151800]	4	2	7800	0.034	0.011	−0.87	D	2
			[24.391]	37900	[4137800]	2	4	2500	0.045	0.0072	−1.05	D	2

Sc 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
21.		^{2}P°–^{2}D	*24.157*	*12633*	[*4152280*]	6	10	1.7(+4)	0.25	0.12	0.18	D	2
			[24.130]	0	[4144200]	4	6	660	0.0087	0.0028	−1.46	D	2
			[24.234]	37900	[4164400]	2	4	4.3(+4)	0.75	0.12	0.18	D	2
			[24.013]	0	[4164400]	4	4	580	0.0050	0.0016	−1.70	E	2
22.		^{2}P°–^{2}S	*23.880*	*12633*	[4200200]	6	2	2.2(+4)	0.064	0.030	−0.42	D	2
			[23.808]	0	[4200200]	4	2	9400	0.040	0.013	−0.80	D	2
			[24.025]	37900	[4200200]	2	2	1.3(+4)	0.11	0.017	−0.66	D	2
23.	$2s^22p^5$–$2s2p^5(^1P)3p$	^{2}P°–^{2}P	*22.878*	*12633*	[*4383733*]	6	6	9900	0.077	0.035	−0.34	D	2
			[22.802]	0	[4385500]	4	4	3000	0.023	0.0069	−1.04	D	2
			[23.029]	37900	[4380200]	2	2	9800	0.078	0.012	−0.81	D	2
			[22.830]	0	[4380200]	4	2	3600	0.014	0.0042	−1.25	D	2
			[23.001]	37900	[4385500]	2	4	5100	0.081	0.012	−0.79	D	2
24.		^{2}P°–^{2}D	*22.947*	*12633*	[*4370480*]	6	10	8900	0.12	0.053	−0.14	D	2
			[22.860]	0	[4374400]	4	6	6600	0.078	0.023	−0.51	D	2
			[23.112]	37900	[4364600]	2	4	9400	0.15	0.023	−0.52	D	2
			[22.912]	0	[4364600]	4	4	2800	0.022	0.0066	−1.06	D	2
25.		^{2}P°–^{2}S	*22.728*	*12633*	[4412500]	6	2	2200	0.0058	0.0026	−1.46	E	2
			[22.663]	0	[4412500]	4	2	390	0.0015	4.5(−4)	−2.22	E	2
			[22.859]	37900	[4412500]	2	2	1800	0.014	0.0021	−1.55	E	2
26.	$2s^22p^5$–$2p^63d$	^{2}P°–^{2}D	*18.620*	*12633*	[*5383320*]	6	10	470	0.0041	0.0015	−1.61	E	2
			[18.574]	0	[5384000]	4	6	18	1.4(−4)	3.4(−5)	−3.25	E	2
			[18.711]	37900	[5382300]	2	4	520	0.0055	6.8(−4)	−1.96	E	2
			[18.579]	0	[5382300]	4	4	640	0.0033	8.1(−4)	−1.88	E	2

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

Sc XIV

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

Ionization Potential 829.79 eV = 6692900 cm^{-1}

Allowed Transitions

The data for this ion of the oxygen isoelectronic sequence were taken from the superposition of configurations calculations of Sinanoglu [1] and the interpolations along the isoelectronic sequence performed by Smith and Wiese [2].

References

[1] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).

Sc 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.	$2s^2 2p^4$–$2s2p^5$	^3P–$^3P^\circ$	*150.81*	*14304*	[*677386*]	9	9	264	0.090	0.402	−0.09	C	1
			150.46	0	[664628]	5	5	200	0.068	0.17	−0.47	D	*ls*
			151.89	31170	[689541]	3	3	65	0.022	0.034	−1.18	D	*ls*
			145.035	0	[689541]	5	3	120	0.024	0.056	−0.93	D	*ls*
			148.47	31170	[704707]	3	1	280	0.031	0.045	−1.04	D	*ls*
			157.86	31170	[664628]	3	5	58	0.036	0.056	−0.97	D	*ls*
			152.85	35223	[689541]	1	3	85	0.089	0.045	−1.05	D	*ls*
2.		^1D–$^1P^\circ$	122.66	98136	[913398]	5	3	910	0.123	0.248	−0.211	C	1
3.		^1S–$^1P^\circ$	139.46	196086	[913398]	1	3	58	0.051	0.0234	−1.292	C	1
4.	$3s$–$3p$	$^3S^\circ$–^3P				3	9		0.43		0.11	D	2
5.		$^5S^\circ$–^5P				5	15		0.22		0.04	D	2

Sc XV

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

Ionization Potential 926.00 eV = 7468900 cm^{-1}

Allowed Transitions

For this ion of the nitrogen isoelectronic sequence, the data were obtained from the superposition of configurations calculations by Sinanoglu [1] and the interpolations along the sequence performed by Smith and Wiese [2]. Whenever wavelength data were available, data for individual lines within the multiplets are presented.

References

[1] Sinanoglu, O., Nucl. Instrum. Methods **110**, 193 (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).

Sc 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.	$2s^2 2p^3$–$2s2p^4$	${}^4S^\circ$–${}^4P$	*176.57*	0	[*566340*]	4	12	81	0.113	0.263	−0.345	C	1, 2
			181.21	0	[551846]	4	6	75	0.055	0.13	−0.66	D	*ls*
			173.27	0	[577134]	4	4	86	0.039	0.088	−0.81	D	*ls*
			170.00	0	[588235]	4	2	91	0.020	0.044	−1.10	D	*ls*
2.		${}^2D^\circ$–${}^2D$	*161*			10	10	172	0.067	0.355	−0.174	C	1
			155.73			6	6	180	0.065	0.20	−0.41	D	*ls*
			153.80			4	4	180	0.063	0.13	−0.60	D	*ls*
			154.89			4	6	13	0.0069	0.014	−1.56	D−	*ls*
3.		${}^2D^\circ$–${}^2P$	*123.35*			10	6	680	0.093	0.378	−0.032	C	1
			125.83			6	4	580	0.091	0.23	−0.26	D−	*ls*
			118.99			4	2	760	0.080	0.13	−0.50	D	*ls*
			124.14			4	4	66	0.015	0.025	−1.22	D	*ls*
4.		${}^2P^\circ$–${}^2D$	*174*			6	10	28	0.021	0.072	−0.90	C	1
			177.47			4	6	26	0.018	0.043	−1.14	D	*ls*
			173.49			2	4	23	0.021	0.024	−1.38	D	*ls*
5.		${}^2P^\circ$–${}^2S$	*145.60*			6	2	380	0.040	0.12	−0.62	C	1
			146.71			4	2	260	0.041	0.080	−0.79	D	*ls*
			143.44			2	2	140	0.042	0.040	−1.08	D	*ls*
6.		${}^2P^\circ$–${}^2P$	*136.40*			6	6	190	0.053	0.0143	−0.498	C	1
			139.60			4	4	150	0.043	0.079	−0.76	D	*ls*
			130.42			2	2	150	0.037	0.032	−1.13	D	*ls*
			133.12			4	2	69	0.0091	0.016	−1.44	D	*ls*
			136.63			2	4	32	0.018	0.016	−1.44	D	*ls*
7.	$3s$–$3p$	${}^4P$–${}^4D^\circ$				12	20		0.17		0.31	D+	2
8.		${}^4P$–${}^4P^\circ$				12	12		0.12		0.16	D+	2
9.		${}^2P$–${}^2D^\circ$				6	10		0.19		0.06	D+	2
10.	$3s'$–$3p'$	${}^2D$–${}^2F^\circ$				10	14		0.13		0.11	D+	2
11.	$3p'$–$3d'$	${}^2F^\circ$–${}^2G$				14	18		0.26		0.56	D	2

Sc XVI

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

Ionization Potential [1009] eV = [8138300] cm^{-1}

Allowed Transitions

The data for this ion of the carbon isoelectronic sequence were obtained from the recent superposition of configurations calculations by Sinanoglu [1] and the interpolations along the isoelectronic sequence by Smith and Wiese [2].

Normally, Sinanoglu's recent work is in close agreement with the earlier results of Smith and Wiese, derived by interpolation. An exception is the $2s^2 2p^2\ ^1D$–$2s2p^3\ ^1D^\circ$ transition where a discrepancy of a factor of two exists. For this transition, a new comprehensive superposition of configurations calculation was performed by Weiss [3] on the ion Si IX of this isoelectronic sequence. His result agrees very well with the interpolated data, so that these were chosen in this case.

References

[1] Sinanoglu, O., Nucl. Instrum. Methods **110,** 193 (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23,** No. 196, 103 (1971).
[3] Weiss, A. W., private communication (1974).

Sc 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.	$2s^2 2p^2$–$2s2p^3$	^3P–$^3D^\circ$	*197.95*	[*32531*]	[*537715*]	9	15	45	0.044	0.26	−0.40	C	1, 2
			201.25	[44849]	[541743]	5	7	43	0.036	0.12	−0.74	D	*ls*
			194.72	[22844]	[536402]	3	5	36	0.034	0.065	−0.99	D	*ls*
			188.50	0	[530504]	1	3	29	0.047	0.029	−1.33	D	*ls*
			[203.44]	[44849]	[536402]	5	5	11	0.0066	0.022	−1.48	D	*ls*
			[196.98]	[22844]	[530504]	3	3	19	0.011	0.022	−1.48	D	*ls*
			[205.91]	[44849]	[530504]	5	3	1.1	4.1(−4)[a]	0.0014	−2.69	D−	*ls*
2.		^3P–$^3P^\circ$	*166.74*	[*32531*]	[*632261*]	9	9	122	0.051	0.252	−0.338	C	1, 2
			169.65	[44849]	[634298]	5	5	87	0.038	0.11	−0.73	D	*ls*
			164.67	[22844]	[630119]	3	3	32	0.013	0.021	−1.41	D	*ls*
			[170.86]	[44849]	[630119]	5	3	47	0.012	0.035	−1.21	D	*ls*
			165.11	[22844]	[628501]	3	1	130	0.017	0.028	−1.29	D	*ls*
			163.44	[22844]	[634298]	3	5	33	0.022	0.035	−1.19	D	*ls*
			158.68	0	[630119]	1	3	47	0.054	0.028	−1.27	D	*ls*
3.		^3P–$^3S^\circ$	*133.39*	[*32531*]	[782203]	9	3	700	0.062	0.245	−0.253	C	1, 2
			135.62	[44849]	[782203]	5	3	370	0.061	0.14	−0.52	D	*ls*
			131.69	[22844]	[782203]	3	3	240	0.063	0.082	−0.72	D	*ls*
			127.844	0	[782203]	1	3	87	0.064	0.027	−1.19	D−	*ls*
4.		^1D–$^1D^\circ$	150.94	[123900]	[786415]	5	5	410	0.14	0.35	−0.15	C+	2
5.		^1D–$^1P^\circ$	132.67	[123900]	[877650]	5	3	448	0.071	0.155	−0.450	C	1
6.		^1S–$^1P^\circ$	157.94 ?			1	3	102	0.115	0.060	−0.94	C	1
7.	$2s^2 2p^2$–$2s^2 2p3s$	^3P–$^3P^\circ$				9	9		0.051		−0.338	C+	2
8.		^1D–$^1P^\circ$	22.016	[123900]	[4666000]	5	3	9600	0.042	0.015	−0.68	C+	2
9.	$3s$–$3p$	$^3P^\circ$–^3D				9	15		0.14		0.10	C+	2
10.		$^3P^\circ$–^3P				9	9		0.11		0.00	C	2
11.		$^3P^\circ$–^3S				9	3		0.030		−0.57	C	2
12.		$^1P^\circ$–^1D				3	5		0.22		−0.18	C	2
13.		$^1P^\circ$–^1S				3	1		0.060		−0.74	D+	2

Sc 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
14.	$3p$–$3d$	^{3}D–^{3}F°				15	21		0.18		0.43	C	2
15.		^{3}P–^{3}D°				9	15		0.14		0.10	C	2
16.		^{3}D–^{3}D°				15	15		0.031		−0.33	C	2
17.		^{3}P–^{3}P°				9	9		0.043		−0.41	C	2
18.		^{3}S–^{3}P°				3	9		0.18		−0.27	C	2
19.		^{1}D–^{1}F°				5	7		0.12		−0.22	D+	2
20.		^{1}P–^{1}D°				3	5		0.23		−0.16	D	2
21.		^{1}P–^{1}P°				3	3		0.064		−0.72	D+	2

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

Sc XVII

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

Ionization Potential [1094] eV = [8823900] cm^{-1}

Allowed Transitions

For this ion of the boron isoelectronic sequence, the data have been taken from calculations of Sinanoglu [1], which include configuration interaction, and from the interpolated f-values of Smith and Wiese [2], obtained from systematic trends within this sequence that are well established.

References

[1] Sinanoglu, O., Nucl. Instrum. Methods **110,** 193 (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23,** No. 196, 103 (1971).

Sc XVII: 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.	$2s^2 2p$–$2s2p^2$	^{2}P°–^{2}D				6	10		0.043		−0.59	C	1, 2
2.		^{2}P°–^{2}S	*171.07*	[*30250*]	[614800]	6	2	140	0.021	0.071	−0.90	C	1
			175.61 ?	[45370]	[614800]	4	2	88	0.020	0.047	−1.10	D	*ls*
			162.65 ?	0	[614800]	2	2	57	0.022	0.024	−1.36	D	*ls*
3.		^{2}P°–^{2}P				6	6		0.112		−0.173	C	1, 2
4.	$2s^2 2p$–$2s^2 3s$	^{2}P°–^{2}S	*20.41*	[*30250*]	[4931000]	6	2	1.0(+4)[a]	0.021	0.0085	−0.90	C	2
			20.47 ?	[45370]	[4931000]	4	2	6700	0.021	0.0057	−1.08	D	*ls*
			[20.28]	0	[4931000]	2	2	3400	0.021	0.0028	−1.38	D	*ls*
5.	$2s^2 2p$–$2s^2 3d$	^{2}P°–^{2}D				6	10		0.65		0.59	C	2
6.	$2s2p^2$–$2p^3$	^{4}P–^{4}S°				12	4		0.046		−0.26	C	2
7.		^{2}P–^{2}D°				6	10		0.061		−0.44	D+	2
8.		^{2}D–^{2}D°				10	10		0.55		0.74	D+	2
9.	$2s^2 3s$–$2s^2 3p$	^{2}S–^{2}P°				2	6		0.18		−0.44	C	2
10.	$2s^2 3p$–$2s^2 3d$	^{2}P°–^{2}D				6	10		0.058		−0.46	D+	2

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

Sc XVIII

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

Ionization Potential [1210] eV = [9759600] cm^{-1}

Allowed Transitions

The data chosen for this ion of the Be isoelectronic sequence are the interpolated values derived from studies of systematic trends of f-values within the isoelectronic sequence by Smith and Wiese [1]. The interpolated data are derived mainly from calculations and beam-foil lifetimes. For one transition, $2s2p\ {}^1P^\circ - 2p^2\ {}^1D$, the results of very recent nuclear charge expansion calculations of Laughlin and Dalgarno [2] were added, which slightly modify the existing systematic trend.

References

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

[2] Laughlin, C., and Dalgarno, A., Phys. Lett. A **35**, 61 (1971).

Sc 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.	$2s^2-2s2p$	$^1S-^1P^\circ$	188.98 ?	0	[529200]	1	3	120	0.19	0.12	−0.72	B	1
2.	$2s2p-2s3s$	$^3P^\circ-^3S$				9	3		0.029		−0.58	C	1
3.	$2s2p-2p^2$	$^3P^\circ-^3P$				9	9		0.072		−0.188	B	1
4.		$^1P^\circ-^1S$				3	1		0.042		−0.90	C+	1
5.		$^1P^\circ-^1D$				3	5		0.063		−0.72	C+	1, 2
6.	$2s2p-2s3d$	$^1P^\circ-^1D$				3	5		0.54		0.210	C	1
7.		$^3P^\circ-^3D$				9	15		0.73		0.82	C	1
8.	$2s3s-2s3p$	$^3S-^3P^\circ$				3	9		0.21		−0.20	C	1
9.	$2s3p-2s3d$	$^3P^\circ-^3D$				9	15		0.038		−0.47	D+	1

Sc XIX

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

Ionization Potential [1288] eV = [10389000] cm^{-1}

Allowed Transitions

The data for this ion of the Li isoelectronic sequence are taken from studies by Smith and Wiese [1] and Martin and Wiese [2], who derived *f*-values by interpolation from systematic trends within the sequence. For most transitions the data on which the trends are based are plentiful and reliable, so that the trends are well established. In a few cases, wavelength and energy level data are available, which permit the calculation of individual line data within multiplets. We have then used the *LS*-coupling ratios, which should be a fair assumption for this Li-like ion.

References

[1] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).
[2] Martin, G. A., and Wiese, W. L., to be published (1975).

Sc 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.	2*s*–2*p*	^{2}S–^{2}P°	*289.19*	0	[*345800*]	2	6	18.3	0.069	0.131	−0.86	B	1
			275.25	0	[363300]	2	4	21.1	0.0480	0.087	−1.018	B	*ls*
			321.77	0	[310800]	2	2	13.2	0.0205	0.0435	−1.387	B	*ls*
2.	2*s*–3*p*	^{2}S–^{2}P°	*16.832*	0	*5941000*	2	6	2.88(+4)[a]	0.367	0.0407	−0.134	B	1
			16.819	0	5946000	2	4	2.89(+4)	0.245	0.0271	−0.310	B	*ls*
			16.861	0	5931000	2	2	2.87(+4)	0.123	0.0136	−0.609	B	*ls*
3.	2*s*–4*p*	^{2}S–^{2}P°				2	6		0.098		−0.71	C	2
4.	2*s*–5*p*	^{2}S–^{2}P°				2	6		0.040		−1.10	C	2
5.	2*s*–6*p*	^{2}S–^{2}P°				2	6		0.0211		−1.375	C	2
6.	2*s*–7*p*	^{2}S–^{2}P°				2	6		0.0124		−1.61	C	2
7.	2*p*–3*s*	^{2}P°–^{2}S	*18.126*	[*340500*]	[5857500]	6	2	1.08(+4)	0.0178	0.00637	−0.971	C+	1
			18.182	[357500]	[5857500]	4	2	7160	0.0178	0.00425	−1.148	C+	*ls*
			18.026	[306500]	[5857500]	2	2	3670	0.0179	0.00212	−1.446	C+	*ls*
8.	2*p*–4*s*	^{2}P°–^{2}S				6	2		0.0037		−1.65	C+	1
9.	2*p*–3*d*	^{2}P°–^{2}D	*17.730*	[*340500*]	[*5980500*]	6	10	8.7(+4)	0.68	0.238	0.61	C+	1
			17.779	[357500]	[5982500]	4	6	8.6(+4)	0.61	0.143	0.387	C+	*ls*
			17.634	[306500]	[5977500]	2	4	7.3(+4)	0.68	0.079	0.134	C+	*ls*
			[17.794]	[357500]	[5977500]	4	4	1.4(+4)	0.068	0.016	−0.57	D	*ls*
10.	2*p*–4*d*	^{2}P°–^{2}D				6	10		0.12		−0.14	C+	1
11.	3*s*–3*p*	^{2}S–^{2}P°				2	6		0.113		−0.646	C+	1
12.	3*s*–4*p*	^{2}S–^{2}P°				2	6		0.42		−0.076	C	2
13.	3*s*–5*p*	^{2}S–^{2}P°				2	6		0.106		−0.67	C	2
14.	3*s*–6*p*	^{2}S–^{2}P°				2	6		0.047		−1.03	C	2
15.	3*s*–7*p*	^{2}S–^{2}P°				2	6		0.0248		−1.305	C	2
16.	3*p*–4*s*	^{2}P°–^{2}S				6	2		0.040		−0.62	C+	1

Sc 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
17.	3p–3d	^{2}P°–^{2}D				6	10		0.0186		−0.952	C+	1
18.	3p–4d	^{2}P°–^{2}D				6	10		0.59		0.55	C+	1
19.	3p–5d	^{2}P°–^{2}D				6	10		0.137		−0.085	C	2
20.	3d–4f	^{2}D–^{2}F°				10	14		1.00		1.000	C+	1
21.	4s–4p	^{2}S–^{2}P°				2	6		0.185		−0.432	C	2
22.	4s–5p	^{2}S–^{2}P°				2	6		0.464		−0.032	C	2
23.	4s–6p	^{2}S–^{2}P°				2	6		0.127		−0.60	C	2
24.	4s–7p	^{2}S–^{2}P°				2	6		0.055		−0.96	C	2
25.	4p–5s	^{2}P°–^{2}S				6	2		0.066		−0.402	C	2
26.	4p–4d	^{2}P°–^{2}D				6	10		0.037		−0.65	C	2
27.	4p–5d	^{2}P°–^{2}D				6	10		0.58		0.54	C	2
28.	4p–6d	^{2}P°–^{2}D				6	10		0.141		−0.073	C	2

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

Sc XX

Ground State	$1s^2\ ^1S_0$
Ionization Potential	[5675] eV = [45773000] cm^{-1}

Allowed transitions

The data for this ion of the He isoelectronic sequence are taken from the variational calculations by Weiss [1], which represent the most comprehensive and accurate body of data for this sequence. They are well supported for the lower ions of the sequence by other advanced experimental and theoretical material.

Reference

[1] Weiss, A. W., J. Res. Nat. Bur. Stand. **71A**, 163 (1967).

Sc XX: 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–^{1}P°	2.87	0	[34843000]	1	3	2.11(+6) [a]	0.78	0.0074	−0.108	B	1
2.	$1s^2$–$1s3p$	^{1}S–^{1}P°	2.46	0	[40650000]	1	3	5.66(+5)	0.154	0.00125	−0.812	B	1
3.	1s2s–1s2p	^{1}S–^{1}P°				1	3		0.0249		−1.604	B	1
4.		^{3}S–^{3}P°				3	9		0.0342		−0.989	B	1
5.	1s2s–1s3p	^{1}S–^{1}P°				1	3		0.411		−0.386	B	1
6.		^{3}S–^{3}P°				3	9		0.401		0.080	B	1
7.	1s2p–1s3d	^{1}P°–^{1}D				3	5		0.70		0.322	B	1
8.		^{3}P°–^{3}D				9	15		0.68		0.787	B	1
9.	1s3p–1s3d	^{3}P°–^{3}D				9	15		0.0140		−0.900	B	1

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

Sc XXI

Ground State	$1s\ ^2S_{1/2}$
Ionization Potential	[6033.6] eV = [48665500] 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

$$f_{\mathrm{Sc\,XXI}} = f_{\mathrm{Hydrogen}},$$

$$A_{\mathrm{Sc\,XXI}} = (21)^4 A_{\mathrm{Hydrogen}},$$

$$S_{\mathrm{Sc\,XXI}} = (21)^{-2} S_{\mathrm{Hydrogen}}.$$

Judging from very recent theoretical studies [2, 3, 4], relativistic effects are expected to introduce uncertainties of a few percent into these data.

References

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

[2] Weiss, A. W., private communication.

[3] Sinanoglu, O., and Luken, W., Chem. Phys. Lett. **20**, 407 (1973).

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

Titanium

Ti I

Ground State $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2\ {}^3F_2$

Ionization Potential 6.82 eV = 55010 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
2541.92	28	3637.97	14	4024.57	8	4544.69	34
2596.60	27	3642.68	15	4026.54	91	4548.76	34
2605.16	27	3646.20	14	4030.51	91	4552.45	34
2641.12	26	3653.50	15	4040.31	91	4555.49	34
2644.28	26	3654.59	14	4078.47	55	4562.64	5
2733.27	60	3658.10	15	4082.46	55	4617.27	75
2735.30	60	3660.63	14	4099.17	100	4623.10	75
2912.07	48	3668.97	14	4112.71	6	4629.34	75
2933.53	25	3671.67	15	4137.28	114	4645.19	75
2948.26	25	3687.35	15	4203.47	101	4650.02	75
2956.80	25	3689.92	14	4224.80	130	4656.47	4
2983.31	24	3709.96	56	4237.89	123	4667.59	4
3123.07	47	3717.39	13	4249.11	113	4675.12	54
3141.54	46	3722.57	13	4256.03	113	4681.91	4
3186.45	23	3724.57	74	4258.52	113	4691.34	53
3191.99	23	3725.16	56	4263.13	86	4693.67	4
3199.92	23	3729.81	13	4270.14	112	4698.77	53
3203.83	23	3741.06	13	4276.44	77	4715.30	4
3205.85	22	3752.86	13	4278.23	126	4731.17	98
3214.24	23	3753.62	13	4281.37	36	4742.79	106
3222.74	22	3771.65	13	4282.70	86	4758.12	106
3243.80	22	3786.04	42	4284.99	77	4758.91	33
3292.08	45	3788.80	12	4286.01	36	4759.27	106
3308.39	59	3858.13	89	4287.41	36	4781.72	33
3309.50	59	3889.95	11	4289.07	36	4783.31	33
3314.42	59	3895.24	89	4290.93	36	4792.48	117
3314.52	59	3898.49	9	4295.75	36	4808.53	131
3341.88	20	3900.96	11	4298.66	36	4820.41	72
3342.15	19	3904.79	41	4299.64	35	4836.13	109
3342.71	21	3911.19	88	4300.57	36	4840.87	40
3348.54	21	3914.33	11	4301.09	36	4848.49	97
3352.94	21	3921.42	10	4305.91	36	4856.01	105
3354.63	20	3924.53	9	4318.63	107	4868.26	105
3358.27	19	3926.32	127	4321.66	107	4870.13	105
3360.99	20	3929.88	9	4325.13	107	4885.08	83
3361.26	19	3934.23	11	4326.36	35	4899.91	83
3361.84	21	3938.01	110	4354.06	99	4913.62	83
3370.44	19	3947.77	10	4360.49	99	4919.87	96
3371.45	20	3948.67	9	4372.38	121	4921.77	96
3377.49	21	3956.34	9	4427.10	73	4928.34	96
3377.58	19	3958.21	9	4440.35	84	4964.71	87
3379.22	20	3962.85	8	4449.14	85	4968.57	87
3382.31	58	3964.27	8	4455.32	71	4973.05	87
3385.66	20	3981.76	8	4457.43	71	4975.34	122
3385.94	19	3982.48	7	4463.54	85	4981.73	32
3480.53	57	3989.76	8	4465.81	76	4991.07	32
3493.28	18	3998.64	8	4496.15	76	4997.10	3
3506.64	18	4002.47	93	4512.73	34	4999.50	32
3598.71	44	4003.79	93	4518.02	34	5007.21	32
3604.28	17	4008.93	8	4522.80	34	5009.65	3
3606.79	16	4009.65	7	4527.31	34	5014.19	3
3610.15	43	4013.59	92	4533.24	34	5014.28	32
3626.09	16	4015.38	91	4534.78	34	5016.16	32
3635.20	16	4017.77	91	4535.57	34	5020.03	32
3635.46	15	4021.81	91	4535.92	34	5022.87	32
				4536.05	34		

List of tabulated lines—Continued

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
5024.84	32	5282.38	52	5514.35	67	6599.11	38
5035.91	70	5283.44	82	5514.54	67	6666.55	64
5036.47	70	5284.38	52	5565.48	104	6743.12	37
5038.40	70	5289.28	30	5644.14	108	7138.91	63
5039.96	3	5295.78	52	5648.57	119	7188.55	63
5052.88	95	5297.24	82	5675.41	111	7209.44	63
5062.11	95	5323.96	30	5689.47	111	7244.86	63
5064.65	3	5338.33	29	5702.67	111	7271.41	62
5087.06	69	5351.07	129	5866.45	51	7299.67	62
5113.45	69	5361.72	29	5880.31	50	7344.72	62
5120.42	125	5366.65	29	5899.30	51	7357.74	62
5145.47	69	5384.63	29	5918.55	50	7364.11	62
5147.48	2	5389.18	29	5922.11	51	8068.24	79
5152.19	2	5401.32	29	5937.81	51	9832.15	78
5173.74	2	5409.61	81	5941.76	51	9927.35	78
5192.97	2	5426.26	1	5953.16	80	9997.94	78
5201.10	90	5429.14	116	5965.83	80	10404.2	103
5206.06	120	5436.70	39	5978.54	80	10460.1	103
5210.39	2	5446.59	1	6064.63	49	10566.0	103
5219.70	2	5460.50	1	6085.23	49	11651.3	102
5238.56	31	5477.70	118	6126.22	49	12738.6	94
5246.57	31	5488.21	118	6258.10	66	12811.9	94
5252.11	2	5490.15	68	6258.71	66	12831.5	61
5255.81	90	5490.84	1	6261.10	66	12919.9	94
5259.98	128	5503.90	124	6303.75	66	14850.0	115
5265.97	82	5512.53	67	6556.07	65	15117.5	115

From the fairly extensive literature on Ti I f-value data, which is almost all of experimental nature, nine papers were utilized for this compilation. The bulk of the tabulated data comes from absorption measurements of King and King [1], arc emission measurements of Klemt [2] and Roberts et al. [5], a shock tube emission study of Wolnik and Berthel [3], and anomalous dispersion (hook) measurements of Ostrovskii et al. [4].

The most comprehensive, accurate set of data is the one measured by Klemt [2], who determined relative oscillator strengths in emission with a wall-stabilized arc. Klemt has used an elaborate normalization scheme to convert his relative data to an absolute scale, which we essentially follow, too, even though it is slightly different from our usual procedure. This scheme utilizes some excited state lifetime data measured by Roberts et al. [6], Witt et al. [7], and Hese [8], as well as the absorption measurements of Reinke [9]. The table below, which is essentially reproduced from Klemt's paper, shows the data from the three lifetime measurements and the conversion, with Klemt's branching ratio measurements, to log gf-values for the strongest line originating from the upper state in each case. The data from Reinke's absorption measurements are directly added and averaged absolute log gf-values are obtained. Klemt then performed an additional modification to this normalization by including sets of relative f-values from the work of other authors for these lines, such as the data of Stekelenburg and Smit [10] and Linevsky [11]. We regard this additional modification as unnecessary since it was primarily done because of good agreement among these authors (which may have occurred accidentally). However, by reproducing Klemt's modification, we found that it caused only a one percent change from the averaged absolute log gf-value. We thus left Klemt's published data unchanged.

Having established Klemt's data as our principal reference, we then normalized the remaining data sources—King and King [1], Wolnik and Berthel [3], Ostrovskii et al. [4], and Roberts et al. [5]—to give optimum agreement with Klemt's data. When the data of these authors overlap, we have first chosen the data of Wolnik and Berthel, then Ostrovskii et al., then Roberts et al., and finally the data of King and King, as arrived on the basis of a critical evaluation of these papers.

Absolute log gf-values for Ti I (according to Klemt)

Upper level	Strongest emission line [Å]	Experimental lifetimes [ns]			Absolute log gf				Averaged log gf[b]
		Roberts et al. (1973)	Witt et al. (1971)	Hese (1972)	Roberts et al.[a] (1973)	Witt et al.[a] (1971)	Hese[a] (1972)	Reinke (1967)	
$y^3G^\circ_3$	3635.5	10.0	10		−0.004	−0.004		−0.105	−0.038
$y^3G^\circ_4$	3642.7							−0.025	−0.025
$y^3G^\circ_5$	3653.5	10.5	11		0.224	0.204		0.061	0.163
$y^3D^\circ_2$	3956.3	18.0			−0.447				−0.447
$y^3D^\circ_3$	3958.2	18.0			−0.272				−0.272
$y^3F^\circ_2$	3981.8	21.0	26	18.9	−0.397	−0.490	−0.350		−0.412
$y^3F^\circ_3$	3989.8	21.6	18	18.4	−0.311	−0.232	−0.241		−0.261
$y^3F^\circ_4$	3998.6	22.0	20	19.4	−0.118	−0.076	−0.063		−0.086
$y^5G^\circ_6$	4981.7	14.5			0.523				0.523
$y^5G^\circ_5$	4991.1	16.5			0.320				0.320

[a] Obtained by using Klemt's branching ratio data.

[b] These values serve only for the normalization of Klemt's relative f-values, and thus differ slightly from our tabulated data, which have been taken directly from Klemt.

We have excluded a small part of the material from the above authors for the following reasons: Ostrovskii et al. disagree substantially with other authors for the few lines which have a lower level above the ground state. Since for all other lines (where the lower state is the ground state) their agreement with other data is good, one must assume that their temperature measurement, applicable only to these few lines, is not correct. Secondly, from the data of King and King we have omitted the very weak lines (which they identified as such), since King and King estimate the data for these lines to be significantly more uncertain than for all others. Finally, we omitted the 7978.9 Å line given by Klemt since the author was uncertain about the correct classification of this transition.

We have been rather conservative in our error estimates for two reasons: First, there is still a fairly substantial uncertainty in the absolute scale due to the disagreement of about 35 percent between Reinke's absorption method on one hand and the three lifetime determinations on the other hand. Secondly, the conversion from the lifetime data to f-values involves an extensive branching ratio analysis where some contributions had to be obtained using uncertain LS-coupling data. Among similar lines, we have generally made the distinction of rating the stronger ones slightly better since they have usually have been measured with slightly higher precision.

References

[1] King, R. B., and King, A. S., Astrophys. J. **87**, 24 (1938).

[2] Klemt, M., Astron. Astrophys. **29**, 419 (1973).

[3] Wolnik, S. J., and Berthel, R. O., Astrophys. J. **179**, 665 (1973).

[4] Ostrovskii, Yu. I., Parchevskii, G. F., and Penkin, N. P., Opt. Spektrosk. **1**, 821 (1956).

[5] Roberts, J. R., Voigt, P. A., and Czernichowski, A., to be published in Astrophys. J. (1975).

[6] Roberts, J. R., Andersen, T., and Sørensen, G., Astrophys. J. **181**, 567 (1973).

[7] Witt, F., Hese, A., and Augusta, N., *Third Conference on Atomic Spectroscopy*, No. 88 (University of Reading, Reading, England, 1971).

[8] Hese, A., Z. Naturforsch. A **27**, 188 (1972); *Second Conference on Atomic Spectroscopy*, No. 8 (Institut A für Experimentalphysik der Technischen Universität, Hannover, Germany, 1970).

[9] Reinke, P., Z. Astrophys. **66**, 234 (1967).

[10] Stekelenburg, L. H. M. van, and Smit, J. A., Physica (Utr.) **14**, 189 (1948).

[11] Linevsky, M. J., Space Sciences Laboratory, General Electric Co., Semi-Annual Report (Feb. 1968).

Note Added in Proof

We have now received a new set of absolute log gf-values measured by G. D. Bell, L. B. Kalman, and E. F. Tubbs (private communication, 1974). These data are determined with an advanced atomic beam-absorption technique, where a diffuse titanium atomic beam emanates from a specially constructed oven, and the number of titanium atoms are measured by

microbalance weighings and chemical analysis of the titanium deposits. The measurements have yielded especially accurate f-values for the two lines at 3998.6 Å and 3653.5 Å, with reported uncertainties of ±10 percent. The following comparison table demonstrates that these new values agree very closely with our absolute scale, usually within a few percent. Since this precise atomic beam method yields absolute f-values directly and not with the extensive branching ratio analysis necessary for the utilization of lifetime data, an important confirmation of our f-value scale is obtained. We suggest, therefore, that with the support of these additional data, the uncertainties of our listed numbers should be closer to a "C" accuracy, i.e., 25 percent, rather than the "D" accuracy as we have listed.

λ[Å]	log gf-values	
	Bell et al.	This compilation
3354.6	−0.01	0.02
3371.4	0.10	0.13
3635.5	0.00	0.01
3642.7	0.08	0.04
3653.5	0.16	0.09
3741.1	−0.25	−0.21
3752.9	−0.05	−0.09
3948.7	−0.43	−0.43
3956.3	−0.40	−0.42
3958.2	−0.15	−0.19
3981.8	−0.34	−0.31
3989.8	−0.22	−0.21
3998.6	−0.07	−0.10

Ti 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.	$a\,^3$F–$z\,^5$D° (3)											
		5460.50	387	18695	9	9	6.5(−4) [a]	2.9(−4) [a]	0.047	−2.58	D	1*n*
		5426.26	170	18594	7	7	5.7(−4)	2.5(−4)	0.031	−2.76	D	1*n*
		5490.84	387	18594	9	7	2.2(−4)	7.7(−5)	0.013	−3.16	D	1*n*
		5446.59	170	18525	7	5	3.1(−4)	1.0(−4)	0.013	−3.15	D	1*n*
2.	$a\,^3$F–$z\,^3$F° (4)	*5195.8*	*223*	*19464*	21	21	0.060	0.024	8.7	−0.29	D	1*n*, 2, 3*n*
		5210.39	387	19574	9	9	0.047	0.019	2.9	−0.77	D	3*n*
		5192.97	170	19422	7	7	0.049	0.020	2.4	−0.85	D	3*n*
		5173.74	0	19323	5	5	0.074	0.030	2.5	−0.83	D	2
		5252.11	387	19422	9	7	0.0012	3.7(−4)	0.058	−2.48	D	1*n*
		5219.70	170	19323	7	5	0.0079	0.0023	0.28	−1.79	D	2
		5152.19	170	19574	7	9	0.0049	0.0025	0.30	−1.76	D	3*n*
		5147.48	0	19422	5	7	0.0063	0.0035	0.30	−1.76	D	3*n*
3.	$a\,^3$F–$z\,^3$D° (5)											
		5064.65	387	20126	9	7	0.049	0.015	2.2	−0.88	D	2
		5039.96	170	20006	7	5	0.054	0.015	1.7	−0.99	D	2
		5014.19	0	19938	5	3	0.057	0.013	1.1	−1.19	D	1*n*
		5009.65	170	20126	7	7	0.0024	9.2(−4)	0.11	−2.19	D	1*n*
		4997.10	0	20006	5	5	0.0045	0.0017	0.14	−2.07	D	1*n*
4.	$a\,^3$F–$z\,^3$G° (6)											
		4681.91	387	21740	9	11	0.030	0.012	1.7	−0.96	D+	2
		4667.59	170	21589	7	9	0.030	0.013	1.4	−1.05	D	2
		4656.47	0	21470	5	7	0.018	0.0082	0.63	−1.39	D	4*n*
		4715.30	387	21589	9	9	5.7(−4)	1.9(−4)	0.027	−2.77	D	1*n*
		4693.67	170	21470	7	7	7.9(−4)	2.6(−4)	0.028	−2.74	D	1*n*
5.	$a\,^3$F–$z\,^1$D° (7)											
		4562.64	170	22081	7	5	0.0016	3.6(−4)	0.038	−2.60	D	1*n*
6.	$a\,^3$F–$z\,^1$G° (9)											
		4112.71	387	24695	9	9	0.013	0.0032	0.39	−1.54	D	3*n*

Ti 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
7.	$a\,^3$F–$z\,^5$S° (11)											
		4009.65	170	25103	7	5	0.024	0.0041	0.38	−1.54	D	4*n*
		3982.48	0	25103	5	5	0.050	0.012	0.79	−1.22	D	4*n*
8.	$a\,^3$F–$y\,^3$F° (12)	*3991.8*	*223*	*25267*	21	21	0.47	0.11	31	0.37	D+	2
		3998.64	387	25388	9	9	0.37	0.088	10	−0.10	D+	2
		3989.76	170	25227	7	7	0.37	0.088	8.1	−0.21	D+	2
		3981.76	0	25107	5	5	0.41	0.098	6.4	−0.31	D+	2
		4024.57	387	25227	9	7	0.085	0.016	1.9	−0.84	D	2
		4008.93	170	25107	7	5	0.11	0.019	1.7	−0.88	D+	2
		3964.27	170	25388	7	9	0.051	0.015	1.4	−0.97	D+	2
		3962.85	0	25227	5	7	0.067	0.022	1.4	−0.96	D+	2
9.	$a\,^3$F–$y\,^3$D° (13)	*3953.5*	*223*	*25510*	21	15	0.48	0.080	22	0.23	D+	2, 4*n*
		3958.21	387	25644	9	7	0.39	0.072	8.4	−0.19	D+	2
		3956.34	170	25439	7	5	0.32	0.054	5.0	−0.42	D+	2
		3948.67	0	25318	5	3	0.53	0.074	4.8	−0.43	D+	4*n*
		3924.53	170	25644	7	7	0.087	0.020	1.8	−0.85	D+	2
		3929.88	0	25439	5	5	0.10	0.024	1.6	−0.92	D+	2
		3898.49	0	25644	5	7	0.0029	9.1(−4)	0.059	−2.34	D	2
10.	$a\,^3$F–$z\,^3$P° (14)											
		3947.77	170	25494	7	5	0.13	0.022	2.0	−0.81	D+	4*n*
		3921.42	0	25494	5	5	0.040	0.0091	0.59	−1.34	D+	2
11.	$a\,^3$F–$y\,^5$D° (15)											
		3914.33	387	25927	9	9	0.025	0.0058	0.67	−1.28	D	1*n*
		3900.96	170	25798	7	7	0.024	0.0055	0.49	−1.41	D	4*n*
		3889.95	0	25700	5	5	0.0048	0.0011	0.070	−2.26	D	1*n*
		3934.23	387	25798	9	7	0.042	0.0075	0.87	−1.17	D	1*n*
12.	$a\,^3$F–$y\,^5$G° (16)											
		3788.80	387	26773	9	11	5.4(−4)	1.4(−4)	0.016	−2.89	D	2
13.	$a\,^3$F–$x\,^3$F° (17)	*3743.4*	*223*	*26929*	21	21	0.51	0.11	28	0.36	D+	4*n*
		3752.86	387	27026	9	9	0.43	0.090	10	−0.09	D+	4*n*
		3741.06	170	26893	7	7	0.42	0.088	7.6	−0.21	D+	4*n*
		3729.81	0	26803	5	5	0.45	0.093	5.7	−0.33	D+	4*n*
		3771.65	387	26893	9	7	0.084	0.014	1.6	−0.90	D	4*n*
		3753.62	170	26803	7	5	0.073	0.011	0.95	−1.11	D	4*n*
		3722.57	170	27026	7	9	0.056	0.015	1.3	−0.98	D	4*n*
		3717.39	0	26893	5	7	0.045	0.013	0.80	−1.19	D	4*n*
14.	$a\,^3$F–$x\,^3$D° (18)	*3673.9*	*223*	*27434*	21	15	0.10	0.015	3.7	−0.51	D	2, 4*n*
		3689.92	387	27480	9	7	0.047	0.0074	0.81	−1.18	D	4*n*
		3668.97	170	27418	7	5	0.069	0.0099	0.84	−1.16	D+	2
		3654.59	0	27355	5	3	0.11	0.013	0.78	−1.19	D+	2
		3660.63	170	27480	7	7	0.035	0.0070	0.59	−1.31	D	4*n*
		3646.20	0	27418	5	5	0.038	0.0076	0.46	−1.42	D+	2
		3637.97	0	27480	5	7	0.013	0.0037	0.22	−1.73	D+	2

Ti 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
15.	$a\,^3F$–$y\,^3G^\circ$ (19)	*3646.3*	*223*	*27640*	21	27	0.67	0.17	43	0.55	D+	2
		3653.50	387	27750	9	11	0.56	0.14	15	0.09	D+	2
		3642.68	170	27615	7	9	0.61	0.16	13	0.04	D+	2
		3635.46	0	27499	5	7	0.74	0.20	12	0.01	D+	2
		3671.67	387	27615	9	9	0.065	0.013	1.4	−0.93	D+	2
		3658.10	170	27499	7	7	0.084	0.017	1.4	−0.93	D+	2
		3687.35	387	27499	9	7	0.012	0.0019	0.21	−1.76	D	2
16.	$a\,^3F$–$z\,^5P^\circ$ (20)											
		3635.20	387	27888	9	7	0.013	0.0020	0.22	−1.74	D	1*n*
		3626.09	170	27740	7	5	0.0043	6.1(−4)	0.051	−2.37	D	1*n*
		3606.79	170	27888	7	7	0.0032	6.3(−4)	0.052	−2.36	D	1*n*
17.	$a\,^3F$–$y\,^1D^\circ$ (21)											
		3604.28	170	27907	7	5	0.0066	9.2(−4)	0.076	−2.19	D	1*n*
18.	$a\,^3F$–$y\,^5F^\circ$ (22)											
		3506.64	387	28896	9	11	0.0080	0.0018	0.19	−1.79	D	4*n*
		3493.28	170	28788	7	9	0.0029	6.8(−4)	0.055	−2.32	D	1*n*
19.	$a\,^3F$–$w\,^3D^\circ$	*3378.4*	*223*	*29814*	21	15	0.63	0.077	18	0.21	D	1*n*, 4*n*
		3385.94	387	29912	9	7	0.46	0.061	6.1	−0.26	D	1*n*
		3377.58	170	29769	7	5	0.57	0.070	5.4	−0.31	D	1*n*
		3370.44	0	29661	5	3	0.69	0.071	3.9	−0.45	D+	4*n*
		3361.26	170	29912	7	7	0.071	0.012	0.93	−1.08	D	1*n*
		3358.27	0	29769	5	5	0.071	0.012	0.66	−1.22	D	1*n*
		3342.15	0	29912	5	7	0.040	0.0093	0.51	−1.33	D	1*n*
20.	$a\,^3F$–$x\,^3G^\circ$ (24)	*3359.1*	*223*	*29984*	21	27	0.75	0.16	38	0.54	D+	1*n*, 4*n*
		3371.45	387	30039	9	11	0.72	0.15	15	0.13	D+	4*n*
		3354.63	170	29971	7	9	0.69	0.15	12	0.02	D+	4*n*
		3341.88	0	29915	5	7	0.64	0.15	8.3	−0.12	D	1*n*
		3379.22	387	29971	9	9	0.064	0.011	1.1	−1.00	D	4*n*
		3360.99	170	29915	7	7	0.050	0.0085	0.66	−1.23	D	1*n*
		3385.66	387	29915	9	7	0.049	0.0065	0.65	−1.23	D	1*n*
21.	$a\,^3F$–$x\,^5D^\circ$ (25)											
		3352.94	170	29986	7	7	0.013	0.0022	0.17	−1.81	D	4*n*
		3342.71	0	29907	5	5	0.0055	9.2(−4)	0.051	−2.34	D	1*n*
		3377.49	387	29986	9	7	0.33	0.044	4.4	−0.40	D	1*n*
		3361.84	170	29907	7	5	0.040	0.0049	0.38	−1.46	D	1*n*
		3348.54	0	29855	5	3	0.011	0.0011	0.061	−2.26	D	1*n*
22.	$a\,^3F$–$v\,^3D^\circ$ (26)											
		3243.80	387	31206	9	7	0.0067	8.2(−4)	0.079	−2.13	D	1*n*
		3222.74	170	31191	7	5	0.011	0.0012	0.089	−2.08	D	1*n*
		3205.85	0	31184	5	3	0.016	0.0015	0.079	−2.12	D	1*n*

Ti 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
23.	$a\,^3$F–$w\,^3$G° (27)											
		3199.92	387	31629	9	11	0.96	0.18	17	0.21	D+	4*n*
		3191.99	170	31489	7	9	0.81	0.16	12	0.05	D+	4*n*
		3186.45	0	31374	5	7	0.75	0.16	8.4	−0.10	D+	4*n*
		3214.24	387	31489	9	9	0.084	0.013	1.2	−0.93	D	4*n*
		3203.83	170	31374	7	7	0.084	0.013	0.96	−1.04	D	4*n*
24.	$a\,^3$F–$w\,^3$F° (29)											
		2983.31	170	33680	7	7	0.19	0.026	1.8	−0.74	D	5*n*
25.	$a\,^3$F–$v\,^3$F° (uv 1)											
		2948.26	170	34079	7	7	0.92	0.12	8.2	−0.08	D	5*n*
		2956.80	170	33981	7	5	1.8	0.17	12	0.08	D	5*n*
		2933.53	0	34079	5	7	0.17	0.031	1.5	−0.81	D	5*n*
26.	$a\,^3$F–$u\,^3$D° (uv 5)											
		2644.28	170	37977	7	5	1.9	0.14	8.5	−0.01	D	5*n*
		2641.12	0	37852	5	3	2.1	0.13	5.7	−0.19	D	5*n*
27.	$a\,^3$F–$t\,^3$F° (uv 6)											
		2605.16	170	38544	7	7	0.67	0.068	4.1	−0.32	D	5*n*
		2596.60	170	38671	7	9	0.42	0.054	3.2	−0.42	D	5*n*
28.	$a\,^3$F–$s\,^3$D° (uv 8)											
		2541.92	387	39716	9	7	0.48	0.036	2.7	−0.49	D	5*n*
29.	$a\,^5$F–$y\,^3$F° (35)											
		5361.72	6743	25388	9	9	4.6(−4)	2.0(−4)	0.031	−2.75	D	2
		5384.63	6661	25227	7	7	5.7(−6)	2.5(−6)	3.1(−4)	−4.76	D	2
		5401.32	6599	25107	5	5	0.0012	5.3(−4)	0.047	−2.58	D	2
		5338.33	6661	25388	7	9	8.4(−4)	4.6(−4)	0.057	−2.49	D	2
		5366.65	6599	25227	5	7	0.0020	0.0012	0.11	−2.21	D	2
		5389.18	6557	25107	3	5	0.0070	0.0050	0.27	−1.82	D	2
30.	$a\,^5$F–$y\,^3$D° (36)											
		5289.28	6743	25644	9	7	8.8(−4)	2.9(−4)	0.045	−2.59	D	2
		5323.96	6661	25439	7	5	0.0014	4.3(−4)	0.053	−2.52	D	2
31.	$a\,^5$F–$y\,^5$D° (37)											
		5238.56	6843	25927	11	9	0.0059	0.0020	0.38	−1.66	D	1*n*
		5246.57	6743	25798	9	7	0.0044	0.0014	0.22	−1.90	D	1*n*

Ti 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
32.	$a\,^5F$–$y\,^5G^\circ$ (38)											
		4981.73	6843	26911	11	13	0.51	0.22	40	0.39	D+	2
		4991.07	6743	26773	9	11	0.38	0.17	25	0.19	D	2
		4999.50	6661	26657	7	9	0.45	0.22	25	0.18	D+	2
		5007.21	6599	26564	5	7	0.50	0.26	22	0.12	D+	2
		5014.28	6557	26494	3	5	0.60	0.38	19	0.06	D	1*n*
		5016.16	6843	26773	11	11	0.061	0.023	4.1	−0.60	D	2
		5020.03	6743	26657	9	9	0.14	0.052	7.7	−0.33	D+	2
		5022.87	6661	26564	7	7	0.16	0.060	6.9	−0.38	D	2
		5024.84	6599	26494	5	5	0.15	0.058	4.8	−0.54	D	1*n*
33.	$a\,^5F$–$y\,^3G^\circ$ (41)											
		4781.72	6843	27750	11	11	0.0059	0.0020	0.35	−1.65	D	2
		4758.91	6743	27750	9	11	0.0036	0.0015	0.21	−1.87	D	2
		4783.31	6599	27499	5	7	0.0014	6.8(−4)	0.053	−2.47	D	2
34.	$a\,^5F$–$y\,^5F^\circ$ (42)	*4534.9*	*6722*	*28767*	35	35	1.2	0.36	190	1.10	D	1*n*, 2, 3*n*
		4533.24	6843	28896	11	11	1.0	0.32	53	0.55	D	1*n*
		4534.78	6743	28788	9	9	0.88	0.27	36	0.39	D	1*n*
		4535.57	6661	28703	7	7	0.62	0.19	20	0.12	D	1*n*
		4535.92	6599	28639	5	5	0.55	0.17	13	−0.07	D	1*n*
		4536.05	6557	28596	3	3	0.68	0.21	9.4	−0.20	D	1*n*
		4555.49	6843	28788	11	9	0.16	0.040	6.5	−0.36	D+	2
		4552.45	6743	28703	9	7	0.30	0.073	9.9	−0.18	D+	2
		4548.76	6661	28639	7	5	0.33	0.074	7.8	−0.29	D	1*n*
		4544.69	6599	28596	5	3	0.38	0.070	5.2	−0.46	D	1*n*
		4512.73	6743	28896	9	11	0.12	0.045	6.1	−0.39	D+	2
		4518.02	6661	28788	7	9	0.19	0.075	7.8	−0.28	D	1*n*
		4522.80	6599	28703	5	7	0.28	0.12	8.9	−0.22	D	3*n*
		4527.31	6557	28639	3	5	0.23	0.12	5.4	−0.44	D	1*n*
35.	$a\,^5F$–$w\,^3D^\circ$ (43)											
		4326.36	6661	29769	7	5	0.092	0.018	1.8	−0.89	D	2
		4299.64	6661	29912	7	7	0.087	0.024	2.4	−0.77	D	1*n*
36.	$a\,^5F$–$x\,^5D^\circ$ (44)											
		4305.91	6843	30060	11	9	0.89	0.20	32	0.35	D+	2
		4301.09	6743	29986	9	7	0.93	0.20	25	0.26	D	1*n*
		4300.57	6661	29907	7	5	1.1	0.21	21	0.17	D	1*n*
		4298.66	6599	29855	5	3	1.1	0.18	13	−0.05	D	1*n*
		4295.75	6557	29829	3	1	1.6	0.15	6.2	−0.36	D+	2
		4287.41	6743	30060	9	9	0.22	0.061	7.7	−0.26	D	1*n*
		4286.01	6661	29986	7	7	0.30	0.082	8.1	−0.24	D+	2
		4289.07	6599	29907	5	5	0.42	0.12	8.1	−0.24	D+	2
		4290.93	6557	29855	3	3	0.58	0.16	6.8	−0.32	D	1*n*
		4281.37	6557	29907	3	5	0.057	0.026	1.1	−1.11	D	1*n*
37.	$a\,^1D$–$z\,^1D^\circ$ (48)	6743.12	7255	22081	5	5	0.010	0.0068	0.75	−1.47	D	1*n*
38.	$a\,^1D$–$z\,^1F^\circ$ (49)	6599.11	7255	22405	5	7	0.0024	0.0022	0.24	−1.96	D	1*n*

Ti 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
39.	$a\,^1D$–$y\,^3D°$ (51)											
		5436.70	7255	25644	5	7	7.9(−4)	4.9(−4)	0.044	−2.61	D	2
40.	$a\,^1D$–$y\,^1D°$ (53)	4840.87	7255	27907	5	5	0.20	0.071	5.7	−0.45	D	2
41.	$a\,^1D$–$y\,^1F°$ (56)	3904.79	7255	32858	5	7	0.67	0.21	14	0.03	D+	2
42.	$a\,^1D$–$z\,^1P°$ (57)	3786.04	7255	33661	5	3	1.6	0.20	12	0.00	D	1*n*
43.	$a\,^1D$–$y\,^1P°$ (58)	3610.15	7255	34947	5	3	0.74	0.087	5.2	−0.36	D+	2
44.	$a\,^1D$–$x\,^1D°$ (59)	3598.71	7255	35035	5	5	0.15	0.028	1.7	−0.85	D+	2
45.	$a\,^1D$–$x\,^1F°$ (62)	3292.08	7255	37623	5	7	0.66	0.15	8.1	−0.12	D	1*n*
46.	$a\,^1D$–$x\,^1P°$ (66)	3141.54	7255	39078	5	3	0.70	0.062	3.2	−0.51	D	1*n*
47.	$a\,^1D$–$w\,^1D°$ (67)	3123.07	7255	39266	5	5	0.54	0.079	4.1	−0.40	D	1*n*
48.	$a\,^1D$–$v\,^1F°$ (uv 23)	2912.07	7255	41585	5	7	1.3	0.24	12	0.08	D	5*n*
49.	$a\,^3P$–$z\,^3S°$ (69)	*6105.6*	*8547*	24921	9	3	0.071	0.013	2.4	−0.92	D	1*n*
		6126.22	8602	24921	5	3	0.033	0.011	1.1	−1.26	D	1*n*
		6085.23	8492	24921	3	3	0.027	0.015	0.90	−1.35	D	1*n*
		6064.63	8437	24921	1	3	0.013	0.021	0.42	−1.68	D	1*n*
50.	$a\,^3P$–$z\,^3P°$ (71)											
		5918.55	8602	25494	5	5	0.013	0.0070	0.68	−1.46	D	1*n*
		5880.31	8492	25494	3	5	0.0081	0.0070	0.41	−1.68	D	1*n*
51.	$a\,^3P$–$y\,^3D°$ (72)											
		5866.45	8602	25644	5	7	0.075	0.054	5.2	−0.57	D	2
		5899.30	8492	25439	3	5	0.055	0.048	2.8	−0.84	D	2
		5922.11	8437	25318	1	3	0.034	0.053	1.0	−1.28	D	1*n*
		5937.81	8602	25439	5	5	0.0095	0.0050	0.49	−1.60	D	2
		5941.76	8492	25318	3	3	0.025	0.013	0.76	−1.41	D	1*n*
52.	$a\,^3P$–$x\,^3D°$ (74)											
		5295.78	8602	27480	5	7	0.016	0.0096	0.84	−1.32	D	1*n*
		5282.38	8492	27418	3	5	0.014	0.0099	0.52	−1.53	D	1*n*
		5284.38	8437	27355	1	3	0.017	0.021	0.37	−1.68	D	1*n*

Ti 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
53.	$a\,^3P$–$w\,^3D°$ (75)											
		4691.34	8602	29912	5	7	0.063	0.029	2.2	−0.84	D	3*n*
		4698.77	8492	29769	3	5	0.11	0.058	2.7	−0.76	D	3*n*
54.	$a\,^3P$–$x\,^5D°$ (77)											
		4675.12	8602	29986	5	7	0.033	0.015	1.2	−1.12	D	3*n*
55.	$a\,^3P$–$x\,^3P°$ (80)											
		4078.47	8602	33114	5	5	0.40	0.10	6.7	−0.30	D	3*n*
		4082.46	8602	33091	5	3	0.23	0.035	2.4	−0.76	D	3*n*
56.	$a\,^3P$–$y\,^3S°$ (83)											
		3725.16	8602	35439	5	3	1.1	0.14	8.6	−0.15	D	1*n*
		3709.96	8492	35439	3	3	0.68	0.14	5.1	−0.38	D	1*n*
57.	$a\,^3P$–$w\,^3P°$ (84)											
		3480.53	8602	37325	5	5	0.42	0.077	4.4	−0.41	D	1*n*
58.	$a\,^3P$–$u\,^3D°$ (86)											
		3382.31	8602	38160	5	7	0.38	0.092	5.1	−0.34	D	1*n*
59.	$a\,^3P$–$t\,^3D°$ (87)											
		3314.42	8602	38765	5	7	1.3	0.31	17	0.19	D	1*n*
		3309.50	8492	38700	3	5	1.1	0.31	10	−0.03	D	1*n*
		3308.39	8437	38654	1	3	0.79	0.39	4.2	−0.41	D	1*n*
		3314.52	8492	38654	3	3	0.73	0.12	3.9	−0.44	D	1*n*
60.	$a\,^3P$–$t\,^3P°$ (uv 32)											
		2733.27	8602	45178	5	5	2.0	0.22	10	0.04	D	5*n*
		2735.30	8492	45041	3	1	4.3	0.16	4.3	−0.32	D	5*n*
61.	$b\,^3F$–$z\,^3F°$											
		12831.5	11532	19323	5	5	0.0063	0.016	3.3	−1.11	D−	2
62.	$b\,^3F$–$y\,^3F°$ (97)											
		7344.72	11777	25388	9	9	0.028	0.023	4.9	−0.69	D	2
		7357.74	11640	25227	7	7	0.022	0.018	3.0	−0.91	D	2
		7364.11	11532	25107	5	5	0.036	0.030	3.6	−0.83	D	2
		7271.41	11640	25388	7	9	0.0028	0.0029	0.49	−1.69	D	2
		7299.67	11532	25227	5	7	0.011	0.012	1.4	−1.23	D	2
63.	$b\,^3F$–$y\,^3D°$ (99)											
		7209.44	11777	25644	9	7	0.10	0.061	13	−0.26	D	2
		7244.86	11640	25439	7	5	0.075	0.042	7.0	−0.53	D	2
		7138.91	11640	25644	7	7	0.0084	0.0064	1.0	−1.35	D	2
		7188.55	11532	25439	5	5	0.013	0.010	1.2	−1.29	D	2

Ti 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
64.	$b\,^3F-y\,^5G^\circ$ (101)											
		6666.55	11777	26773	9	11	0.0031	0.0025	0.50	−1.64	D	2
65.	$b\,^3F-x\,^3F^\circ$ (102)											
		6556.07	11777	27026	9	9	0.019	0.012	2.3	−0.97	D	1*n*
66.	$b\,^3F-y\,^3G^\circ$ (104)											
		6258.71	11777	27750	9	11	0.12	0.086	16	−0.11	D	2
		6258.10	11640	27615	7	9	0.090	0.068	9.8	−0.32	D	1*n*
		6261.10	11532	27499	5	7	0.14	0.12	12	−0.23	D	2
		6303.75	11640	27499	7	7	0.015	0.0090	1.3	−1.20	D	2
67.	$b\,^3F-w\,^3D^\circ$ (106)											
		5512.53	11777	29912	9	7	0.14	0.050	8.1	−0.35	D	2
		5514.54	11640	29769	7	5	0.27	0.087	11	−0.22	D	1*n*
		5514.35	11532	29661	5	3	0.33	0.090	8.2	−0.35	D	1*n*
68.	$b\,^3F-x\,^5D^\circ$ (107)											
		5490.15	11777	29986	9	7	0.065	0.023	3.7	−0.68	D	1*n*
69.	$b\,^3F-v\,^3D^\circ$ (109)											
		5145.47	11777	31206	9	7	0.10	0.032	4.9	−0.54	D	3*n*
		5113.45	11640	31191	7	5	0.14	0.039	4.6	−0.56	D	2
		5087.06	11532	31184	5	3	0.14	0.032	2.7	−0.80	D	3*n*
70.	$b\,^3F-w\,^3G^\circ$ (110)											
		5035.91	11777	31629	9	11	0.43	0.20	30	0.26	D	1*n*
		5036.47	11640	31489	7	9	0.41	0.20	23	0.15	D	1*n*
		5038.40	11532	31374	5	7	0.45	0.24	20	0.08	D	2
71.	$b\,^3F-v\,^3F^\circ$ (113)											
		4457.43	11777	34205	9	9	0.69	0.21	27	0.27	D+	2
		4455.32	11640	34079	7	7	0.66	0.20	20	0.14	D+	2
72.	$a\,^1G-y\,^1F^\circ$ (126)	4820.41	12118	32858	9	7	0.17	0.046	6.6	−0.38	D	2
73.	$a\,^1G-z\,^1H^\circ$ (128)	4427.10	12118	34700	9	11	0.53	0.19	25	0.23	D+	2
74.	$a\,^1G-x\,^1G^\circ$ (131)	3724.57	12118	38960	9	9	1.3	0.27	30	0.39	D	1*n*
75.	$a\,^5P-w\,^5D^\circ$ (145)											
		4617.27	14106	35758	7	9	0.83	0.34	36	0.38	D+	2
		4623.10	14028	35653	5	7	0.62	0.28	21	0.14	D+	2
		4629.34	13982	35577	3	5	0.37	0.20	9.0	−0.23	D+	2
		4650.02	14028	35528	5	3	0.28	0.055	4.2	−0.56	D	3*n*
		4645.19	13982	35503	3	1	1.0	0.11	5.0	−0.48	D	3*n*

Ti 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
76.	$a\,^5P$–$y\,^5P°$ (146)											
		4496.15	14106	36341	7	5	0.55	0.12	12	−0.08	D	3*n*
		4465.81	14028	36415	5	7	0.42	0.17	13	−0.06	D+	2
77.	$a\,^5P$–$y\,^5S°$ (148)											
		4284.99	14028	37359	5	5	0.58	0.16	11	−0.10	D+	2
		4276.44	13982	37359	3	5	0.37	0.17	7.2	−0.29	D	2
78.	$a\,^3G$–$y\,^3F°$ (149)											
		9832.15	15220	25388	11	9	0.019	0.022	7.9	−0.61	D	2
		9927.35	15157	25227	9	7	0.020	0.023	6.8	−0.68	D	2
		9997.94	15108	25107	7	5	0.0042	0.0045	1.0	−1.50	D	2
79.	$a\,^3G$–$y\,^3G°$ (151)											
		8068.24	15108	27499	7	7	0.031	0.031	5.7	−0.67	D	2
80.	$a\,^3G$–$z\,^3H°$ (154)											
		5953.16	15220	32014	11	13	0.10	0.064	14	−0.15	D	2
		5965.83	15157	31914	9	11	0.13	0.086	15	−0.11	D	2
		5978.54	15108	31830	7	9	0.091	0.062	8.6	−0.36	D	2
81.	$a\,^3G$–$w\,^3F°$ (155)											
		5409.61	15220	33701	11	9	0.067	0.024	4.7	−0.58	D	3*n*
82.	$a\,^3G$–$v\,^3F°$ (156)											
		5265.97	15220	34205	11	9	0.11	0.039	7.4	−0.37	D	3*n*
		5283.44	15157	34079	9	7	0.22	0.070	11	−0.20	D	1*n*
		5297.24	15108	33981	7	5	0.28	0.085	10	−0.23	D	1*n*
83.	$a\,^3G$–$y\,^3H°$ (157)											
		4885.08	15220	35685	11	13	0.53	0.22	39	0.39	D+	2
		4899.91	15157	35560	9	11	0.46	0.20	29	0.26	D	2
		4913.62	15108	35454	7	9	0.46	0.22	24	0.18	D	2
84.	$a\,^3G$–$x\,^1F°$ (159)											
		4440.35	15108	37623	7	7	0.29	0.086	8.8	−0.22	D+	2
85.	$a\,^3G$–$v\,^3G°$ (160)											
		4449.14	15220	37690	11	11	0.86	0.26	41	0.45	D+	2
		4463.54	15220	37618	11	9	0.20	0.049	7.9	−0.27	D	2
86.	$a\,^3G$–$t\,^3F°$ (162)											
		4263.13	15220	38671	11	9	0.74	0.17	26	0.26	D+	2
		4282.70	15108	38451	7	5	0.89	0.18	17	0.09	D+	2

Ti 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
87.	$z\,^5G^\circ$–$e\,^5F$ (173)											
		4973.05	16106	36209	9	9	0.11	0.039	5.7	−0.45	D	3*n*
		4968.57	15976	36096	7	7	0.14	0.052	6.0	−0.44	D	3*n*
		4964.71	15877	36014	5	5	0.14	0.052	4.2	−0.59	D	3*n*
88.	$z\,^5G^\circ$–$e\,^5G$ (175)											
		3911.19	16459	42019	13	13	0.16	0.036	6.0	−0.33	D+	2
89.	$z\,^5G^\circ$–$e\,^5H$ (176)											
		3858.13	16106	42018	9	11	0.55	0.15	17	0.13	D	3*n*
		3895.24	16459	42124	13	13	0.37	0.084	14	0.04	D	2
90.	$z\,^5F^\circ$–$e\,^5F$ (183)											
		5255.81	17075	36096	9	7	0.13	0.042	6.5	−0.42	D	3*n*
		5201.10	16875	36096	5	7	0.12	0.067	5.7	−0.47	D	3*n*
91.	$z\,^5F^\circ$–$e\,^5G$ (185)											
		4030.51	17215	42019	11	13	0.49	0.14	20	0.19	D	3*n*
		4026.54	17075	41903	9	11	0.36	0.11	13	−0.02	D+	2
		4021.81	16961	41819	7	9	0.48	0.15	14	0.02	D+	2
		4017.77	16875	41757	5	7	0.45	0.15	10	−0.12	D	2
		4015.38	16817	41714	3	5	0.57	0.23	9.1	−0.16	D+	2
		4040.31	17075	41819	9	9	0.13	0.031	3.7	−0.55	D	3*n*
92.	$z\,^5F^\circ$–$e\,^5H$ (187)											
		4013.59	17215	42124	11	13	0.22	0.063	9.1	−0.16	D	2
93.	$z\,^5F^\circ$–$e\,^5D$ (188)											
		4003.79	17215	42185	11	9	0.41	0.081	12	−0.05	D+	2
		4002.47	17075	42053	9	7	0.47	0.088	10	−0.10	D+	2
94.	$a\,^3D$–$y\,^3F^\circ$											
		12738.6	17540	25388	7	9	0.0026	0.0080	2.4	−1.25	D−	2
		12811.9	17424	25227	5	7	0.0088	0.030	6.4	−0.82	D−	2
		12919.9	17370	25107	3	5	0.0048	0.020	2.6	−1.22	D−	2
95.	$a\,^3D$–$w\,^3P^\circ$ (199)											
		5052.88	17540	37325	7	5	0.34	0.093	11	−0.19	D	3*n*
		5062.11	17424	37173	5	3	0.42	0.096	8.0	−0.32	D	3*n*
96.	$a\,^3D$–$u\,^3F^\circ$ (200)											
		4921.77	17540	37852	7	9	0.30	0.14	16	−0.01	D	3*n*
		4919.87	17424	37744	5	7	0.30	0.15	12	−0.12	D	3*n*
		4928.34	17370	37655	3	5	0.54	0.33	16	0.00	D	3*n*

Ti 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
97.	$a\,^3D$–$u\,^3D^\circ$ (201)											
		4848.49	17540	38160	7	7	0.22	0.079	8.8	−0.26	D	3*n*
98.	$a\,^3D$–$t\,^3F^\circ$ (202)											
		4731.17	17540	38671	7	9	0.13	0.056	6.1	−0.41	D	3*n*
99.	$a\,^3D$–$v\,^3P^\circ$ (204)											
		4360.49	17540	40467	7	5	0.32	0.066	6.6	−0.34	D	3*n*
		4354.06	17424	40385	5	3	0.34	0.058	4.2	−0.54	D	3*n*
100.	$a\,^3D$–$u\,^3P^\circ$ (207)											
		4099.17	17540	41929	7	5	0.41	0.074	7.0	−0.29	D	3*n*
101.	$b\,^3P$–$u\,^3P^\circ$ (220)											
		4203.47	18145	41929	5	5	0.35	0.093	6.4	−0.33	D	3*n*
102.	$a\,^3H$–$y\,^5G^\circ$											
		11651.3	18193	26773	13	11	0.0030	0.0052	2.6	−1.17	D −	2
103.	$a\,^3H$–$y\,^3G^\circ$ (223)											
		10460.1	18193	27750	13	11	0.0031	0.0043	1.9	−1.25	D −	2
		10566.0	18037	27499	9	7	0.0062	0.0080	2.5	−1.14	D −	2
		10404.2	18141	27750	11	11	6.1(−4)	0.0010	0.38	−1.96	D −	2
104.	$a\,^3H$–$y\,^1G^\circ$ (229)											
		5565.48	18037	36000	9	9	0.14	0.065	11	−0.23	D	2
105.	$a\,^3H$–$z\,^3I^\circ$ (231)											
		4856.01	18193	38780	13	15	0.59	0.24	50	0.49	D	3*n*
		4870.13	18141	38669	11	13	0.48	0.20	35	0.34	D	3*n*
		4868.26	18037	38573	9	11	0.41	0.18	26	0.21	D	3*n*
106.	$a\,^3H$–$x\,^3H^\circ$ (233)											
		4759.27	18193	39198	13	13	0.82	0.28	57	0.56	D +	2
		4758.12	18141	39152	11	11	0.77	0.26	45	0.46	D +	2
		4742.79	18037	39116	9	9	0.56	0.19	27	0.23	D +	2
107.	$a\,^3H$–$u\,^3G^\circ$ (235)											
		4318.63	18193	41342	13	11	0.76	0.18	33	0.37	D +	2
		4325.13	18141	41255	11	9	0.72	0.17	26	0.26	D +	2
		4321.66	18037	41170	9	7	0.61	0.13	17	0.08	D	2
108.	$b\,^1G$–$y\,^1G^\circ$ (240)	5644.14	18288	36000	9	9	0.25	0.12	20	0.03	D	3*n*

Ti 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
109.	$b\ ^1G$–$x\ ^1G^\circ$ (241)	4836.13	18288	38960	9	9	0.12	0.043	6.2	−0.41	D	3*n*
110.	$b\ ^1G$–$v\ ^1G^\circ$ (246)	3938.01	18288	43674	9	9	0.24	0.056	6.5	−0.30	D	3*n*
111.	$z\ ^5D^\circ$–$e\ ^5F$ (249)											
		5675.41	18594	36209	7	9	0.16	0.099	13	−0.16	D	3*n*
		5689.47	18525	36096	5	7	0.14	0.096	9.0	−0.32	D	3*n*
		5702.67	18483	36014	3	5	0.15	0.12	6.8	−0.44	D	3*n*
112.	$z\ ^5D^\circ$–$g\ ^3F$ (251)											
		4270.14	18695	42107	9	9	0.27	0.075	9.5	−0.17	D	2
113.	$z\ ^5D^\circ$–$e\ ^5D$ (252)											
		4256.03	18695	42185	9	9	0.63	0.17	22	0.19	D	2
		4249.11	18525	42053	5	7	0.26	0.10	7.0	−0.30	D	3*n*
		4258.52	18483	41959	3	5	0.42	0.19	8.0	−0.24	D	3*n*
114.	$z\ ^5D^\circ$–$e\ ^5P$ (253)											
		4137.28	18695	42859	9	7	0.65	0.13	16	0.07	D	3*n*
115.	$c\ ^3P$–$y\ ^3D^\circ$											
		14850.0	18912	25644	5	7	0.0039	0.018	4.4	−1.05	D −	2
		15117.5	18826	25439	3	5	0.0034	0.020	2.9	−1.23	D −	2
116.	$c\ ^3P$–$w\ ^3P^\circ$ (259)											
		5429.14	18912	37325	5	5	0.16	0.072	6.4	−0.44	D	3*n*
117.	$c\ ^3P$–$s\ ^3D^\circ$ (260)											
		4792.48	18826	39686	3	5	0.47	0.27	13	−0.09	D	3*n*
118.	$z\ ^3F^\circ$–$e\ ^3F$ (265)											
		5477.70	19574	37825	9	9	0.22	0.098	16	−0.05	D	3*n*
		5488.21	19323	37539	5	5	0.22	0.10	9.0	−0.30	D	3*n*
119.	$z\ ^3D^\circ$–$e\ ^3F$ (269)											
		5648.57	20126	37825	7	9	0.15	0.093	12	−0.19	D	3*n*
120.	$a\ ^1P$–$w\ ^1D^\circ$ (276)	5206.06	20063	39266	3	5	5.8	3.9	200	1.07	D	1*n*
121.	$a\ ^1P$–$w\ ^1P^\circ$ (277)	4372.38	20063	42928	3	3	0.77	0.22	9.5	−0.18	D	3*n*
122.	$b\ ^1D$–$w\ ^1F^\circ$ (283)	4975.34	20210	40303	5	7	0.62	0.32	26	0.20	D	3*n*

Ti 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
123.	b ^{1}D–v ^{1}D° (284)	4237.89	20210	43710	5	5	1.2	0.31	22	0.19	D +	2
124.	a ^{1}H–x ^{1}G° (287)	5503.90	20796	38960	11	9	0.27	0.099	20	0.04	D	3n
125.	a ^{1}H–z ^{1}I° (288)	5120.42	20796	40320	11	13	0.47	0.22	40	0.38	D	2
126.	a ^{1}H–x ^{1}H° (291)	4278.23	20796	44163	11	11	0.20	0.055	8.5	−0.22	D +	2
127.	a ^{1}H–u ^{1}G° (292)	3926.32	20796	46258	11	9	0.78	0.15	21	0.21	D +	2
128.	z ^{1}D°–e ^{1}F (298)	5259.98	22081	41087	5	7	0.28	0.16	14	−0.10	D	3n
129.	z ^{1}F°–e ^{1}F (300)	5351.07	22405	41087	7	7	0.35	0.15	18	0.02	D	3n
130.	z ^{1}F°–e ^{1}G (301)	4224.80	22405	46068	7	9	0.47	0.16	16	0.05	D +	2
131.	z ^{1}G°–e ^{1}H (305)	4808.53	24695	45485	9	11	0.33	0.14	20	0.10	D	3n

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

Ti II

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

Ionization Potential 13.58 eV = 109506 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
2440.21	78	2820.36	21	3059.74	5, 51	3214.14	80
2442.67	78	2821.41	102	3063.50	51	3214.75	3
2447.92	78	2827.22	102	3066.22	5	3217.06	2
2450.44	78	2828.15	103	3066.35	5	3218.27	80
2474.22	7	2828.80	102	3066.51	51	3222.84	2
2477.21	7	2828.87	103	3071.24	51	3224.24	80
2478.64	7	2832.16	21	3072.11	5	3226.77	3
2481.49	24	2834.14	102	3072.97	5	3228.61	30
2498.94	24	2836.60	102	3075.23	5	3229.19	2
2510.90	12	2839.70	103	3078.65	5	3229.40	41
2517.45	12	2841.91	21	3081.58	101	3231.32	10
2519.79	12	2844.09	102	3088.03	5	3232.28	41
2524.66	12	2846.09	102	3089.40	86	3234.52	2
2525.62	12	2851.09	61	3096.42	75	3236.12	30
2529.74	12	2853.92	21	3097.19	68	3236.57	2
2531.27	12	2855.49	102	3101.52	60	3239.04	2
2534.64	12	2856.24	102	3102.98	60	3239.66	30
2535.88	12	2856.62	77	3103.80	86	3241.98	2
2555.99	23	2858.40	20	3104.59	86	3248.60	67
2571.04	23	2861.29	61	3105.08	68	3249.37	29
2573.72	23	2862.34	61	3106.23	68	3251.91	2
2635.60	108	2868.73	19	3110.10	75	3252.91	2
2638.70	108	2874.08	42	3110.62	68	3254.25	2
2642.15	108	2877.42	42	3112.05	68	3260.26	50
2646.08	108	2880.28	77	3117.67	68	3261.60	67, 85
2713.76	35	2884.10	42	3118.82	33	3263.69	50
2716.20	35	2887.46	42	3119.80	68	3271.65	67
2717.30	43	2888.92	19	3121.60	4	3272.08	67
2719.39	35	2891.05	19	3122.07	60	3275.29	29
2725.79	43	2909.91	6	3127.88	109	3276.77	50
2730.95	92	2910.76	106	3128.64	109	3278.29	67
2738.70	92	2918.77	110	3130.80	4	3278.92	29
2746.70	111	2926.75	106	3143.76	4	3280.00	40
2751.70	111	2931.27	110	3144.73	97	3282.33	67
2752.85	114	2936.17	105	3144.74	11	3286.76	85
2757.62	114	2938.69	105	3145.40	11	3287.66	85
2758.35	114	2941.99	105	3148.03	4	3288.43	67
2758.93	114	2943.12	110	3152.25	11	3288.58	67
2761.29	34	2945.47	105	3154.20	11	3301.71	49
2762.22	34	2952.10	105	3155.67	11	3308.81	9
2762.92	114	2954.76	117	3157.40	4	3312.90	59
2763.90	22	2958.30	105	3161.21	11	3315.32	66
2764.28	114	2958.98	117	3161.76	11	3318.02	9
2764.82	34	2979.20	113	3162.57	11	3321.70	66
2778.48	107	2990.17	113	3168.52	11	3322.94	9
2780.55	22	3008.32	81	3181.84	112	3326.76	9
2782.30	107	3017.19	81	3182.57	112	3329.46	9
2784.65	22	3022.82	116	3184.09	3	3332.11	66
2785.99	107	3023.86	116	3189.52	104	3335.19	9
2788.00	107	3029.73	81	3190.87	32	3337.85	58
2790.62	107	3038.71	81	3192.26	31	3340.34	9
2800.65	107	3043.85	76	3195.72	31	3341.88	18
2805.00	103	3046.69	51	3197.52	3	3343.77	9
2806.41	62	3048.77	76	3202.54	32	3346.72	9
2810.28	103	3056.74	51	3203.44	3	3348.84	9
2817.84	103	3057.40	5	3205.99	32	3349.04	18
2819.99	103	3058.09	51	3213.15	3	3349.40	1

List of tabulated lines—Continued

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
3352.07	57	3561.91	48	4025.14	13	4441.73	46
3361.21	1	3565.33	74	4028.33	83	4443.80	26
3366.18	57	3566.00	48	4053.81	83	4444.56	37
3369.21	65	3573.74	17	4161.52	28	4450.49	26
3372.21	18	3587.13	17	4163.64	95	4464.46	46
3372.80	1	3593.09	74	4171.90	95	4468.49	37
3374.35	57	3596.05	17	4174.09	95	4470.86	46
3380.28	1	3624.83	55	4287.89	27	4488.32	100
3383.76	1	3641.33	55	4290.22	47	4493.53	25
3387.83	1	3659.77	73	4294.10	27	4501.27	37
3388.76	56	3662.24	73	4300.05	47	4529.47	79
3394.57	1	3679.67	73	4301.93	47	4533.97	53
3402.42	56	3685.19	16	4307.90	47	4549.62	79
3407.21	1	3706.22	72	4312.86	47	4563.76	53
3409.81	1	3721.63	15	4314.98	47	4568.31	63
3416.96	56	3741.63	71	4320.97	47	4571.97	79
3443.39	91	3748.01	96	4330.71	47	4580.46	63
3444.31	8	3757.68	71	4337.92	27	4583.44	45
3452.47	91	3759.29	15	4341.37	38	4589.96	53
3456.39	91	3761.32	15	4344.29	27	4629.29	44
3461.50	8	3761.87	96	4350.83	89	4708.66	52
3465.56	91	3770.41	96	4367.66	94	4779.99	87
3477.18	8	3774.65	14	4374.83	88	4805.11	87
3483.80	115	3776.06	71	4386.86	94	4865.62	36
3489.74	8	3786.33	14	4390.98	64	4874.03	99
3491.05	8	3796.90	14	4394.06	54	4911.21	99
3492.39	115	3799.81	15	4395.03	26	5072.30	98
3500.34	8	3813.39	14	4395.85	64	5129.14	82
3504.89	84	3814.58	14	4399.77	54	5154.06	70
3505.90	84	3882.28	39	4407.68	54	5185.90	82
3509.84	84	3900.55	39	4411.08	100	5188.70	70
3510.84	84	3913.46	39	4417.72	46	5226.53	70
3520.25	90	3932.01	39	4418.34	54	5268.62	93
3533.87	90	3987.63	13	4421.95	88	5336.81	69
3535.41	90	4012.37	13	4432.09	54	5381.02	69
3561.58	17						

For this ion, the selected data are all experimental and are principally based on the extensive measurements of Roberts, Andersen, and Sørensen [1] and Roberts, Voigt, and Czernichowski [3]. The data have been obtained by a comprehensive experimental approach, in which an emission method using a stabilized arc for the measurement of *relative* oscillator strengths is combined with a lifetime experiment using the beam-foil technique to obtain an accurate absolute scale. In the earlier work of Roberts et al. [1], a gas-flow stabilized arc was used, which was replaced in the later work [3], with a wall-stabilized arc. With this more advanced arc source, the temperature of the plasma was determined spectroscopically and a uniform scale for all relative f-values was established. By remeasuring selected lines of reference [1], the earlier data were also normalized to the same absolute scale.

The results of shock-tube emission measurements by Wolnik and Berthel [2] were used for ten additional lines not measured in papers [1] or [3]. For 18 other lines, the data of Wolnik and Berthel and of Roberts, Andersen, and Sørensen overlapped. Here the agreement was within 50 percent, except for a few of the weaker lines.

Since Roberts et al. present a detailed error budget, which includes uncertainty estimates for the temperature and lifetime determinations, line intensity calibrations, the (partial) thermodynamic equilibrium assumption, and general statistical measurement errors, we follow their error estimates closely. For all lines originating from the highest energy levels, i.e., for states approximately 8 eV above the ground state, the uncertainties become rather large since these lines are quite sensitive to temperature errors.

When feasible, we have completed the data within multiplets by applying LS-coupling ratios, after we found that LS-coupling is a fairly good description for the relative intensities within multiplets. We checked this for a large number of multiplets by comparing the measured line strengths (from references [1–3]) with the corresponding LS-coupling data. We found in all cases that LS-coupling is well approximated, the agreement being within 25 percent for the stronger lines.

References

[1] Roberts, J. R., Andersen, T., and Sørensen, G., Astrophys. J. **181**, 567 (1973).

[2] Wolnik, S. J., and Berthel, R. O., Astrophys. J. **179**, 665 (1973).

[3] Roberts, J. R., Voigt, P. A., and Czernichowski, A., to be published in Astrophys. J. (1975).

Ti 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.	$a\,^4F-z\,^4G^\circ$ (1)	*3364.8*	*225*	*29936*	28	36	1.3	0.29	91	0.91	D	1*n*, 3
		3349.40	393	30241	10	12	1.3	0.27	30	0.43	D	1*n*, *ls*
		3361.21	225	29968	8	10	1.2	0.26	23	0.31	D	1*n*, *ls*
		3372.80	94	29734	6	8	1.1	0.25	16	0.17	C	3
		3383.76	0	29544	4	6	1.1	0.28	12	0.05	C	3
		3380.28	393	29968	10	10	0.161	0.0275	3.06	−0.56	C	3
		3387.83	225	29734	8	8	0.25	0.043	3.9	−0.46	C	3
		3394.57	94	29544	6	6	0.237	0.0409	2.74	−0.61	C	3
		3407.21	393	29734	10	8	0.0081	0.0011	0.13	−1.95	D	3
		3409.81	225	29544	8	6	0.012	0.0016	0.14	−1.89	D	3
2.	$a\,^4F-z\,^4F^\circ$ (2)	*3237.1*	*225*	*31108*	28	28	1.58	0.248	74	0.84	C	1*n*, 3
		3234.52	393	31301	10	10	1.3	0.20	22	0.31	C	3
		3236.57	225	31114	8	8	1.2	0.18	15	0.16	C	1*n*
		3239.04	94	30959	6	6	1.0	0.16	10	−0.02	C	3
		3241.98	0	30837	4	4	1.2	0.19	8.1	−0.12	C	3
		3254.25	393	31114	10	8	0.202	0.0257	2.75	−0.59	C	3
		3252.91	225	30959	8	6	0.41	0.049	4.2	−0.41	C	3
		3251.91	94	30837	6	4	0.345	0.0365	2.34	−0.66	C	3
		3217.06	225	31301	8	10	0.186	0.0361	3.05	−0.54	C	3
		3222.84	94	31114	6	8	0.26	0.054	3.4	−0.49	C	3
		3229.19	0	30959	4	6	0.29	0.067	2.9	−0.57	D	1*n*, *ls*
3.	$a\,^4F-z\,^2F^\circ$ (3)											
		3214.75	393	31491	10	8	0.036	0.0045	0.47	−1.35	C	3
		3226.77	225	31207	8	6	0.018	0.0021	0.18	−1.78	D	3
		3197.52	225	31491	8	8	0.011	0.0016	0.14	−1.88	D	3
		3213.15	94	31207	6	6	0.0062	9.6(−4)[a]	0.061	−2.24	D	1*n*
		3184.09	94	31491	6	8	0.0047	9.6(−4)	0.060	−2.24	D	1*n*
		3203.44	0	31207	4	6	0.021	0.0049	0.21	−1.71	D	1*n*
4.	$a\,^4F-z\,^2D^\circ$ (4)											
		3143.76	225	32026	8	6	0.063	0.0070	0.58	−1.25	C	1*n*
		3157.40	94	31757	6	4	0.012	0.0012	0.077	−2.13	D	3
		3130.80	94	32026	6	6	0.084	0.012	0.76	−1.13	C	1*n*
		3148.03	0	31757	4	4	0.11	0.016	0.65	−1.20	C	3
		3121.60	0	32026	4	6	0.0060	0.0013	0.054	−2.28	D	1*n*
5.	$a\,^4F-z\,^4D^\circ$ (5)	*3079.4*	*225*	*32690*	28	20	1.51	0.153	43.5	0.63	C	1*n*, 3
		3088.03	393	32767	10	8	1.3	0.14	15	0.16	C	3
		3078.65	225	32698	8	6	1.1	0.12	9.9	−0.01	C	3
		3075.23	94	32603	6	4	1.2	0.11	6.7	−0.18	C	3
		3072.97	0	32532	4	2	1.6	0.11	4.6	−0.34	C	3
		3072.11	225	32767	8	8	0.202	0.0286	2.32	−0.64	C	3
		3066.22	94	32698	6	6	0.30	0.043	2.6	−0.59	D	1*n*, *ls*
		3066.35	0	32603	4	4	0.35	0.049	2.0	−0.71	D	1*n*, *ls*
		3059.74	94	32767	6	8	0.012	0.0023	0.14	−1.86	D	1*n*, *ls*
		3057.40	0	32698	4	6	0.023	0.0049	0.20	−1.71	D	1*n*

Ti 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
6.	a ^{4}F–z ^{2}G° (uv 1)											
		2909.91	393	34749	10	10	0.0079	0.0010	0.096	−2.00	D	3
7.	a ^{4}F–y ^{4}D° (uv 2)											
		2474.22	393	40798	10	8	0.0057	4.2(−4)	0.034	−2.38	D	1*n*
		2477.21	225	40582	8	6	0.0079	5.5(−4)	0.036	−2.36	D	1*n*
		2478.64	94	40426	6	4	0.016	0.0010	0.049	−2.22	D	1*n*
8.	b ^{4}F–z ^{4}G° (6)											
		3444.31	1216	30241	10	12	0.076	0.0162	1.84	−0.79	C	1*n*
		3461.50	1087	29968	8	10	0.073	0.0165	1.50	−0.88	C	3
		3477.18	984	29734	6	8	0.071	0.0171	1.17	−0.99	C	3
		3491.05	908	29544	4	6	0.068	0.019	0.85	−1.13	C	3
		3489.74	1087	29734	8	8	0.0082	0.0015	0.14	−1.92	D	3
		3500.34	984	29544	6	6	0.0079	0.0015	0.10	−2.06	D	3
9.	b ^{4}F–z ^{4}F° (7)	*3329.8*	*1085*	*31108*	28	28	0.453	0.075	23.1	0.324	C	1*n*, 3
		3322.94	1216	31301	10	10	0.39	0.065	7.1	−0.19	C	3
		3329.46	1087	31114	8	8	0.34	0.056	4.9	−0.35	C	3
		3335.19	984	30959	6	6	0.32	0.054	3.6	−0.49	C	3
		3340.34	908	30837	4	4	0.384	0.064	2.83	−0.59	C	3
		3343.77	1216	31114	10	8	0.043	0.0058	0.63	−1.24	C	1*n*
		3346.72	1087	30959	8	6	0.083	0.010	0.92	−1.08	C	3
		3348.84	984	30837	6	4	0.084	0.0094	0.62	−1.25	D	1*n*, *ls*
		3308.81	1087	31301	8	10	0.038	0.0079	0.69	−1.20	C	1*n*
		3318.02	984	31114	6	8	0.062	0.014	0.89	−1.09	C	1*n*
		3326.76	908	30959	4	6	0.084	0.021	0.91	−1.08	C	3
10.	b ^{4}F–z ^{2}D° (9)											
		3231.32	1087	32026	8	6	0.0337	0.00395	0.336	−1.50	C	3
11.	b ^{4}F–z ^{4}D° (10)	*3163.1*	*1085*	*32690*	28	20	0.52	0.056	16.2	0.192	C	1*n*, 3
		3168.52	1216	32767	10	8	0.41	0.049	5.1	−0.31	C	3
		3162.57	1087	32698	8	6	0.39	0.044	3.7	−0.45	C	3
		3161.76	984	32603	6	4	0.470	0.0470	2.93	−0.55	C	3
		3161.21	908	32532	4	2	0.64	0.0476	1.98	−0.72	C	3
		3155.67	1087	32767	8	8	0.070	0.010	0.86	−1.08	C	3
		3152.25	984	32698	6	6	0.097	0.015	0.90	−1.06	C	3
		3154.20	908	32603	4	4	0.11	0.017	0.69	−1.18	C	3
		3145.40	984	32767	6	8	0.0018	3.6(−4)	0.022	−2.67	D	1*n*
		3144.74	908	32698	4	6	0.0044	9.7(−4)	0.040	−2.41	D	1*n*
12.	b ^{4}F–y ^{4}D° (uv 4)	*2529.2*	*1085*	*40612*	28	20	0.64	0.0442	10.3	0.092	C	1*n*, 3
		2525.62	1216	40798	10	8	0.56	0.043	3.5	−0.37	C	1*n*
		2531.27	1087	40582	8	6	0.489	0.0352	2.35	−0.55	C	1*n*
		2534.64	984	40426	6	4	0.54	0.0348	1.74	−0.68	C	1*n*
		2535.88	908	40330	4	2	0.68	0.0330	1.10	−0.88	C	1*n*
		2517.45	1087	40798	8	8	0.060	0.0057	0.38	−1.34	D	3
		2524.66	984	40582	6	6	0.12	0.012	0.59	−1.15	D	3
		2529.74	908	40426	4	4	0.17	0.017	0.55	−1.18	D	3
		2510.90	984	40798	6	8	0.0028	3.6(−4)	0.018	−2.67	D	1*n*
		2519.79	908	40582	4	6	0.0049	7.0(−4)	0.023	−2.55	D	1*n*

Ti 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
13.	$a\,^2$F–$z\,^4$G° (11)											
		3987.63	4898	29968	8	10	9.8(−4)	2.9(−4)	0.031	−2.63	D	1*n*
		4025.14	4898	29734	8	8	0.0056	0.0014	0.15	−1.96	D	1*n*
		4012.37	4629	29544	6	6	0.017	0.0040	0.32	−1.62	D	1*n*
14.	$a\,^2$F–$z\,^4$F° (12)											
		3786.33	4898	31301	8	10	0.0047	0.0013	0.12	−2.00	D	1*n*
		3774.65	4629	31114	6	8	0.0012	3.3(−4)	0.025	−2.70	D	1*n*
		3813.39	4898	31114	8	8	0.0059	0.0013	0.13	−1.99	D	1*n*
		3796.90	4629	30959	6	6	0.0021	4.5(−4)	0.034	−2.57	D	1*n*
		3814.58	4629	30837	6	4	0.023	0.0034	0.26	−1.69	D	1*n*
15.	$a\,^2$F–$z\,^2$F° (13)	*3760.3*	*4783*	*31369*	14	14	1.03	0.218	37.8	0.485	C	1*n*
		3759.29	4898	31491	8	8	0.98	0.21	21	0.22	C	1*n*
		3761.32	4629	31207	6	6	1.0	0.22	16	0.12	C	1*n*
		3799.81	4898	31207	8	6	9.5(−4)	1.5(−4)	0.015	−2.91	D	1*n*
		3721.63	4629	31491	6	8	0.041	0.011	0.83	−1.17	C	1*n*
16.	$a\,^2$F–$z\,^2$D° (14)											
		3685.19	4898	32026	8	6	0.75	0.11	11	−0.04	D	1*n*, *ls*
		3685.19	4629	31757	6	4	0.81	0.11	8.0	−0.18	D	1*n*, *ls*
17.	$a\,^2$F–$z\,^4$D° (15)											
		3587.13	4898	32767	8	8	0.0115	0.00222	0.210	−1.75	C	1*n*
		3561.58	4629	32698	6	6	0.0046	8.7(−4)	0.062	−2.28	D	1*n*
		3596.05	4898	32698	8	6	0.048	0.0070	0.67	−1.25	C	1*n*
		3573.74	4629	32603	6	4	0.0292	0.00373	0.263	−1.65	C	1*n*
18.	$a\,^2$F–$z\,^2$G° (16)	*3346.4*	*4783*	*34657*	14	18	1.0	0.22	34	0.50	D	1*n*
		3349.04	4898	34749	8	10	1.0	0.21	19	0.23	D	1*n*, *ls*
		3341.88	4629	34543	6	8	0.96	0.21	14	0.11	D	1*n*, *ls*
		3372.21	4898	34543	8	8	0.073	0.013	1.1	−1.00	C	1*n*
19.	$a\,^2$F–$y\,^2$D° (uv 5)	*2890.0*	*4783*	*39379*	14	10	0.212	0.0189	2.52	−0.58	C	1*n*, 3
		2891.05	4898	39477	8	6	0.143	0.0134	1.02	−0.97	C	1*n*
		2888.92	4629	39233	6	4	0.15	0.012	0.71	−1.13	D	1*n*, *ls*
		2868.73	4629	39477	6	6	0.11	0.014	0.79	−1.08	C	3
20.	$a\,^2$F–$z\,^2$P° (uv 6)											
		2858.40	4629	39603	6	4	0.047	0.0038	0.22	−1.64	D	3
21.	$a\,^2$F–$y\,^2$F° (uv 7)	*2837.7*	*4783*	*40012*	14	14	0.306	0.0369	4.83	−0.286	C	1*n*, 3
		2841.91	4898	40075	8	8	0.291	0.0352	2.64	−0.55	C	3
		2832.16	4629	39927	6	6	0.246	0.0296	1.66	−0.75	C	3
		2853.92	4898	39927	8	6	0.052	0.0048	0.36	−1.42	D	3
		2820.36	4629	40075	6	8	0.019	0.0030	0.17	−1.75	D	1*n*

Ti 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
22.	$a\,^2$F–$y\,^4$D° (uv 8)											
		2784.65	4898	40798	8	8	0.016	0.0019	0.14	−1.82	D	3
		2780.55	4629	40582	6	6	0.025	0.0029	0.16	−1.76	D	3
		2763.90	4629	40798	6	8	0.0017	2.6(−4)	0.014	−2.80	D	1*n*
23.	$a\,^2$F–$y\,^2$G° (uv 9)	*2564.7*	*4783*	*43763*	14	18	0.296	0.0375	4.43	−0.280	C	1*n*, 3
		2571.04	4898	43781	8	10	0.259	0.0321	2.18	−0.59	C	1*n*
		2555.99	4629	43741	6	8	0.313	0.0409	2.07	−0.61	C	1*n*
		2573.72	4898	43741	8	8	0.0269	0.00267	0.181	−1.67	C	3
24.	$a\,^2$F–$x\,^2$D° (uv 10)											
		2498.94	4898	44902	8	6	0.0289	0.00203	0.133	−1.79	C	1*n*
		2481.49	4629	44915	6	4	0.020	0.0012	0.061	−2.13	D	1*n*
25.	$a\,^2$D–$z\,^4$F° (18)											
		4493.53	8710	30959	4	6	0.0012	5.5(−4)	0.033	−2.66	D	2
26.	$a\,^2$D–$z\,^2$F° (19)	*4415.9*	*8730*	*31369*	10	14	0.099	0.0406	5.9	−0.392	C	1*n*
		4395.03	8744	31491	6	8	0.097	0.0373	3.24	−0.65	C	1*n*
		4443.80	8710	31207	4	6	0.087	0.0387	2.27	−0.81	C	1*n*
		4450.49	8744	31207	6	6	0.0144	0.00428	0.377	−1.59	C	1*n*
27.	$a\,^2$D–$z\,^2$D° (20)	*4311.4*	*8730*	*31918*	10	10	0.059	0.0164	2.33	−0.78	C	1*n*
		4294.10	8744	32026	6	6	0.048	0.013	1.1	−1.10	C	1*n*
		4337.92	8710	31757	4	4	0.067	0.019	1.1	−1.12	C	1*n*
		4344.29	8744	31757	6	4	0.0073	0.0014	0.12	−2.08	D	1*n*
		4287.89	8710	32026	4	6	0.0059	0.0024	0.014	−2.01	D	1*n*
28.	$a\,^2$D–$z\,^4$D° (21)											
		4161.52	8744	32767	6	8	0.0022	7.6(−4)	0.063	−2.34	D	1*n*
29.	$a\,^2$D–$y\,^2$D° (23)											
		3275.29	8710	39233	4	4	0.055	0.0089	0.38	−1.45	D	3
		3278.92	8744	39233	6	4	0.98	0.11	6.8	−0.20	C	1*n*
		3249.37	8710	39477	4	6	0.042	0.010	0.43	−1.40	D	1*n*
30.	$a\,^2$D–$z\,^2$P° (24)	*3235.5*	*8730*	*39628*	10	6	1.7	0.16	17	0.20	D	1*n*, 3
		3239.66	8744	39603	6	4	0.91	0.096	6.1	−0.24	D	1*n*
		3228.61	8710	39677	4	2	2.0	0.16	6.7	−0.20	C	3
		3236.12	8710	39603	4	4	0.68	0.11	4.5	−0.37	D	1*n*
31.	$a\,^2$D–$z\,^4$S° (25)											
		3195.72	8744	40028	6	4	0.080	0.0082	0.52	−1.31	C	3
		3192.26	8710	40028	4	4	0.0334	0.0051	0.215	−1.69	C	1*n*

Ti 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
32.	$a\,^2$D–$y\,^2$F° (26)	*3195.8*	*8730*	*40012*	10	14	1.20	0.258	27.1	0.411	C	1*n*, 3
		3190.87	8744	40075	6	8	1.3	0.26	16	0.19	C	3
		3202.54	8710	39927	4	6	1.1	0.26	11	0.02	C	3
		3205.99	8744	39927	6	6	0.0067	0.0010	0.065	−2.21	D	1*n*
33.	$a\,^2$D–$y\,^4$D° (27)											
		3118.82	8744	40798	6	8	0.0175	0.00340	0.210	−1.69	C	1*n*
34.	$a\,^2$D–$x\,^2$D° (uv 12)											
		2764.82	8744	44902	6	6	0.159	0.0183	1.00	−0.96	C	3
		2761.29	8710	44915	4	4	0.13	0.015	0.54	−1.23	D	3
		2762.22	8710	44902	4	6	0.047	0.0081	0.29	−1.49	D	3
35.	$a\,^2$D–$y\,^2$P° (uv 13)	*2717.0*	*8730*	*45524*	10	6	0.11	0.0074	0.66	−1.13	D	1*n*, 3
		2716.20	8744	45549	6	4	0.096	0.0071	0.38	−1.37	D	3
		2719.39	8710	45473	4	2	0.11	0.0061	0.22	−1.61	D	1*n*
		2713.76	8710	45549	4	4	0.014	0.0016	0.056	−2.20	D	1*n*
36.	$a\,^2$G–$z\,^4$G° (29)											
		4865.62	8998	29544	8	6	8.6(−4)	2.3(−4)	0.029	−2.74	D	2
37.	$a\,^2$G–$z\,^2$F° (31)	*4482.2*	*9065*	*31369*	18	14	0.074	0.0174	4.61	−0.51	C	1*n*
		4468.49	9118	31491	10	8	0.071	0.0170	2.50	−0.77	C	1*n*
		4501.27	8998	31207	8	6	0.076	0.0173	2.05	−0.86	C	1*n*
		4444.56	8998	31491	8	8	0.0018	5.3(−4)	0.062	−2.37	D	1*n*
38.	$a\,^2$G–$z\,^2$D° (32)											
		4341.37	8998	32026	8	6	0.0032	6.7(−4)	0.077	−2.27	D	1*n*
39.	$a\,^2$G–$z\,^2$G° (34)	*3906.4*	*9065*	*34657*	18	18	0.168	0.0384	8.9	−0.160	C	1*n*
		3900.55	9118	34749	10	10	0.16	0.035	4.6	−0.45	C	1*n*
		3913.46	8998	34543	8	8	0.161	0.0369	3.80	−0.53	C	1*n*
		3932.01	9118	34543	10	8	0.0089	0.00166	0.215	−1.78	C	1*n*
		3882.28	8998	34749	8	10	0.0086	0.00244	0.249	−1.71	C	1*n*
40.	$a\,^2$G–$y\,^2$D° (35)											
		3280.00	8998	39477	8	6	0.075	0.0091	0.78	−1.14	D	3
41.	$a\,^2$G–$y\,^2$F° (36)											
		3229.40	9118	40075	10	8	0.28	0.035	3.8	−0.45	D	1*n*, *ls*
		3232.28	8998	39927	8	6	0.60	0.070	6.0	−0.25	C	3

Ti 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
42.	$a\,^2G$–$y\,^2G°$ (uv 14)	*2881.2*	*9065*	*43763*	18	18	0.56	0.070	12	0.10	D	1*n*, 3
		2884.10	9118	43781	10	10	0.52	0.065	6.1	−0.19	D	3
		2877.42	8998	43741	8	8	0.57	0.070	5.3	−0.25	D	3
		2887.46	9118	43741	10	8	0.010	0.0010	0.097	−1.99	D	1*n*
		2874.08	8998	43781	8	10	0.0099	0.0015	0.12	−1.91	D	1*n*
43.	$a\,^2G$–$z\,^2H°$ (uv 15)											
		2717.30	9118	45909	10	12	0.033	0.0044	0.39	−1.36	D	3
		2725.79	8998	45674	8	10	0.033	0.0046	0.33	−1.43	D	3
44.	$a\,^4P$–$z\,^4F°$ (38)											
		4629.29	9518	31114	6	8	0.0024	0.0010	0.094	−2.21	D	1*n*
45.	$a\,^4P$–$z\,^2F°$ (39)											
		4583.44	9396	31207	4	6	9.9(−4)	4.7(−4)	0.028	−2.73	D	1*n*
46.	$a\,^4P$–$z\,^2D°$ (40)											
		4441.73	9518	32026	6	6	0.0022	6.6(−4)	0.058	−2.40	D	1*n*
		4470.86	9396	31757	4	4	0.0045	0.0013	0.079	−2.27	D	1*n*
		4417.72	9396	32026	4	6	0.022	0.0095	0.55	−1.42	C	1*n*
		4464.46	9364	31757	2	4	0.0071	0.0043	0.13	−2.07	D	1*n*
47.	$a\,^4P$–$z\,^4D°$ (41)	*4302.1*	*9452*	*32690*	12	20	0.081	0.0377	6.4	−0.345	C	1*n*
		4300.05	9518	32767	6	8	0.080	0.0296	2.52	−0.75	C	1*n*
		4290.22	9396	32698	4	6	0.048	0.020	1.1	−1.10	C	1*n*
		4301.93	9364	32603	2	4	0.033	0.019	0.53	−1.43	C	1*n*
		4312.86	9518	32698	6	6	0.029	0.0082	0.70	−1.31	C	1*n*
		4307.90	9396	32603	4	4	0.048	0.013	0.76	−1.27	C	1*n*
		4314.98	9364	32532	2	2	0.070	0.019	0.55	−1.41	C	1*n*
		4330.71	9518	32603	6	4	0.0046	8.5(−4)	0.073	−2.29	D	1*n*
		4320.97	9396	32532	4	2	0.015	0.0020	0.12	−2.09	D	1*n*
48.	$a\,^4P$–$z\,^2S°$ (42)											
		3566.00	9396	37431	4	2	0.039	0.0037	0.17	−1.83	D	1
		3561.91	9364	37431	2	2	0.013	0.0024	0.057	−2.31	D	1
49.	$a\,^4P$–$z\,^2P°$ (44)											
		3301.71	9396	39675	4	2	0.060	0.0049	0.21	−1.71	D	1*n*
50.	$a\,^4P$–$z\,^4S°$ (45)	*3270.0*	*9452*	40028	12	4	0.429	0.0229	2.96	−0.56	C	1*n*, 3
		3276.77	9518	40028	6	4	0.235	0.0252	1.63	−0.82	C	3
		3263.69	9396	40028	4	4	0.12	0.019	0.83	−1.11	C	3
		3260.26	9364	40028	2	4	0.073	0.023	0.50	−1.33	C	1*n*

Ti 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
51.	$a\,^4P$–$z\,^4P°$ (47)	*3060.0*	*9452*	*42127*	12	12	0.77	0.11	13	0.11	D	1*n*, 3
		3058.09	9518	42209	6	6	0.50	0.069	4.2	− 0.38	D	3
		3059.74	9396	42069	4	4	0.098	0.014	0.55	− 1.26	D	1*n*, *ls*
		3063.50	9364	41997	2	2	0.12	0.017	0.35	− 1.46	D	1*n*, *ls*
		3071.24	9518	42069	6	4	0.36	0.034	2.1	− 0.69	D	3
		3066.51	9396	41997	4	2	0.68	0.048	1.9	− 0.72	D	1*n*, *ls*
		3046.69	9396	42209	4	6	0.22	0.045	1.8	− 0.74	D	3
		3056.74	9364	42069	2	4	0.32	0.091	1.8	− 0.74	D	3
52.	$a\,^2P$–$z\,^2F°$ (49)											
		4708.66	9976	31207	4	6	0.0012	5.9(− 4)	0.036	− 2.63	D	1*n*
53.	$a\,^2P$–$z\,^2D°$ (50)	*4547.5*	*9934*	*31918*	6	10	0.098	0.050	4.53	−0.52	C	1*n*
		4533.97	9976	32026	4	6	0.094	0.0434	2.59	−0.76	C	1*n*
		4563.76	9851	31757	2	4	0.090	0.056	1.69	−0.95	C	1*n*
		4589.96	9976	31757	4	4	0.0131	0.00415	0.251	−1.78	C	1*n*
54.	$a\,^2P$–$z\,^4D°$ (51)											
		4399.77	9976	32698	4	6	0.020	0.0089	0.51	−1.45	C	1*n*
		4394.06	9851	32603	2	4	0.0117	0.0067	0.195	−1.87	C	1*n*
		4418.34	9976	32603	4	4	0.0031	9.1(−4)	0.053	−2.44	D	1*n*
		4407.68	9851	32532	2	2	0.0048	0.0014	0.041	−2.55	D	2
		4432.09	9976	32532	4	2	0.014	0.0021	0.12	−2.08	D	1*n*
55.	$a\,^2P$–$z\,^2S°$ (52)	*3635.7*	*9934*	37431	6	2	0.78	0.052	3.7	−0.51	D	1
		3641.33	9976	37431	4	2	0.49	0.049	2.3	−0.71	D	1
		3624.83	9851	37431	2	2	0.29	0.057	1.4	−0.94	D	1
56.	$a\,^2P$–$y\,^2D°$ (53)	*3395.2*	*9934*	*39379*	6	10	0.124	0.0358	2.40	−0.67	C	3
		3388.76	9976	39477	4	6	0.090	0.023	1.0	−1.03	C	3
		3402.42	9851	39233	2	4	0.14	0.050	1.1	−1.00	C	3
		3416.96	9976	39233	4	4	0.0384	0.0067	0.303	−1.57	C	3
57.	$a\,^2P$–$z\,^2P°$ (54)											
		3374.35	9976	39603	4	4	0.164	0.0281	1.25	−0.95	C	3
		3352.07	9851	39675	2	2	0.13	0.022	0.49	−1.35	D	1*n*
		3366.18	9976	39675	4	2	0.25	0.021	0.94	−1.07	D	1*n*
58.	$a\,^2P$–$y\,^2F°$ (55)											
		3337.85	9976	39927	4	6	0.050	0.013	0.55	−1.30	D	3
59.	a^2P–$z\,^4S°$ (56)											
		3312.90	9851	40028	2	4	0.0065	0.0021	0.047	−2.37	D	1*n*

Ti 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
60.	$a\,^2P-z\,^4P^\circ$ (58)											
		3101.52	9976	42209	4	6	0.0284	0.0061	0.251	−1.61	C	1*n*
		3102.98	9851	42069	2	4	0.0274	0.0079	0.162	−1.80	C	1*n*
		3122.07	9976	41997	4	2	0.11	0.0081	0.33	−1.49	C	1*n*
61.	$a\,^2P-x\,^2D^\circ$ (uv 16)	*2858.5*	*9934*	*44907*	6	10	0.422	0.086	4.86	−0.287	C	1*n*, 3
		2862.34	9976	44902	4	6	0.400	0.074	2.78	−0.53	C	1*n*
		2851.09	9851	44915	2	4	0.409	0.100	1.87	−0.70	C	3
		2861.29	9976	44915	4	4	0.0456	0.0056	0.211	−1.65	C	1*n*
62.	$a\,^2P-y\,^2P^\circ$ (uv 17)											
		2806.41	9851	45473	2	2	0.19	0.022	0.41	−1.35	D	3
63.	$b\,^4P-z\,^2D^\circ$ (60)											
		4580.46	9931	31757	4	4	0.0013	4.1(−4)	0.025	−2.78	D	1*n*
		4568.31	9873	31757	2	4	0.0016	0.0010	0.030	−2.70	D	2
64.	$b\,^4P-z\,^4D^\circ$ (61)											
		4395.85	10025	32767	6	8	0.0031	0.0012	0.10	−2.15	D	1*n*
		4390.98	9931	32698	4	6	0.0011	4.7(−4)	0.027	−2.73	D	1*n*
65.	$b\,^4P-z\,^2P^\circ$ (64)											
		3369.21	9931	39603	4	4	0.064	0.011	0.48	−1.36	D	1*n*
66.	$b\,^4P-z\,^4S^\circ$ (65)	*3325.7*	*9968*	*40028*	12	4	2.19	0.121	15.9	0.162	C	1*n*, 3
		3332.11	10025	40028	6	4	1.1	0.12	7.8	−0.15	C	3
		3321.70	9931	40028	4	4	0.74	0.12	5.4	−0.31	C	1*n*
		3315.32	9873	40028	2	4	0.381	0.126	2.74	−0.60	C	3
67.	$b\,^4P-y\,^4D^\circ$ (66)	*3262.3*	*9968*	*40612*	12	20	0.96	0.26	33	0.49	D	1*n*, 3
		3248.60	10025	40798	6	8	0.75	0.16	10	−0.02	D	1*n*, *ls*
		3261.60	9931	40582	4	6	0.54	0.13	5.5	−0.29	C	1*n*
		3272.08	9873	40426	2	4	0.318	0.102	2.20	−0.69	C	1*n*
		3271.65	10025	40582	6	6	0.243	0.0391	2.52	−0.63	C	1*n*
		3278.29	9931	40426	4	4	0.96	0.15	6.7	−0.21	C	3
		3282.33	9873	40330	2	2	1.6	0.26	5.5	−0.29	C	3
		3288.43	10025	40426	6	4	0.042	0.0046	0.30	−1.56	D	1*n*, *ls*
		3288.58	9931	40330	4	2	0.14	0.011	0.48	−1.35	D	1*n*, *ls*
68.	$b\,^4P-z\,^4P^\circ$ (67)	*3108.7*	*9968*	*42127*	12	12	1.33	0.193	23.7	0.365	C	1*n*, 3
		3106.23	10025	42209	6	6	0.78	0.11	6.9	−0.17	C	3
		3110.62	9931	42069	4	4	0.273	0.0396	1.62	−0.80	C	1*n*
		3112.05	9873	41997	2	2	0.23	0.034	0.69	−1.17	D	3
		3119.80	10025	42069	6	4	0.61	0.059	3.6	−0.45	C	1*n*
		3117.67	9931	41997	4	2	1.09	0.079	3.25	−0.50	C	3
		3097.19	9931	42209	4	6	0.44	0.095	3.9	−0.42	C	3
		3105.08	9873	42069	2	4	0.63	0.18	3.7	−0.44	D	3

Ti 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
69.	$b\,^2D$–$z\,^2F^\circ$ (69)											
		5336.81	12758	31491	6	8	0.0049	0.0028	0.30	−1.77	D	2
		5381.02	12629	31207	4	6	0.0032	0.0021	0.15	−2.08	D	2
70.	$b\,^2D$–$z\,^2D^\circ$ (70)											
		5188.70	12758	32026	6	6	0.026	0.011	1.1	−1.20	C	1*n*
		5226.53	12629	31757	4	4	0.031	0.013	0.88	−1.29	C	1*n*
		5154.06	12629	32026	4	6	0.0050	0.0030	0.20	−1.92	D	2
71.	$b\,^2D$–$y\,^2D^\circ$ (72)											
		3741.63	12758	39477	6	6	0.58	0.12	8.9	−0.14	C	1*n*
		3757.68	12629	39233	4	4	0.38	0.081	4.0	−0.49	C	1*n*
		3776.06	12758	39233	6	4	0.050	0.0071	0.53	−1.37	C	1*n*
72.	$b\,^2D$–$z\,^2P^\circ$ (73)											
		3706.22	12629	39603	4	4	0.30	0.063	3.1	−0.60	D	1*n*
73.	$b\,^2D$–$y\,^2F^\circ$ (75)	*3661.2*	*12706*	*40012*	10	14	0.131	0.0368	4.44	−0.434	C	1*n*
		3659.77	12758	40075	6	8	0.113	0.0303	2.19	−0.74	C	1*n*
		3662.24	12629	39927	4	6	0.138	0.0415	2.00	−0.78	C	1*n*
		3679.67	12758	39927	6	6	0.0172	0.00348	0.253	−1.68	C	1*n*
74.	$b\,^2D$–$y\,^4D^\circ$ (76)											
		3565.33	12758	40798	6	8	0.0058	0.0015	0.10	−2.05	D	1*n*
		3593.09	12758	40582	6	6	0.0039	7.6(−4)	0.054	−2.34	D	1*n*
75.	$b\,^2D$–$x\,^2D^\circ$ (77)											
		3110.10	12758	44902	6	6	0.071	0.010	0.63	−1.21	C	1*n*
		3096.42	12629	44915	4	4	0.060	0.0087	0.35	−1.46	C	1*n*
76.	$b\,^2D$–$y\,^2P^\circ$ (78)											
		3048.77	12758	45549	6	4	0.15	0.014	0.83	−1.08	C	3
		3043.85	12629	45473	4	2	0.14	0.010	0.40	−1.40	D	3
77.	$b\,^2D$–$x\,^2F^\circ$ (uv 20)											
		2880.28	12758	47467	6	8	0.0258	0.00428	0.244	−1.59	C	1*n*
		2856.62	12629	47625	4	6	0.0237	0.00434	0.163	−1.76	C	1*n*
78.	$b\,^2D$–$w\,^2D^\circ$ (uv 21)	*2446.3*	*12706*	*53572*	10	10	0.51	0.0462	3.72	−0.335	C	1*n*, 3
		2450.44	12758	53555	6	6	0.454	0.0409	1.98	−0.61	C	3
		2440.21	12629	53597	4	4	0.51	0.0455	1.46	−0.74	C	3
		2447.92	12758	53597	6	4	0.0358	0.00215	0.104	−1.89	C	1*n*
		2442.67	12629	53555	4	6	0.0398	0.0053	0.172	−1.67	C	1*n*

Ti 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
79.	$a\,^2$H–$z\,^2$G° (82)	*4559.3*	*12730*	*34657*	22	18	0.118	0.0300	9.9	−0.181	C	1*n*
		4549.62	12775	34749	12	10	0.11	0.030	5.3	−0.45	C	1*n*
		4571.97	12677	34543	10	8	0.118	0.0295	4.44	−0.53	C	1*n*
		4529.47	12677	34749	10	10	0.0030	9.3(−4)	0.14	−2.03	D	1*n*
80.	$a\,^2$H–$y\,^2$G° (84)	*3221.4*	*12730*	*43763*	22	18	0.76	0.097	22.6	0.329	C	1*n*, 3
		3224.24	12775	43781	12	10	0.70	0.091	12	0.04	C	3
		3218.27	12677	43741	10	8	0.70	0.087	9.2	−0.06	C	3
		3214.14	12677	43781	10	10	0.083	0.0129	1.36	−0.89	C	1*n*
81.	$a\,^2$H–$z\,^2$H° (85)	*3022.8*	*12730*	*45802*	22	22	0.387	0.053	11.6	0.067	C	1*n*, 3
		3017.19	12775	45909	12	12	0.36	0.049	5.8	−0.23	C	3
		3029.73	12677	45674	10	10	0.35	0.048	4.8	−0.32	C	3
		3038.71	12775	45674	12	10	0.042	0.0048	0.58	−1.24	D	3
		3008.32	12677	45909	10	12	0.026	0.0043	0.42	−1.37	D	1*n*
82.	$b\,^2$G–$z\,^2$G° (86)											
		5129.14	15258	34749	10	10	0.010	0.0041	0.69	−1.39	C	1*n*
		5185.90	15266	34543	8	8	0.011	0.0045	0.62	−1.44	C	1*n*
83.	$b\,^2$G–$y\,^2$F° (87)											
		4028.33	15258	40075	10	8	0.051	0.010	1.3	−1.00	C	1*n*
		4053.81	15266	39927	8	6	0.042	0.0077	0.82	−1.21	C	1*n*
84.	$b\,^2$G–$y\,^2$G° (88)	*3507.7*	*15262*	*43763*	18	18	0.88	0.162	33.6	0.464	C	1*n*
		3504.89	15258	43781	10	10	0.80	0.15	17	0.17	C	1*n*
		3510.84	15266	43741	8	8	0.91	0.17	16	0.13	C	1*n*
		3509.84	15258	43741	10	8	0.029	0.0043	0.49	−1.37	C	1*n*
		3505.90	15266	43781	8	10	0.0064	0.00147	0.136	−1.93	C	1*n*
85.	$b\,^2$G–$z\,^2$H° (89)	*3273.5*	*15262*	*45802*	18	22	0.84	0.16	32	0.47	D	1*n*, 3
		3261.60	15258	45909	10	12	0.40	0.076	8.1	−0.12	D	1*n*, *ls*
		3287.66	15266	45674	8	10	1.4	0.27	24	0.34	C	3
		3286.76	15258	45674	10	10	0.015	0.0025	0.27	−1.61	D	1*n*
86.	$b\,^2$G–$x\,^2$F° (90)	3097.7	15262	47535	18	14	1.3	0.14	26	0.41	C	1*n*, 3
		3103.80	15258	47467	10	8	1.1	0.13	13	0.11	C	3
		3089.40	15266	47625	8	6	1.3	0.14	12	0.06	C	3
		3104.59	15266	47467	8	8	0.063	0.0091	0.74	−1.14	C	1*n*
87.	$b\,^2$P–$z\,^2$S° (92)	*4796.7*	*16589*	37431	6	2	0.18	0.021	2.0	−0.90	D	1
		4805.11	16625	37431	4	2	0.11	0.020	1.3	−1.10	D	1
		4779.99	16516	37431	2	2	0.062	0.021	0.67	−1.37	D	1

Ti 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
88.	$b\,^2P-y\,^2D^\circ$ (93)											
		4374.83	16625	39477	4	6	0.0103	0.00445	0.256	−1.75	C	1*n*
		4421.95	16625	39233	4	4	0.0135	0.00396	0.231	−1.80	C	1*n*
89.	$b\,^2P-z\,^2P^\circ$ (94)											
		4350.83	16625	39603	4	4	0.016	0.0045	0.26	−1.74	D	2
90.	$b\,^2P-x\,^2D^\circ$ (98)	*3530.3*	*16589*	*44907*	6	10	0.53	0.165	11.5	−0.005	C	1*n*
		3535.41	16625	44902	4	6	0.55	0.15	7.2	−0.21	C	1*n*
		3520.25	16516	44915	2	4	0.48	0.18	4.1	−0.45	C	1*n*
		3533.87	16625	44915	4	4	0.0285	0.0053	0.249	−1.67	C	1*n*
91.	$b\,^2P-y\,^2P^\circ$ (99)	*3455.0*	*16589*	*45524*	6	6	0.98	0.18	12	0.02	D	1*n*, 3
		3456.39	16625	45549	4	4	0.78	0.14	6.4	−0.25	D	1*n*
		3452.47	16516	45473	2	2	0.77	0.138	3.13	−0.56	C	3
		3465.56	16625	45473	4	2	0.411	0.0370	1.69	−0.83	C	3
		3443.39	16516	45549	2	4	0.11	0.041	0.92	−1.09	D	1*n*
92.	$b\,^2P-x\,^2P^\circ$ (uv 23)											
		2738.70	16625	53128	4	4	0.16	0.019	0.67	−1.13	D	3
		2730.95	16516	53121	2	2	0.66	0.074	1.33	−0.83	C	3
93.	$b\,^2F-y\,^2F^\circ$ (103)											
		5268.62	20952	39927	6	6	0.0096	0.0040	0.42	−1.62	D	2
94.	$b\,^2F-y\,^2G^\circ$ (104)											
		4367.66	20892	43781	8	10	0.018	0.0066	0.75	−1.28	C	1*n*
		4386.86	20952	43741	6	8	0.023	0.0090	0.78	−1.27	C	1*n*
95.	$b\,^2F-x\,^2D^\circ$ (105)	*4167.4*	*20918*	*44907*	14	10	0.283	0.053	10.1	−0.133	C	1*n*
		4163.64	20892	44902	8	6	0.26	0.050	5.5	−0.40	C	1*n*
		4171.90	20952	44915	6	4	0.264	0.0459	3.78	−0.56	C	1*n*
		4174.09	20952	44902	6	6	0.036	0.0094	0.77	−1.25	C	1*n*
96.	$b\,^2F-x\,^2F^\circ$ (107)											
		3761.87	20892	47467	8	8	0.141	0.0300	2.97	−0.62	C	1*n*
		3748.01	20952	47625	6	6	0.141	0.0296	2.19	−0.75	C	1*n*
		3770.41	20952	47467	6	8	0.0051	0.0015	0.11	−2.06	D	1*n*
97.	$a\,^2S-x\,^2P^\circ$ (111)											
		3144.73	21338	53121	2	4	0.56	0.17	3.4	−0.48	C	1*n*
98.	$c\,^2D-x\,^2D^\circ$ (113)											
		5072.30	25193	44902	6	6	0.025	0.0098	0.98	−1.23	C	1*n*

Ti 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
99.	$c\ ^2$D–$y\ ^2$P° (114)											
		4911.21	25193	45549	6	4	0.12	0.028	2.7	−0.77	D	2
		4874.03	24961	45473	4	2	0.11	0.020	1.3	−1.10	D	1n
100.	$c\ ^2$D–$x\ ^2$F° (115)											
		4488.32	25193	47467	6	8	0.060	0.0241	2.14	−0.84	C	1n
		4411.08	24961	47625	4	6	0.049	0.021	1.2	−1.07	C	1n
101.	$z\ ^4$G°–$e\ ^4$F (119)											
		3081.58	29968	62410	10	8	1.1	0.12	12	0.08	D	3
102.	$z\ ^4$G°–$e\ ^4$G (uv 24)											
		2856.24	30241	65242	12	12	1.5	0.18	20	0.33	D	3
		2846.09	29968	65094	10	10	1.2	0.15	14	0.18	D	3
		2836.60	29734	64978	8	8	1.2	0.15	11	0.08	D	3
		2828.80	29544	64885	6	6	1.2	0.15	8.1	−0.06	D	1n
		2855.49	29968	64978	10	8	0.14	0.014	1.3	−0.86	D	1n
		2844.09	29734	64885	8	6	0.15	0.013	1.0	−0.97	D	1n
		2834.14	29968	65242	10	12	0.79	0.11	11	0.06	D	3
		2827.22	29734	65094	8	10	1.0	0.15	11	0.08	D	3
		2821.41	29544	64978	6	8	0.79	0.13	7.0	−0.12	D	3
103.	$z\ ^4$G°–$e\ ^4$H (uv 25)											
		2828.15	30241	65589	12	14	4.4	0.62	69	0.87	D	3
		2817.84	29968	65446	10	12	3.8	0.54	50	0.73	D	3
		2810.28	29734	65307	8	10	5.1	0.75	56	0.78	D	3
		2805.00	29544	65185	6	8	4.6	0.73	40	0.64	D	3
		2839.70	30241	65446	12	12	0.83	0.10	11	0.08	D	3
		2828.87	29968	65307	10	10	0.91	0.11	10	0.04	D	1n
		2819.99	29734	65185	8	8	0.65	0.077	5.7	−0.21	D	1n
104.	$z\ ^4$F°–$e\ ^4$F (120)											
		3189.52	30837	62180	4	4	0.92	0.14	5.9	−0.25	D	3
105.	$z\ ^4$F°–$e\ ^4$G (uv 26)											
		2945.47	31301	65242	10	12	2.7	0.42	40	0.62	D	3
		2941.99	31114	65094	8	10	1.7	0.28	22	0.35	D	1n
		2938.69	30959	64978	6	8	2.4	0.42	24	0.40	D	3
		2936.17	30837	64885	4	6	2.7	0.52	20	0.32	D	3
		2958.30	31301	65094	10	10	0.13	0.017	1.7	−0.76	D	1n
		2952.10	31114	64978	8	8	0.30	0.040	3.1	−0.50	D	3
106.	$z\ ^4$F°–$f\ ^2$F (uv 27)											
		2926.75	31301	65459	10	8	0.89	0.091	8.8	−0.04	D	3
		2910.76	31114	65459	8	8	0.46	0.058	4.5	−0.33	D	1n

Ti 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
107.	$z\,^4F^\circ$–$e\,^4D$ (uv 28)											
		2800.65	31301	66997	10	8	1.8	0.17	16	0.24	D	3
		2790.62	31114	66938	8	6	0.53	0.046	3.4	−0.43	D	3
		2788.00	30959	66816	6	4	1.5	0.12	6.5	−0.15	D	3
		2782.30	30837	66767 ?	4	2	2.2	0.13	4.6	−0.30	D	1*n*
		2785.99	31114	66997	8	8	0.60	0.070	5.2	−0.25	D	3
		2778.48	30959	66938	6	6	0.38	0.044	2.4	−0.58	D	1*n*, *ls*
		2778.48	30837	66816	4	4	0.43	0.050	1.8	−0.70	D	1*n*, *ls*
108.	$z\,^4F^\circ$–$f\,^4F$ (uv 29)											
		2646.08	31301	69081	10	10	2.7	0.28	25	0.45	D	3
		2642.15	31114	68950	8	8	1.8	0.19	13	0.19	D	3
		2638.70	30959	68845	6	6	1.7	0.17	9.1	0.02	D	3
		2635.60	30837	68768	4	4	1.9	0.20	6.9	−0.10	D	3
109.	$z\,^2F^\circ$–$e\,^2F$ (121)											
		3128.64	31491	63445	8	8	1.3	0.19	16	0.18	D	1*n*
		3127.88	31207	63168	6	6	1.7	0.25	16	0.18	D	1*n*
110.	$z\,^2F^\circ$–$f\,^2F$ (uv 30)											
		2943.12	31491	65459	8	8	1.1	0.15	11	0.07	D	3
		2931.27	31207	65313	6	6	3.2	0.41	24	0.39	D	3
		2918.77	31207	65459	6	8	0.040	0.0068	0.39	−1.39	D	1*n*
111.	$z\,^2F^\circ$–$e\,^2G$ (uv 31)											
		2751.70	31491	67821	8	10	3.7	0.52	38	0.62	D	3
		2746.70	31207	67604	6	8	2.6	0.39	21	0.37	D	3
112.	$z\,^2D^\circ$–$e\,^2F$ (122)											
		3181.84	32026	63445	6	8	0.46	0.094	5.9	−0.25	D	3
		3182.57	31757	63168	4	6	0.43	0.097	4.1	−0.41	D	3
113.	$z\,^2D^\circ$–$f\,^2F$ (uv 32)											
		2990.17	32026	65459	6	8	0.57	0.10	6.1	−0.21	D	1*n*
		2979.20	31757	65313	4	6	1.2	0.23	9.2	−0.03	D	3
114.	$z\,^4D^\circ$–$f\,^4F$ (uv 33)											
		2752.85	32767	69081	8	10	1.1	0.16	11	0.10	D	3
		2757.62	32698	68950	6	8	0.74	0.11	6.1	−0.17	D	1*n*
		2758.35	32603	68845	4	6	0.99	0.17	6.1	−0.17	D	1*n*
		2758.93	32532	68768	2	4	0.44	0.10	1.8	−0.70	D	1*n*
		2762.92	32767	68950	8	8	0.072	0.0083	0.60	−1.18	D	1*n*
		2764.28	32603	68768	4	4	0.74	0.085	3.1	−0.47	D	1*n*
115.	$z\,^2G^\circ$–$e\,^2F$ (125)											
		3483.80	34749	63445	10	8	0.97	0.14	16	0.15	D	3
		3492.39	34543	63168	8	6	0.98	0.13	12	0.03	D	3

Ti 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
116.	$z\,^2G°-e\,^2G$ (126)											
		3022.82	34749	67821	10	10	1.2	0.17	17	0.23	D	3
		3023.86	34543	67604	8	8	1.0	0.14	11	0.06	D	3
117.	$z\,^2G°-e\,^2H$ (uv 34)											
		2954.76	34749	68582	10	12	4.0	0.63	61	0.80	D	3
		2958.98	34749	68329	10	10	4.0	0.52	51	0.72	D	3

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

Ti III

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

Ionization Potential 27.491 eV = 221735 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
1282.484	2	1298.659	1	1504.974	6	2548.6	9
1286.228	2	1298.67	1	1506.084	6	2548.7	10
1286.365	2	1298.970	1	1508.8	6	2556.6	9
1289.299	2	1327.592	5	1948.7	8	2563.42	9
1291.6	1	1339.691	4	2375.02	13	2563.6	10
1291.622	2	1455.194	7	2413.97	12	2565.42	9
1293.228	2	1498.697	3	2516.01	10	2567.53	9
1294.67	2	1499.173	6	2527.80	10	2576.43	9
1294.698	1	1502.311	6	2540.02	10	2580.43	9
1295.883	1	1504.621	6	2542.4	10	2984.76	11

The data for this ion were obtained directly from the calculations of Warner and Kirkpatrick [1]. These authors used the scaled Thomas-Fermi potential approach in a single configuration approximation and calculated the individual line strengths in intermediate coupling. The data may be compared with some beam-foil lifetime results of Roberts, Andersen, and Sørensen [2]. Lifetimes of five levels were measured, which are compared in the table below with the relevant inverse transition probability sums of reference [1].

State	Beam-foil lifetimes [ns] (Ref. [2])	$(\Sigma A)^{-1}$ [ns] (Ref. [1])
$z\ ^1D_2^\circ$	2.4	2.2
$z\ ^3D_3^\circ$	1.6	1.4
$z\ ^3F_2^\circ$	2.3	1.5
$z\ ^1F_3^\circ$	1.3	0.93
$z\ ^1P_1^\circ$	1.95	1.2

Except for the $z\ ^1P_1^\circ$ level, the agreement is generally within 50 percent.

Roberts, Voigt, and Czernichowski [3] have recently measured f-values for a few Ti III lines with a stabilized arc. These data as stated by the authors are very uncertain on an absolute scale and indeed disagree with Warner and Kirkpatrick's data by more than a factor of 2, so that we did not use this experimental material. Warner and Kirkpatrick provide data for many more lines of Ti III than we have tabulated here. However, these lines are not as prominent and their accuracy cannot be checked with reliable lifetime data or by other comparisons. Also, configuration interaction, which is not taken into account, may lead to substantial uncertainties for lines which involve $3d4p$ levels.

References

[1] Warner, B., and Kirkpatrick, R. C., Mon. Not. R. Astron. Soc. **144**, 397 (1969); Publications of the Department of Astronomy, University of Texas at Austin, Vol. III, No. 2 (1969).

[2] Roberts, J. R., Andersen, T., and Sørensen, G., Astrophys. J. **181**, 567 (1973); private communication (1973).

[3] Roberts, J. R., Voigt, P. A., and Czernichowski, A., to be published in Astrophys. J. (1975).

Ti III: 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.	$a\ ^3F - z\ ^3D^\circ$ (uv 1)	*1298.5*	*242*	*77254*	21	15	4.3	0.077	6.9	0.21	D	1
		1298.659	422	77424	9	7	1.2	0.023	0.87	−0.69	D	1
		1298.970	184	77167	7	5	0.59	0.011	0.32	−1.13	D	1
		1298.67	0	77000	5	3	6.8	0.10	2.2	−0.29	D	1
		1294.698	184	77424	7	7	2.5	0.064	1.9	−0.35	D	1
		1295.883	0	77167	5	5	2.8	0.071	1.5	−0.45	D	1
		[1291.6]	0	77424	5	7	0.19	0.0066	0.14	−1.48	E	1

Ti III: 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
2.	$a\,^3F-z\,^3F^\circ$ (uv 2)	*1288.6*	*242*	*77846*	21	21	4.3	0.11	9.5	0.35	D	1
		1286.365	422	78159	9	9	2.4	0.058	2.2	−0.28	D	1
		1289.299	184	77746	7	7	0.050	0.0012	0.037	−2.06	E	1
		1291.622	0	77422	5	5	0.0017	4.3(−5) [a]	9.1(−4) [a]	−3.67	E	1
		1293.228	422	77746	9	7	5.3	0.10	4.0	−0.03	D	1
		1294.67	184	77422	7	5	5.8	0.10	3.1	−0.14	D	1
		1282.484	184	78159	7	9	0.16	0.0051	0.15	−1.45	E	1
		1286.228	0	77746	5	7	0.024	8.3(−4)	0.018	−2.38	E	1
3.	$a\,^1D-z\,^1D^\circ$ (uv 3)	1498.697	8473	75197	5	5	2.7	0.089	2.2	−0.35	D	1
4.	$a\,^1D-z\,^1F^\circ$	1339.691	8473	83117	5	7	0.31	0.012	0.26	−1.23	D	1
5.	$a\,^1D-z\,^1P^\circ$ (uv 4)	1327.592	8473	83796	5	3	3.9	0.062	1.4	−0.51	D	1
6.	$a\,^3P-z\,^3D^\circ$	*1501.7*	*10661*	*77254*	9	15	0.32	0.018	0.79	−0.80	D	1
		1499.173	10721	77424	5	7	0.23	0.011	0.27	−1.26	D	1
		1502.311	10604	77167	3	5	0.16	0.0088	0.13	−1.58	D	1
		1504.621	10536	77000	1	3	0.45	0.046	0.23	−1.34	D	1
		1504.974	10721	77167	5	5	0.028	9.4(−4)	0.023	−2.33	E	1
		1506.084	10604	77000	3	3	0.25	0.0086	0.13	−1.59	D	1
		[1508.8]	10721	77000	5	3	0.0087	1.8(−4)	0.0044	−3.05	E	1
7.	$a\,^1G-z\,^1F^\circ$ (uv 5)	1455.194	14399	83117	9	7	6.7	0.16	7.1	0.17	D	1
8.	$a\,^1S-z\,^1P^\circ$	[1948.7]	[32480]	83796	1	3	0.72	0.12	0.79	−0.91	D	1
9.	$a\,^3D-z\,^3D^\circ$ (uv 6)	*2564.9*	*38277*	*77254*	15	15	3.1	0.31	39	0.66	D	1
		2563.42	38425	77424	7	7	2.1	0.21	12	0.17	D	1
		2565.42	38198	77167	5	5	1.6	0.16	6.9	−0.09	D	1
		2567.53	38064	77000	3	3	2.3	0.23	5.7	−0.17	D	1
		2580.43	38425	77167	7	5	0.25	0.018	1.1	−0.90	D	1
		2576.43	38198	77000	5	3	0.92	0.055	2.3	−0.56	D	1
		[2548.6]	38198	77424	5	7	1.1	0.15	6.2	−0.13	D	1
		[2556.6]	38064	77167	3	5	1.1	0.19	4.7	−0.25	D	1
10.	$a\,^3D-z\,^3F^\circ$ (uv 7)	*2526.5*	*38277*	*77846*	15	21	3.4	0.45	56	0.83	D	1
		2516.01	38425	78159	7	9	3.4	0.41	24	0.46	D	1
		2527.80	38198	77746	5	7	2.2	0.30	12	0.17	D	1
		2540.02	38064	77422	3	5	2.0	0.33	8.2	−0.01	D	1
		[2542.4]	38425	77746	7	7	1.1	0.11	6.2	−0.13	D	1
		[2548.7]	38198	77422	5	5	0.88	0.085	3.6	−0.37	D	1
		[2563.6]	38425	77422	7	5	0.39	0.027	1.6	−0.72	D	1
11.	$b\,^1D-z\,^1D^\circ$ (uv 8)	2984.76	41704	75197	5	5	1.9	0.26	13	0.11	D	1
12.	$b\,^1D-z\,^1F^\circ$ (uv 9)	2413.97	41704	83117	5	7	3.8	0.47	19	0.37	D	1
13.	$b\,^1D-z\,^1P^\circ$ (uv 10)	2375.02	41704	83796	5	3	4.0	0.20	8.0	0.01	D	1

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

Ti IV

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

Ionization Potential 43.266 eV = 348973 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
776.82	1	1469.21	3	2547.4	4	4397.37	5
779.14	1	2067.50	2	3541.44	7	4403.54	5
781.78	1	2103.08	2	3576.44	7	4647.40	8
1451.75	3	2541.75	4	3581.4	7	5398.82	6
1467.25	3	2546.85	4	4395.9	5	5492.43	6

As in the case of Sc III, we have used the Coulomb approximation, which works very well for the relatively simple alkali-like atomic systems. However, in accordance with the predictions of nuclear charge expansion theory, the character of the spectra along this isoelectronic sequence changes. Starting with Ti IV, a transition occurs from a simple spectrum to a complex spectrum since levels involving two $3d$ electrons move below the first ionization limit. Because of possible mixing effects, especially for the higher levels, which are not taken into account by the Coulomb approximation, we have been very conservative with our error estimates.

The only other available material with which we could compare our calculated values is the lifetime of the $5d\ ^2D$ level measured by Roberts et al. [1] with the beam-foil technique. Their value for τ_{5d} is a factor of 4 longer than the inverse sum $\left(\sum_i A_{ki}\right)^{-1}$ from the Coulomb approximation. Such a discrepancy would arise if either the slower cascades from the $6f\ ^2F°$ or $6p\ ^2P°$ levels were observed rather than the $5d$ level lifetime or if configuration interaction is appreciable.

Reference

[1] Roberts, J. R., Andersen, T., and Sørensen, G., Astrophys. J. **181**, 567 (1973).

Ti 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.	$3d$–$4p$	^2D–$^2P°$ (uv 1)	*779.86*	*230*	*128458*	10	6	11	0.062	1.6	−0.21	D	*ca*
			779.14	384	128731	6	4	10	0.062	0.96	−0.43	D	*ls*
			781.78	0	127913	4	2	11	0.051	0.53	−0.69	D	*ls*
			776.82	0	128731	4	4	1.2	0.011	0.11	−1.36	E	*ls*
2.	$4s$–$4p$	^2S–$^2P°$ (uv 2)	*2079.3*	80379	*128458*	2	6	4.9	0.95	13	0.28	D	*ca*
			2067.50	80379	128731	2	4	5.0	0.64	8.7	0.11	D	*ls*
			2103.08	80379	127913	2	2	4.7	0.31	4.3	−0.21	D	*ls*
3.	$4p$–$4d$	$^2P°$–^2D (uv 3)	*1462.2*	*128458*	*196847*	6	10	21	1.1	33	0.82	E	*ca*
			1467.25	128731	196881	4	6	21	1.0	20	0.60	E	*ls*
			1451.75	127913	196795	2	4	18	1.2	11	0.38	E	*ls*
			1469.21	128731	196795	4	4	3.5	0.11	2.2	−0.36	E	*ls*
4.	$4d$—$4f$	^2D–$^2F°$ (uv 4)	*2544.9*	*196847*	*236130*	10	14	7.6	1.0	86	1.00	E	*ca*
			2546.85	196881	236133	6	8	7.5	0.97	49	0.76	E	*ls*
			2541.75	196795	236125	4	6	7.0	1.0	34	0.60	E	*ls*
			[2547.4]	196881	236125	6	6	0.51	0.050	2.5	−0.52	E	*ls*

Ti IV: Allowed transitions – Continued

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki}(10^8s^{-1})	f_{ik}	S(at.u.)	log gf	Accuracy	Source
5.	4*f*–5*d*	^{2}F°–^{2}D (3)	*4400.0*	*236130*	*258851*	14	10	0.76	0.16	32	0.35	E	*ca*
			4397.37	236133	258867	8	6	0.71	0.16	18	0.11	E	*ls*
			4403.54	236125	258827	6	4	0.77	0.15	13	−0.05	E	*ls*
			[4395.9]	236125	258867	6	6	0.036	0.010	0.91	−1.22	E	*ls*
6.	5*s*–5*p*	^{2}S–^{2}P° (1)	*5429.7*	212396	*230808*	2	6	1.0	1.3	48	0.41	E	*ca*
			5398.82	212396	230913	2	4	1.0	0.90	32	0.26	E	*ls*
			5492.43	212396	230598	2	2	0.98	0.44	16	−0.06	E	*ls*
7.	5*p*–5*d*	^{2}P°–^{2}D (2)	*3564.9*	*230808*	*258851*	6	10	4.5	1.4	100	0.92	E	*ca*
			3576.44	230913	258867	4	6	4.4	1.3	60	0.72	E	*ls*
			3541.44	230598	258827	2	4	3.8	1.4	33	0.45	E	*ls*
			[3581.4]	230913	258827	4	4	0.74	0.14	6.7	−0.25	E	*ls*
8.	5*g*–6*h*	^{2}G–^{2}H° (4)	*4647.4*	278501	300013	18	22	4.2	1.7	460	1.49	E	*ca*
			4647.40	278501	300013	10	12	4.2	1.6	250	1.20	E	*ls*
			4647.40	278501	300013	8	10	4.0	1.6	200	1.11	E	*ls*
			4647.40	278501	300013	10	10	0.093	0.030	4.6	−0.52	E	*ls*

Ti V

Ground State $1s^22s^22p^63s^23p^6\ ^1S_0$

Ionization Potential 99.20 eV = 800300 cm^{-1}

Allowed Transitions

Cowan's calculations [1], done in a multi-configuration approximation based on self-consistent field wave functions, provide all the listed data. The two very weak intercombination lines are estimated to be of rather low accuracy.

Reference

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

Ti V: 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*p*^{6}–3*p*^{5}3*d*	^{1}S–^{3}P°											
			363.145	0	275372	1	3	0.038	2.3(−4)[a]	2.7(−4)[a]	−3.64	E	1
2.		^{1}S–^{3}D°											
			323.365	0	309248	1	3	0.50	0.0024	0.0025	−2.62	E	1
3.		^{1}S–^{1}P°	252.958	0	395323	1	3	1800	5.3	4.4	0.72	D	1

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

Ti VIII

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

Ionization Potential 168.5 eV = 1359000 cm^{-1}

Allowed Transitions

The data for this ion are the result of calculations by Ali and Joy [1] done in a single-configuration Hartree-Fock approximation. Thus, configuration interaction was not taken into account, which may be important for the one listed transition. However, a comparison with a transition integral calculated by Ali with the nuclear charge expansion method (unpublished result), which presumably 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.

Reference

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

Ti VIII: Allowed transitions

No.	Transition array	Multiplet	λ(Å)	E_i(cm^{-1})	E_k(cm^{-1})	g_i	g_k	A_{ki}($10^8 s^{-1}$)4	f_{ik}	S(at.u.)	log gf	Accuracy	Source
1.	$3p^3$–$3p^2(^3P)3d$	$^4S^\circ$–^4P	*268.72*	0	*372130*	4	12	580	1.9	6.7	0.88	E	1
			269.533	0	371012	4	6	590	0.96	3.4	0.58	E	*ls*
			268.178	0	372887	4	4	580	0.62	2.2	0.39	E	*ls*
			267.401	0	373971	4	2	580	0.31	1.1	0.09	E	*ls*

Ti X

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

Ionization Potential 215.91 eV = 1741500 cm^{-1}

Allowed Transitions

All data for this ion of the aluminum isoelectronic sequence are taken from the superposition of configurations calculations by Froese-Fischer [1]. While the configuration interaction treatment is limited to a few, presumably dominant interactions, comparisons with experiment for a few lower ions of the Al sequence suggest that the results should be accurate within 50 percent.

Reference

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

Ti 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.	$3s^2(^1S)3p$–$3s3p^2$	$^2P^\circ$–^2D	*482.28*	*5028*	*212377*	6	10	8.6	0.050	0.48	−0.52	D	1
			487.672	7542	212598	4	6	8.4	0.045	0.29	−0.74	D	*ls*
			471.595	0	212046	2	4	7.7	0.052	0.16	−0.98	D	*ls*
			[488.99]	7542	212046	4	4	1.4	0.0050	0.032	−1.70	E	*ls*
2.	$3s^2(^1S)3p$–$3s^2(^1S)3d$	$^2P^\circ$–^2D	*293.58*	*5028*	*345645*	6	10	350	0.76	4.4	0.66	D	1
			295.584	7542	345856	4	6	340	0.67	2.6	0.43	D	*ls*
			289.579	0	345329	2	4	310	0.79	1.5	0.20	D	*ls*
			[296.04]	7542	345329	4	4	57	0.074	0.29	−0.53	E	*ls*

Ti XI

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

Ionization Potential 265.23 eV = 2139300 cm^{-1}

Allowed Transitions

The chosen values represent data obtained from studies of the *f*-value dependence on the nuclear charge [1]. For Ti XI, an ion of the Mg isoelectronic sequence, the material available for the neutral end of the sequence is particularly reliable and plentiful, and for some transitions the nuclear charge expansion calculations by Crossley and Dalgarno [2] yield data up to very high nuclear charges. In addition, other calculated data for some very highly charged ions of the sequence have made possible reliable interpolations. The graphically derived *f*-values from such regularities have been chosen over the directly calculated ones, since they represent "best" values incorporating all results.

References

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

[2] Crossley, R. J. S., and Dalgarno, A., Proc. Roy. Soc., Ser. A **286**, 510 (1965).

Ti 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.	$3s^2$–$3s3p$	^1S–$^1P^o$	386.140	0	258973	1	3	140	0.96	1.2	−0.02	B	1
2.	$3s3p$–$3p^2$	$^3P^o$–^3P	*418.77*	*176680*	*415474*	9	9	130	0.34	4.2	0.49	C+	1
			417.85	179473	418775	5	5	100	0.26	1.8	0.11	C+	*ls*
			419.45	173827	412226	3	3	32	0.084	0.35	−0.60	C	*ls*
			429.60	179473	412226	5	3	49	0.082	0.58	−0.39	C	*ls*
			425.74	173827	408712	3	1	120	0.11	0.47	−0.48	C	*ls*
			408.28	173827	418775	3	5	35	0.14	0.58	−0.38	C	*ls*
			415.07	171274	412226	1	3	44	0.34	0.47	−0.49	C	*ls*
3.		$^1P^o$–^1D	[667.34]	258973	408821	3	5	12	0.13	0.86	−0.41	C	1
4.		$^1P^o$–^1S	[446.69]	258973	[482842]	3	1	130	0.13	0.57	−0.41	D	1
5.	$3s3p$–$3s3d$	$^3P^o$–^3D	*310.83*	*176680*	*498403*	9	15	170	0.42	3.9	0.58	C+	1
			313.229	179473	498728	5	7	170	0.35	1.8	0.24	C+	*ls*
			308.250	173827	498239	3	5	140	0.32	0.98	−0.02	C	*ls*
			306.144	171274	497918	1	3	100	0.43	0.43	−0.37	C	*ls*
			313.710	179473	498239	5	5	43	0.064	0.33	−0.49	C	*ls*
			308.568	173827	497918	3	3	76	0.11	0.33	−0.48	C	*ls*
			[314.03]	179473	497918	5	3	4.8	0.0043	0.022	−1.67	D	*ls*
6.	$3s3p$–$3s3d$	$^1P^o$–^1D	327.192	258973	564604	3	5	300	0.80	2.6	0.38	C	1
7.	$3s4s$–$3s4p$	^1S–$^1P^o$	[1348.7]	1065777	1139922	1	3	4.3	0.35	1.6	−0.46	D+	1
8.		^3S–$^3P^o$				3	9		0.71		0.33	D+	1

Ti XII

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

Ionization Potential 291.497 eV = 2351140 cm^{-1}

Allowed Transitions

List of tabulated lines

Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.	Wavelength (Å)	No.
60.701	3	82.344	2	139.80	9	340.66	7
60.762	3	82.368	11	139.884	9	349.933	7
60.971	6	82.372	11	140.361	9	351.06	7
61.286	6	89.844	8	194.58	14	460.69	1
70.973	12	90.512	8	195.14	14	479.86	1
70.986	12	90.547	8	206.95	18	934.14	17
71.018	12	108.086	4	208.30	18	959.97	17
71.785	5	109.107	4	208.39	18	964.23	17
72.234	5	116.497	10	257.90	15	1186.2	13
82.121	2	116.597	10	260.145	15	1235.2	13
82.307	11	116.62	10				

The *f*-value data chosen for this ion of the Na isoelectronic sequence have been derived by interpolation from studies of systematic trends in this sequence. The interpolated values are primarily based on theoretical data and have been modified for some transitions from Smith and Wiese's [1] original values where more recent data sources have become available. The additional sources are the nuclear charge expansion calculations by Ali [2] and Laughlin et al. [3] and a Coulomb approximation calculation by Kunze and Datla [4]. The interpolated *f*-values are expected to be quite accurate, since most regularities are based on fairly extensive and reliable material for the lower end of the Na isoelectronic sequence.

References

[1] Smith, M. W., and Wiese, W. L., Astrophys. J. Suppl. Ser. **23**, No. 196, 103 (1971).
[2] Ali, M. A., J. Phys. B **4**, 748 (1971).
[3] Laughlin, C., Lewis, M. N., and Horak, Z J., J, Opt. Soc. Am. **63**, 736 (1973).
[4] Kunze, H.-J., and Datla, R. U., Astrophys. J. **169**, 425 (1971).

Ti 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.	3*s*–3*p*	^2S–$^2P^o$	*467.13*	0	*214073*	2	6	48.7	0.478	1.47	−0.020	B	1
			460.69	0	216960	2	4	50.8	0.323	0.980	−0.190	B	*ls*
			479.86	0	208300	2	2	44.9	0.155	0.490	−0.509	B	*ls*
2.	3*s*–4*p*	^2S–$^2P^o$	*82.199*	0	*1216557*	2	6	582	0.177	0.0958	−0.451	C+	1, 4
			82.121	0	1217670	2	4	584	0.118	0.0639	−0.627	C+	*ls*
			82.344	0	1214330	2	2	579	0.0588	0.0319	−0.930	C+	*ls*
3.	3*s*–5*p*	^2S–$^2P^o$	*60.723*	0	*1646813*	2	6	330	0.054	0.022	−0.97	D+	1
			60.701	0	1647310	2	4	340	0.038	0.015	−1.12	D+	*ls*
			60.762	0	1645820	2	2	330	0.018	0.0073	−1.44	D+	*ls*
4.	3*p*–4*s*	$^2P^o$–^2S	*108.78*	*214073*	1133370	6	2	1400	0.085	0.18	−0.29	D+	1
			109.107	216960	1133370	4	2	940	0.084	0.12	−0.47	D+	*ls*
			108.086	208300	1133370	2	2	480	0.084	0.060	−0.77	D+	*ls*
5.	3*p*–5*s*	$^2P^o$–^2S	*72.084*	*214073*	[1601350]	6	2	580	0.015	0.021	−1.05	D+	1
			72.234	216960	[1601350]	4	2	380	0.015	0.014	−1.22	D+	*ls*
			[71.785]	208300	[1601350]	2	2	190	0.015	0.0070	−1.52	D+	*ls*

Ti 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
6.	3*p*–6*s*	^{2}P°–^{2}S	*61.186*	*214073*	[1848424]	6	2	280	0.0053	0.0064	−1.50	D+	1
			61.286	216960	[1848424]	4	2	190	0.0053	0.0043	−1.67	D+	*ls*
			60.971	208300	[1848424]	2	2	94	0.0052	0.0021	−1.98	D+	*ls*
7.	3*p*–3*d*	^{2}P°–^{2}D	*346.22*	*214073*	*502904*	6	10	120	0.37	2.5	0.35	C+	1
			349.933	216960	503260	4	6	120	0.33	1.5	0.12	C+	*ls*
			340.66	208300	502370	2	4	110	0.37	0.83	−0.13	C+	*ls*
			351.06	216960	502370	4	4	20	0.037	0.17	−0.83	D	*ls*
8.	3*p*–4*d*	^{2}P°–^{2}D	*90.287*	*214073*	*1321656*	6	10	1100	0.23	0.41	0.14	D	1
			90.512	216960	1321840	4	6	1100	0.21	0.25	−0.08	D	*ls*
			89.844	208300	1321380	2	4	980	0.24	0.14	−0.32	D	*ls*
			90.547	216960	1321380	4	4	180	0.023	0.027	−1.04	E	*ls*
9.	3*d*–4*p*	^{2}D–^{2}P°	*140.12*	*502904*	*1216557*	10	6	311	0.055	0.254	−0.260	C	1, 3
			139.884	503260	1217670	6	4	281	0.055	0.152	−0.481	C	*ls*
			140.361	502370	1214330	4	2	311	0.0460	0.085	−0.74	C	*ls*
			[139.80]	502370	1217670	4	4	32	0.0092	0.017	−1.43	D	*ls*
10.	3*d*–4*f*	^{2}D–^{2}F°	*116.56*	*502904*	*1360861*	10	14	3330	0.95	3.65	0.98	C	1
			116.597	503260	1360930	6	8	3360	0.91	2.1	0.74	C	*ls*
			116.497	502370	1360770	4	6	2990	0.91	1.4	0.56	C	*ls*
			[116.62]	503260	1360770	6	6	210	0.043	0.10	−0.59	D	*ls*
11.	3*d*–5*f*	^{2}D–^{2}F°	*82.342*	*502904*	*1717350*	10	14	1100	0.16	0.43	0.20	D+	1
			82.368	503260	1717410	6	8	1100	0.15	0.25	−0.05	D+	*ls*
			82.307	502370	1717270	4	6	1000	0.16	0.17	−0.19	D+	*ls*
			[82.372]	503260	1717270	6	6	73	0.0074	0.012	−1.35	E	*ls*
12.	3*d*–6*f*	^{2}D–^{2}F°	*70.997*	*502904*	*1911419*	10	14	560	0.059	0.14	−0.23	D	1
			70.986	503260	1911470	6	8	570	0.057	0.080	−0.47	D	*ls*
			[70.973]	502370	[1911350]	4	6	530	0.060	0.056	−0.62	D	*ls*
			[71.018]	503260	[1911350]	6	6	38	0.0029	0.0040	−1.76	E	*ls*
13.	4*s*–4*p*	^{2}S–^{2}P°	*1212.1*	1133370	*1216557*	2	6	10.0	0.66	5.3	0.121	C	1, 2
			[1186.2]	1133370	1217670	2	4	10.7	0.452	3.53	−0.044	C	*ls*
			[1235.2]	1133370	1214330	2	2	9.5	0.218	1.77	−0.361	C	*ls*
14.	4*s*–5*p*	^{2}S–^{2}P°	*194.76*	1133370	*1646813*	2	6	130	0.22	0.28	−0.36	D	1
			[194.58]	1133370	1647310	2	4	130	0.15	0.19	−0.52	D	*ls*
			[195.14]	1133370	1645820	2	2	130	0.072	0.093	−0.84	D	*ls*
15.	4*p*–5*s*	^{2}P°–^{2}S	*259.39*	*1216557*	[1602071]	6	2	420	0.14	0.72	−0.08	D+	1
			260.145	1217670	[1602071]	4	2	280	0.14	0.48	−0.25	D+	*ls*
			[257.90]	1214330	[1602071]	2	2	140	0.14	0.24	−0.55	D+	*ls*
16.	4*p*–6*s*	^{2}P°–^{2}S				6	2		0.024		−0.84	D	1

Ti 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
17.	4*p*–4*d*	^{2}P°–^{2}D	*951.48*	*1216557*	*1321656*	6	10	26.1	0.59	11.1	0.55	C	1, 2
			[959.97]	1217670	1321840	4	6	25.6	0.53	6.7	0.326	C	*ls*
			[934.14]	1214330	1321380	2	4	23.0	0.60	3.70	0.079	C	*ls*
			[964.23]	1217670	1321380	4	4	4.2	0.058	0.74	−0.63	D	*ls*
18.	4*p*–5*d*	^{2}P°–^{2}D	*207.86*	*1216557*	*1697656*	6	10	190	0.21	0.86	0.10	D	1
			[208.30]	1217670	1697740	4	6	190	0.19	0.52	−0.12	D	*ls*
			[206.95]	1214330	1697530	2	4	170	0.21	0.29	−0.38	D	*ls*
			[208.39]	1217670	1697530	4	4	32	0.021	0.057	−1.08	E	*ls*
19.	4*p*–6*d*	^{2}P°–^{2}D				6	10		0.051		−0.51	D	1

Ti XIII

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

Ionization Potential 787.33 eV = 6350400 cm^{-1}

Allowed Transitions

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 agreements 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 more affected by uncertainties in the calculated intermediate coupling coefficients than the stronger lines, and the accuracy ratings have been correspondingly lowered.

References

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

Ti XIII: Allowed transitions

No.	Transition array	Multiplet or transition	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–$^3P^\circ$											
			[26.960]	0	3709200	1	3	1900	0.063	0.0056	−1.20	D−	1
2.		^1S–$^1P^\circ$	[26.641]	0	3753600	1	3	2300	0.075	0.0066	−1.12	D−	1
3.	$2p^6$–$2p^5 4s$	^1S–[1½]°	[20.135]	0	4966500	1	3	930	0.017	0.0011	−1.77	D−	1
4.		^1S–[1/2]°	[19.943]	0	5014300	1	3	630	0.011	7.4(−4)[a]	−1.96	D−	1
5.	$2p^6$–$2p^5 5s$	^1S–[1½]°				1	3		0.0070		−2.15	E	1
6.		^1S–[1/2]°				1	3		0.0040		−2.40	E	1
7.	$2p^6$–$2p^5 6s$	^1S–[1½]°				1	3		0.0036		−2.44	E	1
8.		^1S–[1/2]°				1	3		0.0019		−2.72	E	1
9.	$2p^6$–$2p^5 3d$	^1S–$^3D^\circ$											
			[23.698]	0	4219800	1	3	1.3(+4)	0.33	0.026	−0.48	D	1
10.		^1S–$^1P^\circ$	[23.356]	0	4281600	1	3	9.7(+4)	2.4	0.18	0.38	D	1
11.	$2p^6$–$2p^5 4d$	^1S–$^3D^\circ$											
			[19.366]	0	5163700	1	3	1.7(+4)	0.28	0.018	−0.55	D	1
12.		^1S–$^1P^\circ$	[19.204]	0	5207200	1	3	2.7(+4)	0.45	0.028	−0.35	D	1
13.	$2p^6$–$2p^5 5d$	^1S–$^3D^\circ$											
			17.869			1	3	9700	0.14	0.0082	−0.85	D	1
14.		^1S–$^1P^\circ$	17.727			1	3	1.1(+4)	0.16	0.0093	−0.80	D	1

Ti XIII: Allowed Transitions—Continued

No.	Transition array	Multiplet or transition	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.	$2p^6$–$2p^5 6d$	^{1}S–^{3}P°											
						1	3		0.0012		−2.92	E	1
16.		^{1}S–^{3}D°											
						1	3		0.065		−1.19	E	1
17.		^{1}S–^{1}P°				1	3		0.094		−1.03	E	1
18.	$2p^5 3s$–$2p^5 3p$	^{3}P°–^{3}S	569.48	[3704400]	[3880000]	9	3	25	0.040	0.67	−0.45	D	1
			[535.62]	[3693300]	[3880000]	5	3	26	0.067	0.59	−0.47	D	1
			[585.48]	3709200	[3880000]	3	3	2.0	0.010	0.059	−1.51	E	1
			[742.39]	[3745300]	[3880000]	1	3	0.27	0.0067	0.016	−2.17	E	1
19.		^{3}P°–^{3}D											
			[474.61]	[3693300]	[3904000]	5	7	42	0.20	1.6	−0.00	D	1
			[522.19]	3709200	[3900700]	3	5	18	0.12	0.63	−0.43	D	1
			[488.04]	[3745300]	[3950200]	1	3	18	0.19	0.31	−0.71	D	1
			[482.16]	[3693300]	[3900700]	5	5	19	0.066	0.53	−0.48	D	1
			[414.94]	3709200	[3950200]	3	3	0.20	5.2(−4)	0.0021	−2.81	E	1
20.		^{3}P°–^{1}P											
			[455.37]	[3693300]	[3912900]	5	3	3.6	0.0067	0.050	−1.47	E	1
			[490.92]	3709200	[3912900]	3	3	37	0.13	0.65	−0.40	D	1
			[596.66]	[3745300]	[3912900]	1	3	0.25	0.0040	0.0079	−2.40	E	1
21.		^{3}P°–^{3}P											
			[437.45]	[3693300]	[3921900]	5	5	28	0.080	0.58	−0.40	D	1
			[368.32]	[3693300]	[3964800]	5	3	5.3	0.0065	0.039	−1.49	E	1
			[419.99]	3709200	[3947300]	3	1	43	0.038	0.16	−0.94	D	1
			[470.15]	3709200	[3921900]	3	5	21	0.12	0.54	−0.46	D	1
			[455.58]	[3745300]	[3964800]	1	3	24	0.22	0.34	−0.65	D	1
22.		^{3}P°–^{1}D											
			[366.97]	[3693300]	[3965800]	5	5	1.0	0.0020	0.012	−2.00	E	1
			[389.71]	3709200	[3965800]	3	5	1.3	0.0049	0.019	−1.83	E	1
23.		^{3}P°–^{1}S											
			[264.48]	3709200	[4087300]	3	1	81	0.028	0.074	−1.07	E	1
24.		^{1}P°–^{3}S											
			[791.14]	3753600	[3880000]	3	3	0.23	0.0022	0.017	−2.19	E	1
25.		^{1}P°–^{3}D											
			[508.65]	3753600	[3950200]	3	3	19	0.074	0.37	−0.66	D	1
26.		^{1}P°–^{3}P											
			[594.18]	3753600	[3921900]	3	5	0.58	0.0051	0.030	−1.81	E	1
			[473.48]	3753600	[3964800]	3	3	18	0.060	0.28	−0.74	D	1
			[516.26]	3753600	[3947300]	3	1	11	0.015	0.075	−1.36	E	1
27.		^{1}P°–^{1}D	[471.25]	3753600	[3965800]	3	5	42	0.23	1.1	−0.16	D	1
28.		^{1}P°–^{1}S	[299.67]	3753600	[4087300]	3	1	110	0.049	0.15	−0.83	D	1

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

Ti XIV

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

Ionization Potential 861.33 eV = 6947300 cm^{-1}

Allowed Transitions

Two theoretical values exist for the single multiplet listed, which are from the superposition of configurations calculations of Nicolaides and Sinanoglu [1] and the nuclear charge expansion calculations of Cohen and Dalgarno [2]. The data agree quite well; we have chosen the work of the first mentioned authors since their configuration interaction treatment is more extensive.

References

[1] Nicolaides, C. A., and Sinanoglu, O., private communication (1973).
[2] Cohen, M., and Dalgarno, A., Proc. Roy. Soc., Ser. A **280**, 258 (1964).

Ti 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.	$2s^2 2p^5$–$2s2p^6$	$^2P^o$–^2S	*124.37*	*15733*	819810	6	2	620	0.048	0.12	−0.54	C	1
			121.994	0	819810	4	2	450	0.050	0.080	−0.70	D	*ls*
			129.384	47200	819810	2	2	190	0.047	0.040	−1.03	D	*ls*

Ti XV

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

Ionization Potential 940.36 eV = 7584700 cm^{-1}

Allowed Transitions

The data for this ion of the oxygen isoelectronic sequence were taken from the superposition of configurations calculations of Nicolaides and Sinanoglu [1] and the interpolations along the isoelectronic sequence performed by Smith and Wiese [2].

References

[1] Nicolaides, C. A., and Sinanoglu, O., private communication (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).

Ti 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.	$2s^2 2p^4$–$2s2p^5$	^3P–$^3P^o$	*140.76*	*17782*	[*728220*]	9	9	303	0.090	0.375	−0.092	C	1
			140.34	0	[712560]	5	5	230	0.068	0.16	−0.47	D	*ls*
			142.09	39249	[743030]	3	3	74	0.022	0.031	−1.18	D	*ls*
			134.57	0	[743030]	5	3	140	0.024	0.052	−0.93	D	*ls*
			138.33	39249	[762160]	3	1	320	0.031	0.042	−1.04	D	*ls*
			148.54	39249	[712560]	3	5	64	0.035	0.052	−0.97	D	*ls*
			142.72	42293	[743030]	1	3	97	0.089	0.042	−1.05	D	*ls*
2.		^1D–$^1P^o$	115.02	109116	[978530]	5	3	1080	0.128	0.242	−0.194	C	1
3.		^1S–$^1P^o$	131.12	215706	[978530]	1	3	65	0.050	0.0216	−1.301	C	1
4.	$3s$–$3p$	$^3S^o$–^3P				3	9		0.41		0.09	D	2
5.		$^5S^o$–^5P				5	15		0.21		0.02	D	2

Ti XVI

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

Ionization Potential [1042] eV = [8404500] cm^{-1}

Allowed Transitions

For this ion of the nitrogen isoelectronic sequence, the data were obtained from the superposition of configurations calculations by Nicolaides and Sinanoglu [1] and the interpolations along the sequence performed by Smith and Wiese [2]. Whenever wavelength data were available, data for individual lines within the multiplets are presented.

References

[1] Nicolaides, C. A., and Sinanoglu, O., private communication (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).

Ti 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.	$2s^2 2p^3$–$2s2p^4$	${}^4S^\circ$–${}^4P$	*164.74*	0	[*607000*]	4	12	90	0.11	0.24	−0.36	C	1, 2
			169.74	0	[589100]	4	6	83	0.054	0.12	−0.67	D	*ls*
			161.17	0	[620500]	4	4	97	0.038	0.080	−0.82	D	*ls*
			157.81	0	[633700]	4	2	100	0.019	0.040	−1.12	D	*ls*
2.		${}^2D^\circ$–${}^2D$				10	10		0.063		−0.201	C	1
3.		${}^2D^\circ$–${}^2P$	*115.42*			10	6	750	0.090	0.342	−0.046	C	1
			118.21			6	4	630	0.088	0.21	−0.28	D	*ls*
			110.56			4	2	850	0.078	0.11	−0.51	D	*ls*
			116.21			4	4	74	0.015	0.023	−1.22	D−	*ls*
4.		${}^2P^\circ$–${}^2D$				6	10		0.020		−0.94	C	1
5.		${}^2P^\circ$–${}^2S$				6	2		0.038		−0.67	C	1
6.		${}^2P^\circ$–${}^2P$	*128.36*			6	6	190	0.048	0.12	−0.54	C	1
			132.04			4	4	150	0.039	0.067	−0.81	D	*ls*
			[121.58]			2	2	150	0.034	0.027	−1.17	D	*ls*
			124.82			4	2	68	0.0079	0.013	−1.50	D	*ls*
			128.42			2	4	31	0.015	0.013	−1.52	D	*ls*
7.	$3s$–$3p$	${}^4P$–${}^4D^\circ$				12	20		0.17		0.31	D+	2
8.		${}^4P$–${}^4P^\circ$				12	12		0.11		0.12	D+	2
9.		${}^2P$–${}^2D^\circ$				6	10		0.18		0.03	D+	2
10.	$3s'$–$3p'$	${}^2D$–${}^2F^\circ$				10	14		0.12		0.08	D+	2
11.	$3p'$–$3d'$	${}^2F^\circ$–${}^2G$				14	18		0.25		0.54	D	2

Ti XVII

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

Ionization Potential [1131] eV = [9122400] cm^{-1}

Allowed Transitions

The data for this ion of the carbon isoelectronic sequence were obtained from the recent superposition of configurations calculations by Nicolaides and Sinanoglu [1] and the interpolations along the isoelectronic sequence by Smith and Wiese [2].

Normally, Sinanoglu's recent work is in close agreement with the earlier results of Smith and Wiese. An exception is the $2s^2 2p^2\ ^1D$–$2s2p^3\ ^1D^\circ$ transition where a discrepancy of a factor of two exists. For this transition, a new comprehensive superposition of configurations calculation was performed by Weiss [3] on the ion Si IX of this isoelectronic sequence. His result agrees very well with the interpolated data so that these were chosen in this case.

References

[1] Nicolaides, C. A., and Sinanoglu, O., private communication (1973).
[2] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).
[3] Weiss, A. W., private communication (1974).

Ti 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.	$2s^2 2p^2$–$2s2p^3$	^3P–$^3D^\circ$				9	15		0.044		−0.40	C	1, 2
2.		^3P–$^3P^\circ$				9	9		0.048		−0.36	C	1, 2
3.		^3P–$^3S^\circ$				9	3		0.065		−0.23	C	1, 2
4.		^1D–$^1D^\circ$	147.78 ?	[141800]	[818500]	5	5	430	0.14	0.34	−0.15	C+	2
5.		^1D–$^1P^\circ$	130.87 ?	[141800]	[905900]	5	3	422	0.065	0.140	−0.488	C	1
6.		^1S–$^1P^\circ$	149.66 ?			1	3	110	0.11	0.054	−0.96	C	1
7.	$2s^2 2p^2$–$2s^2 2p3s$	^3P–$^3P^\circ$				9	9		0.051		−0.34	C+	2
8.		^1D–$^1P^\circ$	19.718	[141800]	[5213000]	5	3	1.2(+4)[a]	0.042	0.014	−0.68	C+	2
9.	$3s$–$3p$	$^3P^\circ$–^3D				9	15		0.13		0.07	C+	2
10.		$^3P^\circ$–^3P				9	9		0.10		−0.05	C	2
11.		$^3P^\circ$–^3S				9	3		0.029		−0.58	C	2
12.		$^1P^\circ$–^1D				3	5		0.21		−0.20	C	2
13.		$^1P^\circ$–^1S				3	1		0.057		−0.77	D+	2
14.	$3p$–$3d$	^3D–$^3F^\circ$				15	21		0.17		0.41	C	2
15.		^3P–$^3D^\circ$				9	15		0.13		0.07	C	2
16.		^3D–$^3D^\circ$				15	15		0.030		−0.35	C	2
17.		^3P–$^3P^\circ$				9	9		0.041		−0.43	C	2
18.		^3S–$^3P^\circ$				3	9		0.17		−0.29	C	2
19.		^1D–$^1F^\circ$				5	7		0.12		−0.22	D+	2
20.		^1P–$^1D^\circ$				3	5		0.22		−0.18	D	2
21.		^1P–$^1P^\circ$				3	3		0.061		−0.74	D+	2

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

Ti XVIII

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

Ionization Potential [1220] eV = [9840200] cm^{-1}

Allowed Transitions

For this ion of the boron isoelectronic sequence, the data have been taken from calculations of Nicolaides and Sinanoglu [1], which include configuration interaction, and from the interpolated f-values of Smith and Wiese [2] obtained from systematic trends within this sequence that are well established.

References

[1] Nicolaides, C. A., and Sinanoglu, O., private communication (1973).

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

Ti 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.	$2s^2 2p-2s2p^2$	$^2P^o-^2D$				6	10		0.041		−0.61	C	1, 2
2.		$^2P^o-^2S$	*163.01*	[*37400*]	[650900]	6	2	140	0.018	0.058	−0.97	C	1
			168.13 ?	[56090]	[650900]	4	2	83	0.018	0.039	−1.14	D	*ls*
			153.64 ?	0	[650900]	2	2	53	0.019	0.019	−1.42	D	*ls*
3.		$^2P^o-^2P$				6	6		0.10		−0.22	C	1, 2
4.	$2s^2 2p-2s^2 3s$	$^2P^o-^2S$	*18.32*	[*37400*]	[5497000]	6	2	1.2(+4)[a]	0.020	0.0072	−0.92	C	2
			18.38 ?	[56090]	[5497000]	4	2	7800	0.020	0.0048	−1.10	D	*ls*
			[18.19]	0	[5497000]	2	2	4000	0.020	0.0024	−1.40	D	*ls*
5.	$2s^2 2p-2s^2 3d$	$^2P^o-^2D$				6	10		0.65		0.59	C	2
6.	$2s2p^2-2p^3$	$^4P-^4S^o$				12	4		0.044		−0.28	C	2
7.		$^2P-^2D^o$				6	10		0.058		−0.46	D+	2
8.		$^2D-^2D^o$				10	10		0.52		0.72	D+	2
9.	$2s^2 3s-2s^2 3p$	$^2S-^2P^o$				2	6		0.18		−0.44	C	2
10.	$2s^2 3p-2s^2 3d$	$^2P^o-^2D$				6	10		0.054		−0.49	D+	2

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

Ti XIX

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

Ionization Potential [1342] eV = [10824000] cm^{-1}

Allowed Transitions

The data chosen for this ion of the Be isoelectronic sequence are the interpolated values derived from studies of systematic trends of f-values within the isoelectronic sequence by Smith and Wiese [1]. The interpolated data are derived mainly from calculations and beam-foil lifetimes. For one transition, $2s2p\ ^1P^o$–$2p^2\ ^1D$, the results of very recent nuclear charge expansion calculations of Laughlin and Dalgarno [2] were added which slightly modify the existing systematic trend.

References

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

[2] Laughlin, C., and Dalgarno, A., Phys. Lett. A **35**, 61 (1971).

Ti 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.	$2s^2$–$2s2p$	^1S–$^1P^o$	169.326	0	590600	1	3	140	0.18	0.100	−0.745	B	1
2.	$2s2p$–$2s3s$	$^3P^o$–^3S				9	3		0.029		−0.58	C	1
3.	$2s2p$–$2p^2$	$^3P^o$–^3P	*201.55*	[*329500*]	[*825600*]	9	9	112	0.068	0.406	−0.213	B	1
			203.422	[350200]	[841800]	5	5	81	0.050	0.169	−0.60	*C*	*ls*
			197.800	[307800]	[813200]	3	3	29.5	0.0173	0.0338	−1.285	C	*ls*
			216.035	[350200]	[813200]	5	3	37.5	0.0157	0.056	−1.104	C	*ls*
			[210.84]	[307800]	[782100]	3	1	97	0.0217	0.0451	−1.187	C	*ls*
			187.309	[307800]	[841800]	3	5	34.5	0.0303	0.056	−1.042	C	*ls*
			191.461	[290900]	[813200]	1	3	43.4	0.072	0.0451	−1.145	C	*ls*
4.		$^1P^o$–^1S				3	1		0.040		−0.92	C+	1
5.		$^1P^o$–^1D	297.889	590600	[926300]	3	5	27.1	0.060	0.177	−0.74	C+	1, 2
6.	$2s2p$–$2s3d$	$^1P^o$–^1D				3	5		0.54		0.210	C	1
7.		$^3P^o$–^3D				9	15		0.74		0.82	C	1
8.	$2s3s$–$2s3p$	^3S–$^3P^o$				3	9		0.19		−0.24	C	1
9.	$2s3p$–$2s3d$	$^3P^o$–^3D				9	15		0.036		−0.49	D+	1

Ti XX

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

Ionization Potential [1425] eV = [11494000] cm^{-1}

Allowed Transitions

The data for this ion of the Li isoelectronic sequence are taken from studies by Smith and Wiese [1] and Martin and Wiese [2], who derived *f*-values graphically by interpolation from systematic trends within the sequence. For most transitions the data on which the trends are based are plentiful and reliable, so that the trends are well established. In a few cases, wavelength and energy level data are available, which permit the calculation of individual line data within multiplets. We have then used the *LS*-coupling ratios, which should be a fair assumption for this Li-like ion.

References

[1] Smith, M. W., and Wiese, W. L., Astrophys. J., Suppl. Ser. **23**, No. 196, 103 (1971).
[2] Martin, G. A., and Wiese, W. L., to be published (1975).

Ti 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.	2*s*–2*p*	^2S–$^2P^o$	*268.68*	0	[*372200*]	2	6	20.0	0.065	0.115	− 0.89	B	1
			254.01	0	[393700]	2	4	23.8	0.0460	0.077	− 1.036	B	*ls*
			303.75	0	[329200]	2	2	13.9	0.0193	0.0385	− 1.413	B	*ls*
2.	2*s*–3*p*	^2S–$^2P^o$	*15.228*	0	*6567000*	*2*	*6*	3.55(+ 4)[a]	0.370	0.0371	− 0.131	B	1
			15.217	0	6572000	2	4	3.55(+ 4)	0.247	0.0247	− 0.306	B	*ls*
			15.252	0	6557000	2	2	3.54(+ 4)	0.123	0.0124	− 0.609	B	*ls*
3.	2*s*–4*p*	^2S–$^2P^o$				2	6		0.099		− 0.70	C	2
4.	2*s*–5*p*	^2S–$^2P^o$				2	6		0.040		− 1.10	C	2
5.	2*s*–6*p*	^2S–$^2P^o$				2	6		0.0211		− 1.375	C	2
6.	2*s*–7*p*	^2S–$^2P^o$				2	6		0.0124		− 1.61	C	2
7.	2*p*–3*s*	$^2P^o$–^2S	*16.326*	[*365000*]	[6490000]	6	2	1.32(+ 4)	0.0176	0.00568	− 0.976	C +	1
			16.379	[385000]	[6490000]	4	2	8740	0.0176	0.00379	− 1.152	C +	*ls*
			16.218	[324000]	[6490000]	2	2	4490	0.0177	0.00189	− 1.451	C +	*ls*
8.	2*p*–4*s*	$^2P^o$–^2S				6	2		0.0037		− 1.65	C +	1
9.	2*p*–3*d*	$^2P^o$–^2D	*16.010*	[*365000*]	[*6610700*]	6	10	1.06(+ 5)	0.68	0.215	0.61	C +	1
			16.059	[385000]	[6612500]	4	6	1.05(+ 5)	0.61	0.129	0.387	C +	*ls*
			15.914	[324000]	[6608000]	2	4	9.1(+ 4)	0.69	0.072	0.140	C +	*ls*
			[16.069]	[385000]	[6608000]	4	4	1.8(+ 4)	0.068	0.014	− 0.57	D	*ls*
10.	2*p*–4*d*	$^2P^o$–^2D				6	10		0.12		− 0.14	C +	1
11.	3*s*–3*p*	^2S–$^2P^o$				2	6		0.108		− 0.666	C +	1
12.	3*s*–4*p*	^2S–$^2P^o$				2	6		0.42		− 0.076	C	2
13.	3*s*–5*p*	^2S–$^2P^o$				2	6		0.107		− 0.67	C	2
14.	3*s*–6*p*	^2S–$^2P^o$				2	6		0.047		− 1.03	C	2
15.	3*s*–7*p*	^2S–$^2P^o$				2	6		0.0248		− 1.305	C	2
16.	3*p*–4*s*	$^2P^o$–^2S				6	2		0.040		− 0.62	C +	1

Ti 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
17.	$3p$–$3d$	^{2}P°–^{2}D				6	10		0.0179		−0.969	C+	1
18.	$3p$–$4d$	^{2}P°–^{2}D				6	10		0.59		0.55	C+	1
19.	$3p$–$5d$	^{2}P°–^{2}D				6	10		0.137		−0.085	C	2
20.	$3d$–$4f$	^{2}D–^{2}F°				10	14		1.00		1.000	C+	1
21.	$4s$–$4p$	^{2}S–^{2}P°				2	6		0.177		−0.451	C	2
22.	$4s$–$5p$	^{2}S–^{2}P°				2	6		0.467		−0.030	C	2
23.	$4s$–$6p$	^{2}S–^{2}P°				2	6		0.127		−0.60	C	2
24.	$4s$–$7p$	^{2}S–^{2}P°				2	6		0.055		−0.96	C	2
25.	$4p$–$5s$	^{2}P°–^{2}S				6	2		0.065		−0.409	C	2
26.	$4p$–$4d$	^{2}P°–^{2}D				6	10		0.035		−0.68	C	2
27.	$4p$–$5d$	^{2}P°–^{2}D				6	10		0.58		0.54	C	2
28.	$4p$–$6d$	^{2}P°–^{2}D				6	10		0.141		−0.073	C	2

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

Ti XXI

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

Ionization Potential [6249] eV = [50403000] cm^{-1}

Allowed Transitions

The data for this ion of the He isoelectronic sequence are taken from the variational calculations by Weiss [1], which represent the most comprehensive and accurate body of data for this sequence. They are well supported for the lower ions of the sequence by other advanced experimental and theoretical material.

Reference

[1] Weiss, A. W., J. Res. Nat. Bur. Stand. **71A**, 163 (1967).

Ti 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.	$1s^2$–$1s2p$	^{1}S–^{1}P°	2.62	0	[38168000]	1	3	2.56(+6)[a]	0.79	0.0068	−0.102	B	1
2.	$1s^2$–$1s3p$	^{1}S–^{1}P°	2.23	0	[44843000]	1	3	6.93(+5)	0.155	0.00114	−0.810	B	1
3.	$1s2s$–$1s2p$	^{1}S–^{1}P°				1	3		0.0239		−1.622	B	1
4.		^{3}S–^{3}P°				3	9		0.0326		−1.010	B	1
5.	$1s2s$–$1s3p$	^{1}S–^{1}P°				1	3		0.412		−0.385	B	1
6.		^{3}S–^{3}P°				3	9		0.403		0.082	B	1
7.	$1s2p$–$1s3d$	^{1}P°–^{1}D				3	5		0.70		0.322	B	1
8.		^{3}P°–^{3}D				9	15		0.68		0.79	B	1
9.	$1s3p$–$1s3d$	^{3}P°–^{3}D				9	15		0.0134		−0.919	B	1

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

Ti XXII

Ground State	$1s\,^2S_{1/2}$
Ionization Potential	[6625.6] eV = [53443400] 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

$$f_{\text{Ti XXII}} = f_{\text{Hydrogen}},$$
$$A_{\text{Ti XXII}} = (22)^4 A_{\text{Hydrogen}},$$
$$S_{\text{Ti XXII}} = (22)^{-2} S_{\text{Hydrogen}}.$$

Judging from very recent theoretical studies [2, 3, 4], relativistic effects are expected to introduce uncertainties of a few percent into these data.

References

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

[2] Weiss, A. W., private communication.

[3] Sinanoglu, O., and Luken, W., Chem. Phys. Lett. **20**, 407 (1973).

[4] 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).

7. List of Recent Additional Material

(New material which would have been considered if received before the cut-off date.)

Spectrum	References
Sc I	1, 3
Ti I	1, 3, 4
Ti II	1
Ti VIII	2
Ti XV	2
Ti XVI	2
Ti XVII	2

References and Comments

[1] Kurucz, R. L., Smithsonian Astrophysical Observatory Special Report 360 (1974).

Sc I, Ti I, II

Semi-empirical calculations based on scaled Thomas-Fermi-Dirac wave functions, done in intermediate coupling.

[2] Kastner, S. O., and Wade, C., Astrophys. J., Suppl. Ser. **27**, No. 243, 247 (1974).

Ti VIII, XV, XVI, XVII

Calculations based on the Coulomb approximation, used in conjunction with binding-energy values obtained by a screening approximation.

[3] Biemont, E., J. Quant. Spectrosc. Radiat. Transfer **14**, 959 (1974).

Sc I, Ti I

Calculations based on scaled Thomas-Fermi wave functions.

[4] Biemont, E., Solar Phys. **38**, 15 (1974).

Ti I

Calculations based on scaled Thomas-Fermi wave functions.