Energy Levels of Vanadium, V I through V XXIII

Jack Sugar and Charles Corliss

Center for Radiation Research, National Measurement Laboratory, National Bureau of Standards, Washington, D.C. 20234

The energy levels of the vanadium atom in all of its stages of ionization, as derived from the analyses of atomic spectra, have been critically compiled. In cases where only line classifications are given in the literature, level values have been derived. The percentages for the two leading components of the calculated eigenvectors of the levels are given where available. Ionization energies and experimental g-values are also given.

Key words: Atomic energy levels; atomic spectra; vanadium.

Contents

Introduction

A great amount of new experimental work has been carried out since the publication of Atomic Energy Levels, Vol. I, by Moore (1949), particularly in the higher stages of ionization. This was the result of the development of more energetic light sources which was stimulated by the need to interpret new spectroscopic observations of the sun at short wavelengths from rocket and satellite-borne spectrographs. A new impetus for the interpretation of spectra of highly ionized atoms has also arisen from the investigation of hot laboratory plasmas generated to achieve nuclear fusion.

These activities have produced a substantial increase in spectroscopic information, particularly for elements of the iron period; the earlier compilation of energy levels has become inadequate. The previous compilation of vanadium energy levels includes only thirteen of the twenty-three vanadium spectra and many of those have since been significantly revised or corrected. The NBS Atomic Energy Levels Data Center has undertaken the task of providing new compilations of energy levels in the iron period. As the material on each atom and its ions is compiled, it will be published as a separate paper and later revised and collected into one volume. Already completed are the compilations for iron by Reader and Sugar (1975), chromium by Sugar and Corliss (1977), and manganese by Corliss and Sugar (1977). The present work on vanadium will be followed by a compilation for titanium, which is near completion.

The present compilation comprises the energy levels of the vanadium atom and all of its ions, as derived from analyses of atomic spectra. These are primarily levels arising from outer-shell excitations. For the high stages of ionization, inner-shell excitations are included since the distinction in energy becomes less clear. For many of the ions the original papers do not give energy level values, but only classifications of observed lines. In these cases we have derived the level values. Although in most cases we used only published papers as sources of data, unpublished material was included when it constituted a considerable improvement.

We have also derived some of the ionization energies from the observed levels.[1] For a large number of ions, no suitable series are known that permit the derivation of an experimental value of the ionization energy. In these cases we have quoted estimated values obtained by extrapolation along isoelectronic sequences. Although it is not possible to give a quantitative

[1] Values for ionization energies are usually derived in their equivalence in cm^{-1}. The conversion factor 8065.479 cm^{-1}/eV, as given by E. R. Cohen and B. N. Taylor, J. Phys. Chem. Ref. Data 2, 663 (1973), was used to obtain values in eV.

uncertainty for these extrapolated values, they are probably accurate to a few units of the last significant figure given.

Nearly all of the data are the results of observations of various types of laboratory light sources. However, they are sometimes supplemented by data obtained from solar observations. This is particularly true where spin-forbidden lines are required to establish the absolute energy of a system of excited levels and also where parity-forbidden transitions between levels of a ground configuration are used to obtain accurate relative energies for the low levels. Whenever both solar data and equivalent laboratory data were available for a given level system or part of a level system, preference was generally given to the laboratory data in order to avoid the problem of blended lines of various elements in the solar spectra. For V XXII and XXIII, which are isoelectronic with He I and H I, we give the theoretical level values since they are much more accurate than the experimental x-ray wavelengths.

For a convenient source of wavelengths of vanadium lines below 2000 Å we refer the reader to the compilation by Kelly and Palumbo (1973).

Almost every level in the present compilation is accompanied by a quantum mechanical designation (or name). The treatment of the level designations is sometimes a troublesome question. For a given configuration a certain number of terms of various types (^{5}H, ^{7}H, etc. in *LS* coupling, for example) are theoretically expected, and spectroscopists have traditionally tried to give such definite names to terms, even though *g*-values, intensities, and arrangement of the levels may indicate that no such "pure" name is appropriate. It is of interest to know just how well the name of a level describes its quantum properties. To this end, we have included results of theoretical calculations that express the percentage composition of levels in terms of the basis states of a single configuration, or more than one configuration where configuration interaction has been included.

The percentage compositions have the following meaning. Suppose that for a given configuration there is a set of n basis states, written symbolically as $\psi_1, \psi_2, \ldots, \psi_n$. Usually these basis states are taken to be the *LS*-states for a configuration, but other coupling schemes are often used. Then the eigenvector ψ_A of an actual energy level A can be expressed as

$$\psi_A = \alpha_1\psi_1 + \alpha_2\psi_2 + \ldots \alpha_n\psi_n$$

where $\alpha_1^2 + \alpha_2^2 + \ldots \alpha_n^2 = 1$. The squared quantities α_1^2, α_2^2, etc., multiplied by 100, represent the percentage composition of a given level. Generally, levels are given names corresponding to the basis state having the largest percentage.

In the columns of the present tables headed "Leading components" we give first the percentage of the basis state corresponding to the level's name; next the second largest (in a few cases the largest) percentage together with the related basis state. We have not listed any second component whose percentage is less than 4 percent. The percentages show that in many cases it is not possible to group the levels into meaningful terms. However, where levels have been arranged into terms in the original papers or in subsequent theoretical calculations, we have generally retained these groupings.

Of course, the percentage compositions cannot be considered to be as reliable as experimental quantities inasmuch as a new calculation using a different approximation, such as the introduction of configuration interaction where none had been used before, might yield a different set of percentages. For some levels the percentages may change drastically in a new calculation. Therefore the compositions given here should be considered only as a useful guide to the true quantum character of the levels.

It should be noted that the theoretical calculations involved in obtaining the percentage compositions are of two types. The semiempirical method treats the radial integrals appearing in the energy matrix as parameters whose values are determined by a least-squares fit to the observed levels. In the ab initio method, the radial integrations are carried out with wavefunctions found by solving the wave equation for a given atom, as in a Hartree-Fock calculation or variation thereof. In the present tables, the percentages are mostly taken from published least-squares level-fitting calculations. When only ab initio calculations are found in the literature, we have used them if there appears to be a reasonable correspondence with the experimental data. For higher ionization stages there have been fewer publications relating quantitatively the theoretical results to the observations by means of least-squares calculations.

For configurations of equivalent *d* electrons, repeating terms of the same *LS* type sometimes occur. These are generally distinguished by their seniority number. In the present compilation they are designated in the notation of Nielson and Koster (1963). For example, in the $3d^5$ configuration there are three ^{2}D terms with seniorities of 1, 3, and 5, respectively. These terms are denoted as ^{2}D1, ^{2}D2, and ^{2}D3 by Nielson and Koster.

The labeling of terms by lower case letters, *a*, *b*, *c*, etc. (for example *a* ^{5}D, *z* ^{5}G°, etc.) has been dropped, except for V I–III, where their use in connection with various wavelength tables makes their retention desirable.

In assembling the data for each spectrum, we referred to the following bibliographies:

i. papers cited by Moore (1949)
ii. C. E. Moore (1968)
iii. L. Hagan and W. C. Martin (1972)
iv. B. Edlén (1975)
v. L. Hagan (1977)
vi. card file of publications since June 1975 maintained by the NBS Atomic Energy Levels Data Center.

A selection of data was made that, in our judgment, represents the most accurate and reliable available. The text for each ion is not always a complete review of the literature but is intended to credit the major contributions. A final check for new data was made on July 1, 1977, at which time the compilations were considered completed.

Acknowledgements

Throughout this work we have made extensive use of the bibliographical files and reprint collection maintained in the Atomic Energy Levels Data Center by Dr. Romuald Zalubas. Our thanks are extended to him for generous cooperation. The compilation has also benefited greatly from the preprints that were provided by many of our colleagues.

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References for Introduction

Corliss, C., and Sugar, J. (1977), Energy Levels of Manganese, Mn I through Mn XXV, J. Phys. Chem. Ref. Data **6**, 1253.

Edlén, B. (1976), in Beam Foil Spectroscopy, Vol. 1 (Plenum Press, N.Y. and London).

Hagan, L. (1977), Bibliography on Atomic Energy Levels and Spectra, July 1971 through June 1975, Nat. Bur. Stand. (U.S.) Spec. Publ. 363, Suppl. 1 (U.S. Gov't Printing Office, Washington, D.C.).

Hagan, L., and Martin, W. C. (1972), Bibliography on Atomic Energy Levels and Spectra, July 1968 through June 1971, Nat. Bur. Stand. (U.S.) Spec. Publ. 363 (U.S. Gov't Printing Office, Washington, D.C.).

Kelly, R. L., and Palumbo, L. J. (1973), Atomic and Ionic Emission Lines Below 2000 Angstroms—Hydrogen Through Krypton, NRL Report 7599 (U.S. Gov't Printing Office, Washington, D.C.).

Moore, C. E. (1949), Atomic Energy Levels, Nat. Bur. Stand. (U.S.) Circ. 467, Vol. I (U.S. Gov't Printing Office, Washington, D.C.).

Moore, C. E. (1968), Bibliography on the Analyses of Optical Atomic Spectra, Section 1, Nat. Bur. Stand. (U.S.), Spec. Publ. 306 (U.S. Gov't Printing Office, Washington, D.C.).

Nielson, C. W., and Koster, G. F. (1963), Spectroscopic Coefficients for the p^n, d^n, and f^n Configurations (The M.I.T. Press, Cambridge).

Reader, J., and Sugar, J. (1975), Energy Levels of Iron, Fe I through Fe XXVI, J. Phys. Chem. Ref. Data **4**, 353.

Sugar, J., and Corliss, C. (1977), Energy Levels of Chromium, Cr I through Cr XXIV, J. Phys. Chem. Ref. Data **6**, 317.

Energy Level Tables

V I

$Z = 23$

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

Ionization energy = 54 360 cm^{-1} (6.740 eV)

The compilation of levels for this spectrum is based on the analysis by Meggers and Russell (1936). The wavelengths of the lines between 2080 and 2756 Å and between 4494 and 11 911 Å were measured by Meggers at the National Bureau of Standards; those in the intermediate range, 2756 to 4494 Å, were mostly from the earlier literature. The Zeeman-effect data were obtained from previously unpublished measurements of H. D. Babcock. Russell and Babcock (1935) have discussed the g-values. Meggers and Russell noted that a major difficulty with observations of the vanadium arc in air arose from the confusing presence of vanadium-oxide band structures in the spectrum. K. L. Andrew and D. S. Davis have recently reobserved the spectrum with vanadium-halide electrodeless discharge lamps to avoid that problem. The analysis of the new data is in progress.

The alphabetic prefixing of terms with lower case letters for distinguishing repeating terms of the same type has been retained from Meggers and Russell except where the levels were reinterpreted by Roth (1970) on the basis of his theoretical treatment.

The compositions of the terms of $3d^4 4s$ were obtained from an ab initio calculation by Vizbaraite, Kupliauskis, and Tutlys (1968). The odd configurations $3d^3 4s4p$, $3d^4 4p$, and $3d^2 4s^2 4p$ have been calculated using parametric theory with configuration interaction by Roth (1970). He concluded that most of the terms above 43 000 cm^{-1} are strongly perturbed by $(3d + 4s)^4 5p$ levels and he therefore did not include them in his least squares fit. His percentage compositions and designation changes for the experimental levels are adopted here. Roth distinguished repeating terms of the $3d^n$ core by the letters a, b, . . . rather than by seniority. The percentages include the sum of seniority states contributing to the term.

Subsequent to the work of Meggers and Russell, Moore (1939) published seven new high odd terms and 33 miscellaneous high odd levels which could not be assigned to terms. With the exception of the level at 46 707 cm^{-1}, which combines nine times, and the $q\ ^4G°$, $n\ ^4D°$, and $r\ ^2F°$ terms, all the levels make few combinations and many are of uncertain J-value. We therefore conclude that they need further confirmation. The $3d^5\ c\ ^4D$ term is from the unpublished results of Humphreys and Kostkowski (1950).

Meggers and Russell determined the ionization energy from the $3d^3 ns$ and $3d^3 nd$ series ($n=4$, 5) and assigned to it a probable error of ± 16 cm^{-1} (± 0.002 eV).

References

Humphreys, C. J., and Kostkowski, H. J. (1950), J. Opt. Soc. Am. **40**, 801(A).

Meggers, W. F., and Russell, H, N. (1936), J. Res. Nat. Bur. Stand. **17**, 125.

Moore, C. E. (1939), Phys. Rev. **55**, 710.

Roth, C. (1970), J. Res. Nat. Bur. Stand. **74A**, 141.

Russell, H. N., and Babcock, H. D. (1935), Zeeman Verhandelingen p. 286 (Martinus Nijhoff, The Hague).

Vizbaraite, J., Kupliauskis, Z., and Tutlys, V. (1968), Lietuvous Fizikos Rinkinys **8**, 497.

V I

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^3 4s^2$	$a\ ^4F$	3/2	0.00	0.40		
		5/2	137.38	1.01		
		7/2	323.42	1.20		
		9/2	553.02	1.28		
$3d^4(^5D)4s$	$a\ ^6D$	1/2	2112.32	3.29	100	
		3/2	2153.20	1.82	100	
		5/2	2220.13	1.61	100	
		7/2	2311.37	1.53	100	
		9/2	2424.89	1.52	100	

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^4(^5D)4s$	$a\ ^4D$	1/2	8412.94	0.00	100	
		3/2	8476.20	1.19	100	
		5/2	8578.52	1.35	100	
		7/2	8715.72	1.39	100	
$3d^34s^2$	$a\ ^4P$	1/2	9544.54	2.59		
		3/2	9636.96	1.70		
		5/2	9824.58	1.55		
$3d^34s^2$	$a\ ^2G$	7/2	10 892.50	0.88		
		9/2	11 100.65	1.13		
$3d^34s^2$	$a\ ^2P$	3/2	13 801.53	1.20		
		1/2	13 810.90	0.64		
$3d^34s^2$	$a\ ^2D$	3/2	14 514.75	0.97		
		5/2	14 548.83	1.17		
$3d^4(^3H)4s$	$a\ ^4H$	7/2	14 910.04	0.65	100	
		9/2	14 949.30	0.94	100	
		11/2	15 000.84	1.10	98	
		13/2	15 062.94	1.18	100	
$3d^4(^3P2)4s$	$b\ ^4P$	1/2	15 078.25	2.60	61	38 $(^3P1)\ ^4P$
		3/2	15 270.42	1.68	61	38
		5/2	15 571.90	1.54	61	38
$3d^34s^2$	$a\ ^2H$	9/2	15 103.77	0.90		
		11/2	15 264.83	1.07		
$3d^4(^3F2)4s$	$b\ ^4F$	3/2	15 664.75	0.39	78	22 $(^3F1)\ ^4F$
		5/2	15 688.80	1.05	77	21
		7/2	15 724.22	1.22	77	21
		9/2	15 770.72	1.31	77	21
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^6G^\circ$	3/2	*16 361.45*	0.00	100	
		5/2	*16 449.85*	0.78	100	
		7/2	*16 572.54*	1.10	100	
		9/2	*16 728.75*	1.22	100	
		11/2	*16 917.15*	1.26	100	
		13/2	*17 136.44*	1.43	100	
$3d^4(^3G)4s$	$a\ ^4G$	5/2	17 054.87	0.59	100	
		7/2	17 116.92	0.96	100	
		9/2	17 181.98	1.14	100	
		11/2	17 242.05	1.27	98	
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^6D^\circ$	1/2	*18 085.82*	3.20	90	8 $3d^4(\ ^5D)4p\ ^6D^\circ$
		3/2	*18 126.27*	1.76	89	8
		5/2	*18 198.08*	1.58	89	8
		7/2	*18 302.27*	1.56	89	8
		9/2	*18 438.07*	1.55	89	8

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^6F^\circ$	1/2	*18 120.12*	−0.44	95	
		3/2	*18 174.06*	1.14	95	
		5/2	*18 258.89*	1.28	95	
		7/2	*18 372.46*	1.28	95	
		9/2	*18 513.46*	1.38	95	
		11/2	*18 680.12*	1.42	96	
$3d^4(^3P2)4s$	$b\ ^2P$	1/2	18 805.05	0.67	61	38 $(^3P1)\ ^2P$
		3/2	19 189.28	1.37	61	38
$3d^4(^3H)4s$	$b\ ^2H$	9/2	19 023.47	0.91	100	
		11/2	19 145.13	1.08	100	
$3d^4(^3F2)4s$	$a\ ^2F$	5/2	19 026.34	0.86	79	21 $(^3F1)\ ^2F$
		7/2	19 078.15	1.14	77	21
$3d^5$	$a\ ^6S$	5/2	20 202.49			
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^4D^\circ$	1/2	*20 606.43*	−0.04	90	
		3/2	*20 687.75*	1.21	90	
		5/2	*20 828.48*	1.35	90	
		7/2	*21 032.52*	1.45	90	
$3d^4(^3D)4s$	$b\ ^4D$	7/2	20 767.57	1.45	100	
		5/2	20 789.13	1.25	100	
		3/2	20 812.99	1.20	100	
		1/2	20 830.20	0.10	100	
$3d^4(^3G)4s$	$b\ ^2G$	9/2	21 603.17	1.11	100	
		7/2	21 646.39	0.86	98	
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^4G^\circ$	5/2	*21 841.45*	0.55	93	
		7/2	*21 963.50*	0.96	93	
		9/2	*22 121.17*	1.16	93	
		11/2	*22 313.99*	1.24	93	
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^4F^\circ$	3/2	*23 088.06*	0.39?	94	
		5/2	*23 210.56*	0.98?	94	
		7/2	*23 353.09*	1.23	95	
		9/2	*23 519.84*	1.31	95	
$3d^3(^4F)4s4p(^3P^\circ)$	$z\ ^2D^\circ$	3/2	*23 608.80*	0.76	89	
		5/2	*23 935.15*	1.32?	89	
$3d^4(^5D)4p$	$z\ ^6P^\circ$	3/2	*24 648.10*	2.34	71	29 $3d^3(^4P)4s4p(^3P^\circ)\ ^6P^\circ$
		5/2	*24 727.85*	1.85	71	29
		7/2	*24 838.56*	1.67	71	29
$3d^4(^5D)4p$	$z\ ^4P^\circ$	1/2	*24 770.62*	2.54	89	
		3/2	*24 915.16*	1.71	89	
		5/2	*25 130.96*	1.59	89	

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^4(^5D)4p$	$y\ ^6F°$	1/2	*24 789.36*	−0.58	95	
		3/2	*24 830.18*	1.02	95	
		5/2	*24 898.73*	1.23	95	
		7/2	*24 992.88*	1.37	96	
		9/2	*25 111.50*	1.41	96	
		11/2	*25 253.53*	1.41	96	
$3d^4(^5D)4p$	$y\ ^4F°$	3/2	*25 930.51*	0.42	76	17 $3d^3(^4F)4s4p(^1P°)\ ^4F°$
		5/2	*26 004.22*	0.98	73	16
		7/2	*26 122.04*	1.15	67	15
		9/2	*26 171.96*	1.23	64	14
$3d^3(^4F)4s4p(^3P°)$	$z\ ^2G°$	7/2	*26 021.89*	0.92	93	
		9/2	*26 344.94*	1.13	90	
$3d^4(^5D)4p$	$y\ ^4D°$	1/2	*26 182.60*	−0.06	65	30 $3d^3(^4F)4s4p(^1P°)\ ^4D°$
		3/2	*26 249.48*	1.17	65	29
		5/2	*26 352.59*	1.34	65	28
		7/2	*26 480.28*	1.39	63	27
$3d^4(^5D)4p$	$y\ ^6D°$	1/2	*26 397.36*	3.25	82	10 $3d^3(^4F)4s4p(^3P°)\ ^6D°$
		3/2	*26 437.68*	1.86	82	10 $3d^3(^4F)4s4p(^3P°)\ ^6D°$
		5/2	*26 505.88*	1.59	81	10 $3d^3(^4F)4s4p(^3P°)\ ^6D°$
		7/2	*26 604.77*	1.58	78	10 $3d^3(^4F)4s4p(^3P°)\ ^6D°$
		9/2	*26 738.31*	1.50	72	10 $3d^4(^5D)4p\ ^4F°$
$3d^3(^4F)4s4p(^3P°)$	$z\ ^2F°$	5/2	*27 187.77*	1.07?	97	
		7/2	*27 470.88*	1.01	97	
$3d^3(^4P)4s4p(^3P°)$	$x\ ^6D°$	1/2	*28 313.68*	3.23	91	
		3/2	*28 368.76*	1.82	91	
		5/2	*28 462.15*	1.58	91	
		7/2	*28 595.64*	1.52	91	
		9/2	*28 768.13*	1.47	91	
	$z\ ^4S°$	3/2	*28 621.27*			
$3d^3(^4P)4s4p(^3P°)$	$y\ ^6P°$	3/2	*29 202.80*	2.32	71	29 $3d^4(^5D)4p\ ^6P°$
		5/2	*29 296.43*	1.76	71	29
		7/2	*29 418.17*	1.62	71	29
$3d^3(^4P)4s4p(^3P°)$	$y\ ^4P°$	1/2	*30 021.57*	2.67	80	9 $(a\ ^2D)(^3P°)\ ^4P°$
		3/2	*30 094.52*	1.74	82	8
		5/2	*30 120.78*	1.67	83	7
$3d^3(^2G)4s4p(^3P°)$	$y\ ^4G°$	5/2	*30 635.60*	0.53	65	30 $(^4F)(^1P°)\ ^4G°$
		7/2	*30 694.34*	0.93	68	27
		9/2	*30 771.72*	1.13	70	25
		11/2	*30 864.34*	1.21	73	22
$3d^3(^4P)4s4p(^3P°)$	$z\ ^6S°$	5/2	*30 832.58*		96	

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^3(^2G)4s4p(^3P°)$	$x\ ^4F°$	3/2	*31 200.12*	0.38	79	7 $(a\ ^2D)(^3P°)\ ^4F°$
		5/2	*31 228.98*	1.01	80	7
		7/2	*31 268.15*	1.21	80	6
		9/2	*31 317.50*	1.32	81	6
$3d^3(^4F)4s4p(^1P°)$	$x\ ^4G°$	5/2	*31 398.09*	0.53	62	23 $(^2G)(^3P°)\ ^4G°$
		7/2	*31 541.18*	0.95	64	20
		9/2	*31 721.73*	1.12	66	18
		11/2	*31 937.18*	1.20	69	15
$3d^3(^2P)4s4p(^3P°)$	$^4P°$	1/2	*31 786.19*	2.30	63	10 $(a\ ^2D)(^3P°)\ ^4P°$
$3d^4(a\ ^3P)4p$	$y\ ^2S°$	1/2	*31 962.30*	2.21	33	34 $3d^3(^2P)4s4p(^3P°)\ ^2S°$
$3d^3(^2P)4s4p(^3P°)$	$x\ ^4D°$	1/2	*32 348.89*	0.08	56	16 $(^4P)(^3P°)\ ^4D°$
		3/2	*32 456.45*	1.17	58	16
		5/2	*32 660.26*	1.29	59	14
		7/2	*32 891.06*	1.35	60	12
$3d^3(^2H)4s4p(^3P°)$	$z\ ^4H°$	7/2	*32 692.09*	0.68	62	22 $3d^4(^3H)4p\ ^4H°$
		9/2	*32 788.22*	0.98	64	23
		11/2	*32 897.81*	1.11	68	25
		13/2	*32 963.90*	1.21	69	25
$3d^3(^4P)4s4p(^3P°)$	$z\ ^2P°$	1/2	*32 724.86*	0.73?	53	15 $3d^4(a\ ^3P)4p\ ^2P°$
		3/2	*32 767.88*	1.22	64	18
$3d^3(^4F)4s4p(^1P°)$	$w\ ^4F°$	3/2	*32 738.14*	0.52	61	20 $3d^4(^5D)4p\ ^4F°$
		5/2	*32 846.74*	1.01	61	19
		7/2	*32 988.82*	1.18	61	19
		9/2	*33 155.30*	1.30	61	19
$3d^3(^2G)4s4p(^3P°)$	$y\ ^2G°$	9/2	*33 306.96*	1.03	84	5 $(^2H)(^3P°)\ ^4H°$
		7/2	*33 360.31*	0.91	81	6
$3d^3(^2G)4s4p(^3P°)$	$y\ ^2F°$	7/2	*33 481.45*	1.11	76	8 $(a\ ^2D)(^3P°)\ ^2F°$
		5/2	*33 527.64*	0.85	79	8
$3d^3(^2G)4s4p(^3P°)$	$z\ ^2H°$	9/2	*33 640.18*	0.92	85	8 $(^2H)(^3P°)\ ^2H°$
		11/2	*33 695.32*	1.09	87	8
$3d^3(^4P)4s4p(^3P°)$	$w\ ^4D°$	1/2	*33 966.72*	0.09	68	14 $(^2P)(^3P°)\ ^4D°$
		3/2	*33 976.02*	0.80	57	12
		5/2	*34 065.61*	1.30	63	13
		7/2	*34 128.04*	1.35	68	12
$3d^3(^2P)4s4p(^3P°)$	$^4S°$	3/2	*34 019.12*		70	6 $(^4P)(^3P°)\ ^4S°$
$3d^3(^2P)4s4p(^3P°)$	$^2D°$	3/2	*34 030.04*	0.86	26	16 $(a\ ^2D)(^3P°)\ ^2D°$
		5/2	*34 167.84*	1.32?	38	24

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^5$	$c\ ^4$D	1/2	34 329.05			
		3/2	34 343.22			
		5/2	34 359.26			
		7/2	34 366.84			
$3d^3(a\ ^2$D$)4s4p(^3$P°)	^{4}F°	7/2	*34 374.81*	1.21	81	9 $3d^4(^3$G$)4p\ ^4$F°
		3/2	*34 428.76*	0.73	62	8 $3d^3(^2$P$)4s4p(^3$P°) ^{2}D°
		5/2	*34 486.80*	1.18	66	7 $3d^3(^2$P$)4s4p(^3$P°) ^{2}D°
		9/2	*34 529.81*	1.41	82	9 $3d^4(^3$G$)4p\ ^4$F°
$3d^3(^4$F$)4s4p(^1$P°)	$v\ ^4$D°	1/2	*34 477.40*	0.00	24	18 $3d^4(a\ ^3$P$)4p\ ^4$D°
		3/2	*34 537.21*	1.05	25	16
		5/2	*34 619.52*	1.28	27	17
		7/2	*34 747.06*	1.35	28	15
$3d^3(a\ ^2$D$)4s4p(^3$P°)	$u\ ^4$D°	1/2	*35 012.91*		58	16 $(^4$F$)(^1$P°) ^{4}D°
		3/2	*35 092.36*	1.12	58	15
		5/2	*35 225.04*	1.32	63	16
		7/2	*35 379.11*	1.33	67	16
$3d^3(^4$P$)4s4p(^3$P°)	$y\ ^4$S°	3/2	*36 408.23*	1.85	41	25 $(a\ ^2$D$)(^3$P°) ^{4}P°
$3d^3(^4$P$)4s4p(^3$P°)	$x\ ^2$D°	3/2	*36 416.49*	0.89	38	17 $3d^4(a\ ^3$P$)4p\ ^2$D°
		5/2	*36 700.78*	1.13	36	14
$3d^4(^3$G$)4p$	$x\ ^2$G°	7/2	*36 461.26*	0.85	13	21 $(a\ ^3$F$)\ ^2$G°
		9/2	*36 538.58*	1.05	19	31
$3d^4(a\ ^3$P$)4p$	$y\ ^2$P°	1/2	*36 477.75*	0.74	31	32 $3d^3(a\ ^2$D$)4s4p(^3$P°) ^{2}P°
		3/2	*36 580.46*	1.17	29	31
$3d^3(a\ ^2$D$)4s4p(^3$P°)	$x\ ^4$P°	5/2	*36 611.81*	1.54	59	15 $(^2$P$)(^3$P°) ^{4}P°
		1/2	*36 695.49*	2.51	69	18 $(^2$P$)(^3$P°) ^{4}P°
		3/2	*36 814.80*	1.77	44	24 $(^4$P$)(^3$P°) ^{4}S°
	$w\ ^2$G°	7/2	*36 628.82*	0.65?		
		9/2	*36 828.33*			
$3d^3(^2$H$)4s4p(^3$P°)	$w\ ^4$G°	5/2	*36 763.41*		42	19 $3d^4(a\ ^3$F$)4p\ ^4$G°
		7/2	*36 822.86*	1.06	27	11
		9/2	*36 897.88*	1.17	46	14
		11/2	*36 938.42*	1.26	54	15
$3d^4(a\ ^3$F$)4p$	$x\ ^2$F°	5/2	*36 766.00*	0.89	26	25 $3d^3(^2$G$)4s4p(^3$P°) ^{2}F°
		7/2	*36 925.88*	1.05	24	22
$3d^5$	$e\ ^4$F	3/2	36 983.63			
		5/2	36 989.20			
		7/2	37 025.60			
		9/2	37 075.64			

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^4(^5D)5s$	$e\ ^6D$	1/2	37 116.68	3.08		
		3/2	37 158.36	1.87		
		5/2	37 227.44	1.61		
		7/2	37 322.09	1.64		
		9/2	37 440.74	1.48		
$3d^4(^3H)4p$	$v\ ^2G^\circ$	7/2	*37 174.68*	0.99	60	11 $3d^3(^2H)4s4p(^3P^\circ)\ ^2G^\circ$
		9/2	*37 361.95*	1.05	52	20 $3d^4(^3H)4p\ ^4I^\circ$
$3d^3(^2H)4s4p(^3P^\circ)$	$y\ ^2H^\circ$	9/2	*37 180.90*	0.73	67	9 $3d^4(^3H)4p\ ^2H^\circ$
		11/2	*37 210.85*	1.08	74	10
$3d^4(^3H)4p$	$z\ ^4I^\circ$	9/2	*37 285.03*	0.87	76	14 $(^3H)\ ^2G^\circ$
		11/2	*37 315.83*	0.96	98	
		13/2	*37 404.25*	1.08	99	
		15/2	*37 518.36*	1.15	100	
$3d^3(a\ ^2D)4s4p(^3P^\circ)$	$w\ ^2F^\circ$	5/2	*37 342.66*	0.84	34	16 $3d^4(a\ ^3F)4p\ ^2F^\circ$
		7/2	*37 475.08*	1.08	37	20
$3d^34s(^5F)5s$	$e\ ^6F$	1/2	37 374.98	−0.72		
		3/2	37 423.17	1.05		
		5/2	37 503.14	1.30		
		7/2	37 614.97	1.33		
		9/2	37 758.07	1.43		
		11/2	37 931.41	1.52		
$3d^4(a\ ^3F)4p$	$w\ ^2D^\circ$	3/2	*37 457.50*	0.80	30	27 $3d^3(^4P)4s4p(^3P^\circ)\ ^2D^\circ$
		5/2	*37 752.54*	1.18	35	26
	$y\ ^4H^\circ$	7/2	*37 481.36*	0.76		
		9/2	*37 516.95*	1.05		
		11/2	*37 565.88*	1.09		
		13/2	*37 626.44*	1.24		
$3d^4(a\ ^3F)4p$	$v\ ^4G^\circ$	5/2	*37 498.76*	0.60	62	30 $3d^3(^2H)4s4p(^3P^\circ)\ ^4G^\circ$
		7/2	*37 556.00*	1.02	57	26
		9/2	*37 644.41*	1.15	57	24
		11/2	*37 764.89*	1.22	58	23
$3d^4(^3H)4p$	$z\ ^2I^\circ$	11/2	*37 530.29*	0.94	45	44 $3d^3(^2H)4s4p(^3P^\circ)\ ^2I^\circ$
		13/2	*37 606.32*	1.06	42	46
$3d^4(a\ ^3P)4p$	$t\ ^4D^\circ$	1/2	*37 757.24*	0.01	46	14 $3d^3(^4F)4s4p(^1P^\circ)\ ^4D^\circ$
		3/2	*37 834.98*	1.18	46	14
		5/2	*37 959.66*	1.33	45	13
		7/2	*38 115.65*	1.35	44	15
$3d^4(^5D)5s$	$e\ ^4D$	1/2	37 940.08			
		3/2	38 003.93			
		5/2	38 106.32			
		7/2	38 242.46			

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^4(^3H)4p$	$x\ ^2H°$	9/2	*38 123.76*	0.88	55	17 $3d^3(^2H)4s4p(^3P°)\ ^2H°$
		11/2	*38 220.63*	1.10	54	18
$3d^4(^3H)4p$	$x\ ^4H°$	7/2	*38 245.75*	0.67	46	27 $(^3G)\ ^4H°$
		9/2	*38 323.87*	0.93	43	24
		11/2	*38 404.96*	1.11	45	23
		13/2	*38 482.96*	1.22	52	27
$3d^3(^2H)4s4p(^3P°)$	$u\ ^2G°$	9/2	*38 529.78*	0.99	78	9 $(^2F)(^3P°)\ ^2G°$
		7/2	*38 610.94*	0.88?	78	9
$3d^3(^2H)4s4p(^3P°)$	$y\ ^2I°$	11/2	*39 008.60*	0.92	53	46 $3d^4(^3H)4p\ ^2I°$
		13/2	*39 081.10*	1.06	50	49
$3d^34s(^5F)5s$	$f\ ^4F$	3/2	39 127.23	0.46?		
		5/2	39 241.34	1.03		
		7/2	39 398.82	1.22?		
		9/2	39 597.01	1.33?		
$3d^4(a\ ^3P)4p$	$w\ ^4P°$	1/2	*39 237.10*	2.57	72	16 $3d^3(^2P)4s4p(^3P°)\ ^4P°$
		3/2	*39 248.90*	1.60	43	16 $3d^4(a\ ^3P)4p\ ^4S°$
		5/2	*39 422.66*	1.52	52	11 $3d^3(^2P)4s4p(^3P°)\ ^4P°$
$3d^4(a\ ^3F)4p$	$u\ ^4F°$	3/2	*39 266.60*	0.54	47	13 $3d^4(a\ ^3P)4p\ ^4S°$
		5/2	*39 300.48*	1.00	67	9 $3d^3(^2F)4s4p(^3P°)\ ^4F°$
		7/2	*39 341.76*	1.21	66	9 $3d^3(^2F)4s4p(^3P°)\ ^4F°$
		9/2	*39 391.02*	1.30	66	9 $3d^3(^2F)4s4p(^3P°)\ ^4F°$
$3d^4(a\ ^3P)4p$	$x\ ^4S°$	3/2	*39 847.24*	2.00	40	14 $(a\ ^3P)\ ^4P°$
$3d^4(a\ ^3F)4p$	$s\ ^4D°$	1/2	*39 877.62*	0.01	63	18 $(a\ ^3P)\ ^4D°$
		3/2	*39 935.07*	1.10	59	18
		5/2	*39 999.89*	1.33	46	16
		7/2	*40 125.79*	1.38	44	18
$3d^4(a\ ^3P)4p$	$v\ ^2D°$	3/2	*39 884.43*	0.92	40	17 $(a\ ^3F)\ ^2D°$
		5/2	*40 119.26*	1.14	40	16
$3d^4(^3H)4p$	$u\ ^4G°$	5/2	*39 962.17*	0.53	32	21 $(^3G)\ ^4G°$
		7/2	*40 001.18*	0.99	38	25
		9/2	*40 038.95*	1.19	42	27
		11/2	*40 063.78*	1.23	42	28
$3d^3(a\ ^2D)4s4p(^3P°)$	$^2D°$	5/2	*40 153.51*		43	27 $(^2P)(^3P°)\ ^2D°$
		3/2	*40 225.38*	0.70	37	21
	$x\ ^2S°$	1/2	*40 299.81*			
$3d^4(^3G)4p$	$w\ ^4H°$	7/2	*40 314.83*	0.65	59	22 $(^3H)\ ^4H°$
		9/2	*40 378.70*	0.92	66	24
		11/2	*40 452.38*	1.08	67	23
		13/2	*40 535.62*	1.22	70	23

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^4(^3G)4p$	$^2F°$	5/2	*40 325.77*	1.12	40	12 $(a\ ^3F)\ ^4D°$
		7/2	*40 587.35*	1.01	44	14
$3d^3(^2P)4s4p(^3P°)$	$x\ ^2P°$	1/2	*40 328.62*		51	21 $(a\ ^2D)(^3P°)\ ^2P°$
		3/2	*40 437.42*	1.52	35	14
	$w\ ^2P°$	3/2	*40 693.76*			
$3d^4(^3G)4p$	$w\ ^2H°$	11/2	*40 919.68*	0.96	71	10 $3d^3(^2G)4s4p(^3P°)\ ^2H°$
		9/2	*40 980.54*	0.99	66	11
$3d^4(^3G)4p$	$t\ ^4F°$	3/2	*41 389.49*	0.42	47	20 $(^3D)\ ^4F°$
		5/2	*41 428.93*	0.89	25	27 $(^3G)\ ^4G°$
		7/2	*41 492.29*	1.15	26	26 $(^3G)\ ^4G°$
		9/2	*41 599.36*	1.23	27	23 $(^3G)\ ^4G°$
$3d^4(a\ ^3F)4p$	$t\ ^2G°$	7/2	*41 436.58*	0.90	44	30 $(^3G)\ ^2G°$
		9/2	*41 539.14*	1.04	42	30
$3d^3(^2G)4s4p(^1P°)$	$v\ ^2H°$	9/2	*41 501.41*	0.87	43	28 $3d^4(^1I)4p\ ^2H°$
		11/2	*41 659.71*	1.05	42	30
$3d^4(^3G)4p$	$t\ ^4G°$	5/2	*41 654.70*	0.58	27	22 $(^3G)\ ^4F°$
		7/2	*41 758.41*	1.03	26	26 $(^3G)\ ^4F°$
		9/2	*41 860.54*	1.20	29	18 $(^3G)\ ^4F°$
		11/2	*41 918.24*	1.20	52	30 $(^3H)\ ^4G°$
$3d^3(^4P)4s4p(^1P°)$	$v\ ^4P°$	1/2	*41 751.78*	2.56	43	39 $3d^4(^3D)4p\ ^4P°$
		3/2	*41 848.47*	1.62	39	38
		5/2	*42 009.93*	1.48	38	40
$3d^3(^4P)4s4p(^1P°)$	$r\ ^4D°$	1/2	*41 928.47*	0.04	53	17 $3d^2(^3F)4s^24p\ ^4D°$
		3/2	*41 999.10*	1.20	49	16
		5/2	*42 138.00*	1.33	51	16
		7/2	*42 245.61*	1.36	58	18
$3d^4(^3D)4p$	$u\ ^2F°$	5/2	*41 950.35*	0.84	41	19 $(a\ ^3F)\ ^2F°$
		7/2	*42 020.93*	1.11	43	13
$3d^4(^5D)4d$	$e\ ^6G$	3/2	42 033.84			
		5/2	42 070.05			
		7/2	42 114.17	1.08		
		9/2	42 177.31	1.23		
		11/2	42 257.32	1.32		
		13/2	42 353.42	1.35		
	$u\ ^2H°$	9/2	*42 079.14*	0.85		
		11/2	*42 220.69*	1.06		
$3d^4(^5D)4d$	$e\ ^6P$	7/2	42 164.74	1.44?		
	2°	7/2	*42 236.66*			

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^4(^3D)4p$	$v\ ^2P°$	3/2	*42 318.42*	1.34	35	30 $3d^3(^2P)4s4p(^3P°)\ ^2P°$
		1/2	*42 480.62*	1.14	36	28
$3d^3(^4P)4s4p(^3P°)$	$w\ ^2S°$	1/2	*42 362.04*	1.50?	83	10 $3d^4(a\ ^3P)4p\ ^2S°$
$3d^4(^5D)4d$	$f\ ^6F$	7/2	42 363.62			
		9/2	42 506.32			
		11/2	42 577.98	1.39		
$3d^4(^5D)4d$	$f\ ^6D$	7/2	42 404.89			
		9/2	42 553.62	1.61		
	$w\ ^6D°$	5/2	*42 480.31*			
		7/2	*42 587.41*			
		9/2	*42 725.33*			
$3d^3(^4D)4s4p(^1P°)$	$w\ ^4S°$	3/2	*42 969.49*	1.94	70	14 $3d^4(a\ ^3P)4p\ ^4S°$
	$s\ ^4F°$	3/2	*42 981.34*			
		5/2	*43 051.31*			
		7/2	*43 147.09*			
		9/2	*43 266.15*			
	$q\ ^4D°$	1/2	*43 249.44*			
		3/2	*43 308.83*			
		5/2	*43 410.82*			
		7/2	*43 555.12*	1.46		
	$u\ ^4P°$	1/2	*43 443.33*			
		3/2	*43 503.99*			
		5/2	*43 585.59*			
$3d^34s(^5F)4d$	$e\ ^6H$	5/2	43 649.40	0.38		
		7/2	43 706.82	0.88		
		9/2	43 787.60	1.11		
		11/2	43 894.15	1.18		
		13/2	44 028.33	1.30		
		15/2	44 189.95	1.38		
	$x\ ^6F°$	1/2	*43 707.97*			
		3/2	*43 845.80*			
		5/2	*43 959.24*			
		7/2	*44 026.29*			
		9/2,11/2	*44 202.51*			
$3d^34s(^5F)4d$	$f\ ^6G$	3/2	43 818.02	0.38?		
		5/2	43 847.16	0.78		
		7/2	43 911.93	1.12		
		9/2	44 005.14	1.26		
		11/2	44 139.69	1.34		
		13/2	44 327.04	1.35		

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^4(a\ ^1G)4p$	$t\ ^2F°$	7/2	*43 873.79*	1.04?	37	25 $(a\ ^3F)\ ^2F°$
		5/2	*43 875.25*	0.86	40	28
$3d^34s(^3F)5s$	$e\ ^2F$	5/2	43 918.58	0.89		
		7/2	44 066.05	1.18		
	$x\ ^6P°$	7/2	*43 988.00*			
	$s\ ^4G°$	5/2	*43 999.68*			
		7/2	*44 043.36*	0.98		
		9/2	*44 104.55*	1.26		
		11/2	*44 178.45*	1.34		
$3d^4(a\ ^1G)4p$	$t\ ^2H°$	9/2	*44 145.77*	0.90	58	10 $(^3H)\ ^2H°$
		11/2	*44 184.02*	1.06?	40	38 $(^1I)\ ^2I°$
$3d^34s(^5F)4d$	$f\ ^6P$	3/2	44 443.67			
		5/2	44 532.60			
		7/2	44 690.47			
$3d^4(^3F)4p$	$s\ ^2G°$	9/2	*44 463.28*	1.09	21	19 $3d^4(^3G)4p\ ^2G°$
		7/2	*44 495.43*	0.91	25	24
$3d^4(^3D)4p$	$p\ ^4D°$	1/2	*44 514.34*		77	16 $3d^3(a\ ^2D)4s4p(^3P°)\ ^4D°$
		3/2	*44 554.25*	1.22	45	28 $3d^4(^3D)4p\ ^2D°$
		5/2	*44 616.68*	1.37?	70	12 $3d^3(a\ ^2D)4s4p(^3P°)\ ^4D°$
		7/2	*44 700.88*	1.32?	75	13 $3d^3(a\ ^2D)4s4p(^3P°)\ ^4D°$
$3d^34s(^5F)4d$	$g\ ^6D$	3/2	44 844.83			
		5/2	44 921.08	1.55?		
		7/2	45 056.61			
		9/2	45 157.74			
	$r\ ^4F°$	3/2	*44 973.60*	0.58?		
		5/2	*45 049.17*			
		7/2	*45 058.62*	0.97		
		9/2	*45 145.16*	1.26		
	$q\ ^4F°$	3/2	*45 066.56*	0.59		
		5/2	*45 107.21*	0.93		
		7/2	*45 157.72*	1.05		
		9/2	*45 237.16*	1.22		
	$u\ ^2P°$	3/2	*45 159.15*	1.66?		
$3d^4(a\ ^1G)4p$	$r\ ^2G°$	7/2	*45 175.92*	0.98	42	16 $3d^3(^2H)4s4p(^1P°)\ ^2G°$
		9/2	*45 361.42*	1.14	36	17
$3d^34s(^5F)4d$	$g\ ^6F$	3/2	45 638.54			
		5/2	45 700.25			
		7/2	45 743.62	1.26		
		9/2	45 813.25			
		11/2	46 034.58			

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^3(^2F)4s4p(^3P^\circ)$	$p\ ^4F^\circ$	3/2	*45 648.86*	0.60	83	9 $3d^4(^3G)4p\ ^4F^\circ$
		5/2	*45 688.41*		82	9
		7/2	*45 760.03*	1.02	82	9
		9/2	*45 891.55*	1.32	81	9
	$t\ ^2P^\circ$	3/2	*45 654.50*	1.04?		
		1/2	*45 946.66*			
	$o\ ^4D^\circ$	1/2	*45 702.14*			
		3/2	*45 762.24*	0.96?		
		5/2	*45 838.06*			
		7/2	*45 937.07*	1.45		
	$r\ ^4G^\circ$	5/2	*46 052.79*	0.56		
		7/2	*46 139.06*	0.96		
		9/2	*46 243.64*	1.15		
		11/2	*46 363.42*	1.19		
	6°	3/2	*46 707.18*			
	$t\ ^4P^\circ$	1/2	*46 851.10*			
		3/2	*46 862.73*			
		5/2	*46 868.10*			
$3d^3(a\ ^2D)4s4p(^1P^\circ)$	$s\ ^2F^\circ$	5/2	*46 996.84*		19	28 $3d^3(^2F)4s4p(^3P^\circ)\ ^4G^\circ$
		7/2	*47 143.24*	1.02	16	19 $3d^4(a\ ^1D)4p\ ^2F^\circ$
	3°	3/2	*47 423.18*			
$3d^4(^1I)4p$	$s\ ^2H^\circ$	9/2	*47 611.77*	1.01?	19	25 $3d^3(^2G)4s4p(^1P^\circ)\ ^2H^\circ$
		11/2	*47 701.55*	0.94	23	31
	$q\ ^4G^\circ$	5/2	*47 690.5*			
		7/2	*47 823.24*			
		9/2	*48 014.18*			
		11/2	*48 191.04*			
$3d^3(^2F)4s4p(^3P^\circ)$	$q\ ^2G^\circ$	7/2	*47 959.82*	0.89	63	13 $3d^4(^1F)4p\ ^2G^\circ$
		9/2	*48 157.57*	1.08	62	15
	$v\ ^2S^\circ$	1/2	*48 844.67*	2.03		
	$n\ ^4D^\circ$	1/2	*49 189.74*			
		3/2	*49 283.77*			
		5/2	*49 440.31*			
		7/2	*49 584.09*			
$3d^3(^2P)4s4p(^1P^\circ)$	$t\ ^2D^\circ$	5/2	*49 689.01*	1.25	39	15 $3d^4(^3D)4p\ ^2D^\circ$
		3/2	*49 722.88*		38	15

V I—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^34s(^5F)4d$	$f\ ^6H$	5/2	49 717.57			
		7/2	49 797.18			
		9/2	49 875.12			
		11/2	49 983.16			
		13/2	50 164.26			
		15/2	50 301.63			
$3d^34s(^5F)4d$	$g\ ^6G$	7/2	49 789.17			
		9/2	49 932.37			
		11/2	50 114.59			
		13/2	50 209.05			
$3d^3(^2H)4s4p(^1P°)$	$x\ ^2I°$	11/2	*49 977.90*	0.91	86	11 $3d^4(^1I)4p\ ^2I°$
		13/2	*50 120.69*	1.06	87	11
	$r\ ^2F°$	5/2	*50 404.14*			
		7/2	*50 539.27*			
$3d^34p^2$	$h\ ^6G$	3/2	50 584.27			
		5/2	50 654.72			
		7/2	50 751.83			
		9/2	50 876.00			
		11/2	51 026.30			
		13/2	51 201.12			
	$p\ ^2G°$	7/2	*52 774.08*			
		9/2	*52 947.98*			
	$r\ ^2H°$	9/2	*54 081.51*			
		11/2	*54 251.26*			
V II ($^5D_0$)	*Limit*	....	**54 360**			
	$s\ ^2P°$	3/2	*57 561.36*			
		1/2	*57 744.12*			

V II

Ti I isoelectronic sequence $Z = 23$

Ground state: $1s^22s^22p^63s^23p^63d^4$ $^5D_0$

Ionization energy = 118 200 cm^{-1} (14.66 eV)

The first regularities among spark lines of vanadium were presented by Meggers, Kiess, and Walters (1924). Subsequent work ultimately led to an extensive analysis by Meggers and Moore (1940), from which most of the present terms are taken. That paper also contains H. D. Babcock's previously unpublished Zeeman-effect data from which the present g-values were obtained.

Velasco and Gullon (1968) subsequently found a number of new even terms and miscellaneous odd levels, including two new $3d^34d$ and $5s$ terms. The $3d^35s$ terms were used to confirm the validity of the ionization energy proposed by Russell (1950), which is quoted here. The analysis is being continued in Madrid by L. Iglesias. She has provided 23 new terms, including most of the terms in $3d^24s^2$, $3d^3(^4F)4d$ and $3d^35s$, and gave revised values for nearly all of the levels which are adopted here. She has replaced the earlier levels $3d^24s^2$ e ^3F and $3d^24s4p$ y $^5G°$ with new ones.

The alphabetic prefixing of terms with lower case letters for distinguishing repeating terms of the same type has been retained from Meggers and Moore except where the levels were reinterpreted by Roth (1969) on the basis of his theoretical treatment.

Roth has calculated the odd-parity configurations $3d^34p$ and $3d^24s4p$ with configuration interaction. His percentage compositions and designation changes for the experimental levels are adopted here. Roth distinguished repeating terms of the $3d^n$ core by the letters a, b, . . . rather than by seniority. The percentages include the sum of seniority states contributing to the term.

The compositions of levels of the even configurations $3d^4$, $3d^34s$, and $3d^24s^2$ were calculated by Shadmi, Oreg, and Stein (1968). Percentages are given only for cases where the mixing is large. We have applied Roth's designation of repeating core terms to this work as well.

References

Meggers, W. F., Kiess, C. C., and Walters, F. M. (1924), J. Opt. Soc. Soc. Am. **9**, 355.

Meggers, W. F., and Moore, C. E. (1940), J. Res. Nat. Bur. Stand. **25**, 83.

Roth, C. (1969), J. Res. Nat. Bur. Stand. **73A**, 159.

Russell, H. N. (1950), J. Opt. Soc. Am. **40**, 618.

Shadmi, Y., Oreg, J., and Stein, J. (1968), J. Opt. Soc. Am. **58**, 909.

Velasco, R., and Gullon, N. (1968), Optica Pura y Aplicada **1**, 93.

V II

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^4$	a ^5D	0	0.00			
		1	36.05			
		2	106.63			
		3	208.89			
		4	339.21			
$3d^3(^4F)4s$	a ^5F	1	2604.82			
		2	2687.01	0.97		
		3	2808.72	1.20		
		4	2968.22	1.30?		
		5	3162.80	1.28?		
$3d^3(^4F)4s$	a ^3F	2	8640.21	0.65		
		3	8841.97	1.04		
		4	9097.81	1.22		
$3d^4$	a ^3P	0	11 295.57			
		1	11 514.76	1.48		
		2	11 908.27	1.49		
$3d^4$	a ^3H	4	12 545.14	0.83?		
		5	12 621.55	1.02		
		6	12 706.25	1.27?		

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^4$	$b\ ^3F$	2	13 490.89	0.59		
		3	13 542.67	1.06		
		4	13 608.96	1.19		
$3d^3(^4P)4s$	$a\ ^5P$	1	13 511.75	2.39		
		2	13 594.73	1.78		
		3	13 741.61	1.62		
$3d^4$	$a\ ^3G$	3	14 461.75	0.74	57	42 $3d^3(^2G)4s\ ^3G$
		4	14 556.09	1.00	56	42
		5	14 655.63	1.17	58	42
$3d^3(^2G)4s$	$b\ ^3G$	3	16 340.97	0.76	58	42 $3d^4\ ^3G$
		4	16 421.51	1.03	57	42
		5	16 533.00	1.16	58	42
$3d^4$	$a\ ^1G$	4	17 910.94	0.95		
$3d^4$	$a\ ^3D$	1	18 269.49	0.49	52	47 $3d^3(^2D)4s\ ^3D$
		2	18 293.88	1.13	54	44
		3	18 353.88	1.30	60	40
$3d^3(^2G)4s$	$b\ ^1G$	4	19 112.93	0.98		
$3d^3(^2P)4s$	$b\ ^3P$	2	19 132.75	1.38		
		0	19 161.37			
		1	19 166.27	1.40		
$3d^4$	$a\ ^1I$	6	19 191.40	0.96?		
$3d^4$	$a\ ^1S$	0	19 902.57		59	38 $3d^3(^4P)4s\ ^3P$
$3d^3(^4P)4s$	$c\ ^3P$	1	20 089.60	1.35	80	7 $3d^3(^2P)4s\ ^3P$
		0	20 156.64		51	40 $3d^4\ ^1S$
		2	20 343.01	1.36	64	10 $3d^4\ ^3D$
$3d^3(^2H)4s$	$b\ ^3H$	4	20 242.37	0.82		
		5	20 280.23	1.01		
		6	20 363.23	1.14		
$3d^3(a\ ^2D)4s$	$b\ ^3D$	1	20 522.11	0.58	51	43 $3d^4\ ^3D$
		2	20 617.03	1.25	32	20
		3	20 622.95	1.26	60	40
$3d^3(a\ ^2D)4s$	$a\ ^1D$	2	20 980.92	1.02	33	23 $3d^4\ ^1D$
$3d^3(^2P)4s$	$a\ ^1P$	1	22 273.60	0.97		
$3d^3(^2H)4s$	$a\ ^1H$	5	23 391.14	1.04		
$3d^4$	$b\ ^1D$	2	25 191.04	0.99	56	30 $3d^3(a\ ^2D)4s\ ^1D$

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^4$	$a\ ^1F$	3	26 839.77	0.97		
$3d^3(^2F)4s$	$c\ ^3F$	2	30 267.47	0.67	56	33 $3d^4\ ^3F$
		3	30 306.38	1.06	59	31
		4	30 318.55	1.25	62	29
$3d^4$	$d\ ^3F$	4	30 613.92	1.23	60	36 $3d^3(^2F)4s\ ^3F$
		3	30 641.76	1.05	57	39
		2	30 673.08	0.67	54	41
$3d^4$	$d\ ^3P$	2	32 040.64	1.38		
		1	32 299.27	1.48		
		0	32 420.04			
$3d^3(^2F)4s$	$b\ ^1F$	3	34 228.82	1.00		
$3d^3(^4F)4p$	$z\ ^5G^\circ$	2	*34 592.72*	0.31	100	
		3	*34 745.72*	0.93	100	
		4	*34 946.55*	1.14	100	
		5	*35 193.13*	1.16	100	
		6	*35 483.39*		100	
$3d^4$	$c\ ^1G$	4	36 424.92	0.96		
$3d^3(^4F)4p$	$z\ ^3D^\circ$	1	*36 489.36*	0.35	51	42 $(^4F)\ ^5F^\circ$
		2	*37 041.12*	1.08	44	44 $(^4F)\ ^5F^\circ$
		3	*37 204.98*	1.32	55	21 $(^4F)\ ^5D^\circ$
$3d^3(^4F)4p$	$z\ ^5F^\circ$	2	*36 673.48*	1.08	54	38 $(^4F)\ ^3D^\circ$
		3	*36 919.21*	1.24	81	13
		1	*36 954.63*	0.24	56	37
		4	*37 150.51*		98	
		5	*37 352.45*	1.40?	98	
$3d^3(^4F)4p$	$z\ ^5D^\circ$	0	*37 201.35*		97	
		1	*37 259.39*	1.39	94	
		2	*37 369.03*	1.39	87	10 $(^4F)\ ^3D^\circ$
		3	*37 520.57*	1.47	73	23
		4	*37 531.08*	1.44	97	
$3d^24s^2$	$e\ ^3F$	2	37 937.65			
		3	38 192.94			
		4	38 517.06			
$3d^3(^4F)4p$	$z\ ^3G^\circ$	3	*39 234.05*	0.84	91	7 $(^2G)\ ^3G^\circ$
		4	*39 403.74*	1.03	91	7
		5	*39 612.96*	1.19	91	7
$3d^3(^4F)4p$	$z\ ^3F^\circ$	2	*40 001.70*	0.65	94	
		3	*40 195.52*	1.02	94	
		4	*40 430.04*	1.22	94	

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^3(b\ ^2D)4s$	$c\ ^3D$	3	44 098.46	1.27?		
		2	44 159.53	1.14?		
		1	44 201.85	0.50?		
$3d^24s^2$	$c\ ^1D$	2	44 657.94		57	39 $3d^4\ ^1D$
$3d^3(^4P)4p$	$y\ ^5D°$	0	*46 586.37*		48	40 $(^4P)\ ^3P°$
		1	*46 690.42*	1.44	55	33 $(^4P)\ ^3P°$
		2	*47 101.89*	1.47	63	26 $(^4P)\ ^3P°$
		3	*47 181.21*	1.48?	95	
		4	*47 420.25*	2.28	97	
$3d^3(^4P)4p$	$z\ ^3P°$	2	*46 739.99*	1.48	44	34 $(^4P)\ ^5P°$
		0	*47 027.95*		39	48 $(^4P)\ ^5D°$
		1	*47 107.99*	1.43	48	41 $(^4P)\ ^5D°$
$3d^3(^4P)4p$	$z\ ^5P°$	1	*46 754.59*	2.28	94	
		2	*46 879.98*	1.68	62	20 $(^4P)\ ^5D°$
		3	*47 051.86*	1.55	98	
$3d^3(^2G)4p$	$z\ ^3H°$	4	*47 056.32*	0.78	88	12 $(^2H)\ ^3H°$
		5	*47 297.04*	1.01	87	12
		6	*47 607.79*	1.13	87	12
$3d^3(b\ ^2D)4s$	$d\ ^1D$	2	47 324.31			
$3d^3(^2P)4p$	$z\ ^1S°$	0	*48 258.22*		90	7 $(^4P)\ ^3P°$
$3d^3(^2G)4p$	$y\ ^3G°$	3	*48 579.96*	0.67	80	7 $(^4F)\ ^3G°$
		4	*48 730.72*	1.02	87	7
		5	*48 853.04*	1.22	84	7
$3d^24s^2$	$e\ ^3P$	0	48 898.0?			
		1	48 975.72			
		2	49 204.65			
$3d^3(^2G)4p$	$y\ ^3F°$	2	*49 201.64*	0.63	78	15 $(a\ ^2D)\ ^3F°$
		3	*49 210.80*	0.99	46	29 $(^2G)\ ^1F°$
		4	*49 268.60*	1.18	60	28 $(^2G)\ ^1G°$
$3d^3(^2G)4p$	$z\ ^1F°$	3	*49 568.42*	0.97	49	34 $(^2G)\ ^3G°$
$3d^3(^2G)4p$	$z\ ^1H°$	5	*49 593.36*	0.95	72	21 $(^2H)\ ^1H°$
$3d^3(^2G)4p$	$z\ ^1G°$	4	*49 723.68*	0.96	69	23 $(^2G)\ ^3F°$
$3d^3(^4P)4p$	$z\ ^5S°$	2	*49 731.34*		96	
$3d^3(^2P)4p$	$z\ ^1D°$	2	*49 898.19*	0.93	50	36 $(a\ ^2D)\ ^1D°$
$3d^3(^2P)4p$	$y\ ^3D°$	1	*50 473.73*	0.49	52	21 $(^4P)\ ^3D°$
		2	*50 775.47*	1.11	58	27
		3	*51 085.71*	1.27	55	32

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^3(^2P)4p$	$y\ ^3P^\circ$	0	*50 662.27*		63	36 $(a\ ^2D)\ ^3P^\circ$
		1	*50 738.75*	1.39	50	29
		2	*51 123.21*	1.51	58	38
$3d^4$	$e\ ^1D$	2	50 951.7		59	32 $3d^23s^2\ ^1D^\circ$
$3d^3(^2H)4p$	$y\ ^3H^\circ$	4	*52 082.82*	0.70	86	12 $(^2G)\ ^3H^\circ$
		5	*52 153.36*	0.98	87	12
		6	*52 252.60*	1.04?	87	12
$3d^3(^2P)4p$	$z\ ^3S^\circ$	1	*52 181.18*	1.85	82	11 $(^4P)\ ^3S^\circ$
$3d^3(a\ ^2D)4p$	$x\ ^3F^\circ$	2	*52 245.69*	0.68	74	12 $(^2G)\ ^3F^\circ$
		3	*52 391.94*	1.07	58	22 $(^4P)\ ^3D^\circ$
		4	*52 657.47*	1.18?	85	10 $(^2G)\ ^3F^\circ$
$3d^3(^4P)4p$	$x\ ^3D^\circ$	1	*52 604.20*	0.63	52	16 $(^2P)\ ^3D^\circ$
		2	*52 700.05*	1.10	51	25
		3	*52 767.30*	1.26	34	29
$3d^3(a\ ^2D)4p$	$z\ ^1P^\circ$	1	*52 803.75*	0.92	73	11 $(^2P)\ ^1P^\circ$
$3d^3(^2H)4p$	$z\ ^3I^\circ$	5	*52 877.89*	0.84?	99	
		6	*53 076.71*	0.98	100	
		7	*53 319.56*	1.11?	100	
$3d^24s^2$	$d\ ^1G$	4	53 607.2?			
$3d^3(a\ ^2D)4p$	$w\ ^3D^\circ$	1	*53 751.48*	0.49?	76	12 $(^2P)\ ^3D^\circ$
		2	*53 868.61*	1.10	80	11
		3	*53 927.17*	1.37	84	7
$3d^3(^2H)4p$	$y\ ^1G^\circ$	4	*54 144.17*	1.00	82	11 $(^2F)\ ^1G^\circ$
$3d^3(a\ ^2D)4p$	$x\ ^3P^\circ$	2	*54 715.66*		48	32 $(^2P)\ ^3P^\circ$
		1	*54 717.86*		48	28
		0	*54 813.40*		52	30
$3d^3(a\ ^2D)4p$	$y\ ^1F^\circ$	3	*55 142.03*	0.94	53	34 $(^2H)\ ^3G^\circ$
$3d^3(^2H)4p$	$x\ ^3G^\circ$	5	*55 206.79*	1.15	79	10 $3d^3(^2H)4p\ ^1H^\circ$
		4	*55 304.30*	1.02	88	6 $3d^2(^3F)4s4p(^3P^\circ)\ ^3G^\circ$
		3	*55 349.63*	0.82	57	33 $3d^3(a\ ^2D)4p\ ^1F^\circ$
$3d^3(^2H)4p$	$z\ ^1I^\circ$	6	*55 403.30*	1.01?	100	
$3d^3(^2H)4p$	$y\ ^1H^\circ$	5	*55 499.34*	1.03?	66	20 $(^2G)\ ^1H^\circ$
$3d^3(^4P)4p$	$y\ ^3S^\circ$	1	*55 663.23*	1.92	55	22 $(^2P)\ ^1P^\circ$
$3d^3(^2P)4p$	$y\ ^1P^\circ$	1	*56 171.40*	1.05?	60	25 $(^4P)\ ^3S^\circ$

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^3(a\ ^2D)4p$	$y\ ^1D°$	2	*57 342.56*	0.98	54	40 $(^2P)\ ^1D°$
$3d^3(^2F)4p$	$w\ ^3F°$	2	*62 084.94*	0.58?	85	7 $3d^2(^3F)4s4p(^1P°)\ ^3F°$
		3	*62 133.30*	1.00	80	9 $3d^2(^3F)4s4p(^3P°)\ ^5G°$
		4	*62 176.19*	1.36?	78	11 $3d^2(^3F)4s4p(^3P°)\ ^5G°$
$3d^2(^3F)4s4p(^3P°)$	$^5G°$	2	*62 285.8*		96	
		3	*62 444.1*		90	8 $3d^3(^2F)4p\ ^3F°$
		4	*62 682.0*		88	10
		5	*62 987.6*		100	
		6	*63 357.3*		100	
$3d^2(^3F)4s4p(^3P°)$	$y\ ^5F°$	1	*63 549.2*		98	
		2	*63 656.8*		98	
		3	*63 816.7*		98	
		4	*64 026.2*		98	
		5	*64 286.6*		91	7 $3d^3(^2F)4p\ ^3G°$
$3d^3(^2F)4p$	$w\ ^3G°$	3	*64 057.54*	0.72?	95	
		4	*64 130.80*	1.02	94	
		5	*64 229.19*		89	7 $3d^2(^3F)4s4p(^3P°)\ ^5F°$
$3d^3(^2F)4p$	$x\ ^1D°$	2	*64 586.14*	1.03?	67	16 $3d^3(^2F)4p\ ^3D°$
$3d^3(^2F)4p$	$v\ ^3D°$	3	*64 603.47*	1.22?	88	6 $3d^2(^3P)4s4p(^3P°)\ ^3D°$
		2	*64 804.17*	1.02?	72	15 $3d^3(^2F)4p\ ^1D°$
		1	*64 930.69*	0.46?	88	6 $3d^2(^3P)4s4p(^3P°)\ ^3D°$
$3d^2(^3F)4s4p(^3P°)$	$x\ ^5D°$	0	*65 781.8*		94	
		1	*65 815.2*		94	
		2	*65 884.4*		93	
		3	*65 995.6*		93	
		4	*66 157.6*		94	
$3d^3(^2F)4p$	$x\ ^1G°$	4	*65 790.18*	0.94	87	10 $(^2H)\ ^1G°$
$3d^3(^2F)4p$	$x\ ^1F°$	3	*66 303.84*	0.95	74	22 $3d^2(^3F)4s4p(^3P°)\ ^1F°$
$3d^2(^3F)4s4p(^3P°)$	$v\ ^3F°$	2	*67 737.7*		77	11 $3d^2(^1D)4s4p(^3P°)\ ^3F°$
		3	*67 904.8*		77	11
		4	*68 147.0*		78	11
$3d^2(^3F)4s4p(^3P°)$	$u\ ^3D°$	1	*68 759.2*		81	4 $3d^2(^1D)4s4p(^3P°)\ ^3D°$
		2	*68 797.4*		80	4
		3	*68 944.9*		80	4
$3d^3(^4F)5s$	^5F	1	69 146.30			
		2	69 228.20			
		3	69 352.43			
		4	69 518.36			
		5	69 724.14	1.39		

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%) First	Second
$3d^2(^3F)4s4p(^3P°)$	$v\ ^3G°$	3	*69 643.9*		92	
		4	*69 911.8*		92	
		5	*70 227.6*		93	
$3d^3(^4F)5s$	^3F	2	70 415.40			
		3	70 629.71	1.06		
		4	70 898.43	1.23		
$3d^2(^3F)4s4p(^3P°)$	$^1D°$	2	*70 923.28*		82	9 $3d^2(^3P)4s4p(^3P°)\ ^1D°$
$3d^2(^3F)4s4p(^3P°)$	$^1F°$	3	*70 935.97*		73	19 $3d^3(^2F)4p\ ^1F°$
	$w\ ^1G°$	4	*72 292.4?*			
$3d^3(^4F)4d$	$e\ ^5H$	3	72 448.40			
		4	72 551.09			
		5	72 680.70			
		6	72 837.42			
		7	73 020.96			
$3d^3(^4F)4d$	$e\ ^5P$	1	72 518.35			
		2	72 674.58			
		3	72 908.79			
$3d^3(^4F)4d$	^5F	1	72 839.18			
		2	73 027.18			
		3	73 146.21			
		4	73 279.16			
		5	73 417.14			
$3d^3(^4F)4d$	^5G	2	72 877.85			
		3	72 951.38			
		4	73 063.53			
		5	73 223.17			
		6	73 499.60			
$3d^3(^4F)4d$	^3D	1	73 181.42			
		2	73 309.92			
		3	73 530.58			
$3d^3(^4F)4d$	^3P	0	74 949.48			
		1	75 080.58			
		2	75 335.70			
$3d^3(^4F)4d$	^3H	4	75 140.52			
		5	75 346.15			
		6	75 592.36			
$3d^3(^4F)4d$	^3G	3	75 422.77			
		4	75 615.29			
		5	75 854.10			

V II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading components (%)	
					First	Second
$3d^2(^1D)4s4p(^3P°)$	$t\ ^3D°$	1	*75 716.0*	0.50?	58	12 $3d^3(b\ ^2D)4p\ ^3D°$
		2	*75 758.2*	1.14?	56	13 $3d^3(b\ ^2D)4p\ ^3D°$
		3	*75 848.0*	1.27?	54	19 $3d^2(^3P)4s4p(^3P°)\ ^5P°$
$3d^3(^4F)4d$	^3F	2	75 813.38			
		3	75 966.00			
		4	76 142.95			
	$u\ ^3F°$	2	*76 220.4*			
		3	*76 385.8*			
		4	*76 643.5*			
$3d^3(^4F)4d$	^5D	0	76 281.20			
		1	76 322.47			
		2	76 403.48			
		3	76 521.20			
		4	76 672.95			
	2°	3	*76 405.4*			
$3d^3(b\ ^2D)4p$	$v\ ^1D°$	2	*77 603.4*		74	14 $3d^2(^3P)4s4p(^3P°)$
$3d^3(b\ ^2D)4p$	$t\ ^3F°$	3	*77 841.9*		85	8 $3d^2(^1G)4s4p(^3P°)$
		2	*77 857.0*		66	12 $3d^2(b\ ^2D)4s4p(^3P°)$
		4	*77 968.9*		86	8 $3d^2(^1G)4s4p(^3P°)$
$3d^3(b\ ^2D)4p$	$v\ ^3P°$	2	*78 416.8*		55	24 $3d^2(^3P)4s4p(^3P°)$
		1	*78 569.1*		66	23
		0	*78 644.1*		66	33
$3d^3(b\ ^2D)4p$	$u\ ^1F°$	3	*79 327.6*		93	
$3d^3(^4P)5s$	^5P	1	80 542.20			
		2	80 623.12			
		3	80 782.28			
$3d^3(^2G)5s$	^3G	3	81 263.49			
		4	81 342.88			
		5	81 483.15			
$3d^3(^4P)5s$	^3P	0	81 669.39			
		1	81 735.96			
		2	81 914.22			
$3d^3(^2G)5s$	^1G	4	82 025.60			
$3d^3(^2H)5s$	^3H	4	86 027.94			
		5	86 091.61			
		6	86 191.60			
$3d^3(^2H)5s$	^1H	5	86 766.62			
V III ($^4F_{3/2}$)	*Limit*	....	**118 200**			

V III

Sc I isoelectronic sequence $Z = 23$

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

Ionization energy = 236 410 cm^{-1} (29.311 eV)

The initial analysis was by White (1929), who found terms of $3d^3$, $3d^24s$, $3d^24p$, and $3d^24d$.

Many more configurations were discovered by Iglesias (1962, 1969) utilizing a new set of wavelength measurements. Her results are presented here, including revised values for the levels found by White and her determination of the ionization energy from the $3d^2ng$ series (n = 5–7).

Theoretical confirmation of the $3d^3$ and $3d^24s$ levels has been provided by Shadmi, Caspi, and Oreg (1969). Percentage compositions for $3d^3$ are from Pasternak and Goldschmidt (1972). The compositions of the $3d^24d$ levels are from an unpublished calculation by Sugar (1972).

The percentage compositions of the $3d^24p$ levels are from Roth (1968). He has interchanged Iglesias's designations for the (^{3}F) $^2D^\circ_{5/2}$ and (^{3}F) $^4D^\circ_{5/2}$ levels. The percentage compositions of $3d^24f$ levels were calculated by Spector (1970).

References

Iglesias, L. (1962), An. Real Soc. Esp. Fis. y Quim. **58A,** 191.

Iglesias, L. (1969), Optica Pura y Aplicada **2,** 132.

Pasternak, A., and Goldschmidt, Z. B. (1972), Phys. Rev. **6A,** 55.

Roth, C. (1968), J. Res. Nat. Bur. Stand. **72A,** 505.

Shadmi, Y., Caspi, E., and Oreg, J. (1969). J. Res. Nat. Bur. Stand. **73A,** 173.

Spector, N. (1970), Optica Pura y Aplicada **3,** 33.

White, H. E. (1929), Phys. Rev. **33,** 672.

V III

Configuration	Term	J	Level (cm^{-1})	Leading components (%) First	Second
$3d^3$	$a\ ^4$F	3/2	0.0	100	
		5/2	145.5	100	
		7/2	341.5	100	
		9/2	583.8	100	
$3d^3$	$a\ ^4$P	1/2	11 513.8	100	
		3/2	11 591.8	99	
		5/2	11 769.7	100	
$3d^3$	$a\ ^2$G	7/2	11 966.3	100	
		9/2	12 187.0	100	
$3d^3$	$a\ ^2$P	3/2	15 550.3	67	25 ^{2}D2
		1/2	15 579.8	100	
$3d^3$	$a\ ^2$D2	3/2	16 330.5	52	32 ^{2}P
		5/2	16 374.7	77	22 ^{2}D1
$3d^3$	$a\ ^2$H	9/2	16 810.9	100	
		11/2	16 977.6	100	
$3d^3$	$a\ ^2$F	7/2	27 727.8	100	
		5/2	27 846.8	100	
$3d^3$	$b\ ^2$D1	5/2	42 267.4	77	22 ^{2}D2
		3/2	42 371.2	77	23
$3d^2(^3F)4s$	$b\ ^4$F	3/2	43 942.49		
		5/2	44 110.04		
		7/2	44 345.82		
		9/2	44 646.96		

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^2(^3F)4s$	$b\ ^2F$	5/2	49 327.74		
		7/2	49 805.29		
$3d^2(^1D)4s$	$c\ ^2D$	5/2	56 160.42		
		3/2	56 256.75		
$3d^2(^3P)4s$	$b\ ^4P$	1/2	56 529.30		
		3/2	56 669.05		
		5/2	56 922.50		
$3d^2(^3P)4s$	$b\ ^2P$	1/2	61 578.74		
		3/2	61 777.15		
$3d^2(^1G)4s$	$b\ ^2G$	9/2	63 303.12		
		7/2	63 315.05		
$3d^2(^3F)4p$	$z\ ^4G°$	5/2	*85 524.00*	98	
		7/2	*85 875.74*	99	
		9/2	*86 306.40*	100	
		11/2	*86 809.39*	100	
$3d^2(^1S)4s$	$a\ ^2S$	1/2	86 304.0		
$3d^2(^3F)4p$	$z\ ^4F°$	3/2	*86 716.84*	98	
		5/2	*86 938.01*	99	
		7/2	*87 218.92*	99	
		9/2	*87 544.46*	99	
$3d^2(^3F)4p$	$z\ ^2F°$	5/2	*87 880.85*	85	6 $(^1D)\ ^2F°$
		7/2	*88 327.96*	88	5
$3d^2(^3F)4p$	$^2D°$	3/2	*88 559.08*	59	29 $(^3F)\ ^4D°$
		5/2	*89 457.67*	52	35
$3d^2(^3F)4p$	$^4D°$	1/2	*89 005.64*	96	4 $(^3P)\ ^4D°$
		3/2	*89 193.47*	67	25 $(^3F)\ ^2D°$
		5/2	*88 944.38*	59	28 $(^3F)\ ^2D°$
		7/2	*89 417.50*	91	4 $(^3F)\ ^2F°$
$3d^2(^3F)4p$	$z\ ^2G°$	7/2	*91 710.43*	96	
		9/2	*92 052.55*	96	
$3d^2(^3P)4p$	$z\ ^2S°$	1/2	*94 714.25*	99	
$3d^2(^3P)4p$	$z\ ^4S°$	3/2	*97 512.00*	74	25 $(^1D)\ ^2P°$
$3d^2(^1D)4p$	$z\ ^2P°$	3/2	*98 062.22*	70	26 $(^3P)\ ^4S°$
		1/2	*98 399.42*	97	
$3d^2(^1D)4p$	$y\ ^2F°$	5/2	*98 383.53*	88	7 $(^3F)\ ^2F°$
		7/2	*98 825.19*	86	6

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^2(^3P)4p$	$y\ ^4D°$	1/2	*99 073.23*	95	4 $(^3F)\ ^4D°$
		3/2	*99 181.50*	91	4 $(^3F)\ ^4D°$
		5/2	*99 440.10*	88	5 $(^1D)\ ^2D°$
		7/2	*99 941.20*	91	5 $(^1D)\ ^2F°$
$3d^2(^1D)4p$	$y\ ^2D°$	3/2	*99 508.50*	81	6 $(^3P)\ ^2D°$
		5/2	*99 804.57*	80	7 $(^3P)\ ^4D°$
$3d^2(^3P)4p$	$z\ ^4P°$	1/2	*101 645.61*	99	
		3/2	*101 785.81*	99	
		5/2	*102 075.00*	98	
$3d^2(^1G)4p$	$y\ ^2G°$	7/2	*102 961.28*	96	4 $(^3F)\ ^2G°$
		9/2	*103 034.65*	96	4
$3d^2(^3P)4p$	$x\ ^2D°$	5/2	*105 282.65*	82	10 $(^3F)\ ^2D°$
		3/2	*105 320.18*	80	10 $(^1D)\ ^2D°$
$3d^2(^1G)4p$	$z\ ^2H°$	9/2	*106 441.31*	99	
		11/2	*106 903.35*	100	
$3d^2(^3P)4p$	$y\ ^2P°$	1/2	*107 060.41*	99	
		3/2	*107 165.90*	97	
$3d^2(^1G)4p$	$x\ ^2F°$	7/2	*109 854.87*	97	
		5/2	*110 181.47*	97	
$3d^2(^1S)4p$	$x\ ^2P°$	1/2	*129 397.4*	98	
		3/2	*129 998.3*	98	
$3d^2(^3F)4d$	$e\ ^4G$	5/2	140 751.47	89	11 $(^3F)\ ^2F$
		7/2	140 933.85	93	5 $(^3F)\ ^4H$
		9/2	141 144.86	92	8 $(^3F)\ ^4H$
		11/2	141 405.80	91	9 $(^3F)\ ^4H$
$3d^2(^3F)4d$	$e\ ^2F$	5/2	141 196.87	83	11 $(^3F)\ ^4G$
		7/2	141 508.26	86	8 $(^3F)\ ^4D$
$3d^2(^3F)4d$	$e\ ^4H$	7/2	141 271.10	95	5 $(^3F)\ ^4G$
		9/2	141 489.06	92	8 $(^3F)\ ^4G$
		11/2	141 735.42	91	9 $(^3F)\ ^4G$
		13/2	141 991.58	100	
$3d^2(^3F)4d$	$e\ ^4D$	1/2	141 421.87	98	
		3/2	141 531.94	99	
		5/2	141 715.20	97	
		7/2	141 987.95	92	7 $(^3F)\ ^2F$
$3d^2(^3F)4d$	$e\ ^2P$	1/2	143 169.0	91	6 $(^1D)\ ^2P$
		3/2	143 651.5	91	5

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^2(^3F)4d$	$e\ ^4P$	1/2	144 544.13	90	10 $(^3P)\ ^4P$
		3/2	144 828.58	88	10
		5/2	145 073.42	88	10
$3d^2(^3F)4d$	$e\ ^2G$	7/2	144 772.60	88	9 $(^1D)\ ^2G$
		9/2	145 144.00	88	9
$3d^2(^3F)5s$	$e\ ^4F$	3/2	145 822.76		
		5/2	145 978.99		
		7/2	146 223.74		
		9/2	146 550.32		
$3d^2(^3F)4d$	$e\ ^2H$	9/2	145 903.31	93	7 $(^1G)\ ^2H$
		11/2	146 347.77	93	7
$3d^2(^3F)4d$	$e\ ^2D$	3/2	145 953.51	84	13 $(^1D)\ ^2D$
		5/2	146 140.08	82	14
$3d^2(^3F)4d$	$f\ ^4F$	3/2	146 846.99	97	
		5/2	146 984.08	97	
		7/2	147 170.06	97	
		9/2	147 401.29	97	
$3d^2(^3F)5s$	$f\ ^2F$	5/2	147 127.46		
		7/2	147 607.08		
$3d^2(^1D)4d$	$e\ ^2S$	1/2	152 317.7	98	
$3d^2(^3P)4d$	$f\ ^2P$	3/2	152 861.2	56	44 $(^1D)\ ^2P$
		1/2	153 266.4	55	43
$3d^2(^1D)4d$	$g\ ^2F$	5/2	152 940.0	86	13 $(^3P)\ ^2F$
		7/2	153 113.9	88	10
$3d^2(^1D)4d$	$f\ ^2G$	9/2	154 548.9	84	7 $(^3F)\ ^2G$
		7/2	154 572.7	86	7
$3d^2(^3P)4d$	$g\ ^4F$	3/2	155 497.3	96	
		5/2	155 569.8	95	
		7/2	155 682.5	92	
		9/2	155 862.3	93	4 $(^1D)\ ^2G$
$3d^2(^3P)4d$	$f\ ^4D$	3/2	155 802.0	90	6 $(^1D)\ ^2D$
		1/2	155 829.9?	99	
		5/2	155 853.9	92	
		7/2	155 982.0	95	
$3d^2(^1D)4d$	$f\ ^2D$	3/2	156 344.6	62	13 $(^3P)\ ^2D$
		5/2	156 671.7	64	13 $(^3F)\ ^2D$
$3d^2(^3P)4d$	$h\ ^2F$	5/2	157 027.6	59	33 $(^1G)\ ^2F$
		7/2	157 068.0	61	32

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%) First	Second
$3d^2(^1D)5s$	$g\ ^2D$	5/2	157 066.8		
		3/2	157 080.1		
$3d^2(^3P)4d$	$f\ ^4P$	3/2	158 155.5	81	9 $(^3F)\ ^4P$
		1/2	158 188.2	84	9
		5/2	158 240.2	88	10
$3d^2(^3P)5s$	$g\ ^4P$	1/2	158 844.4		
		3/2	158 927.4		
		5/2	159 147.6		
$3d^2(^3P)4d$	^2D	3/2	158 976.0?	29	22 $(^1D)\ ^2P$
		5/2	159 067.6	55	27 $(^1G)\ ^2D$
$3d^2(^1D)4d$	^2P	3/2	159 250.5	25	24 $(^3P)\ ^2D$
$3d\,4s(^3D)4p$	$x\ ^4D^\circ$	1/2	*159 684.4*		
		3/2	*159 787.8*		
		5/2	*159 996.0*		
		7/2	*160 351.5*		
$3d^2(^3P)5s$	$h\ ^2P$	1/2	160 098.6?		
		3/2	160 308.4		
$3d^2(^3F)5p$	$y\ ^4F^\circ$	3/2	*160 144.92*		
		5/2	*160 380.35*		
		7/2	*160 682.19*		
		9/2	*161 028.02*		
$3d^2(^3F)5p$	$y\ ^4G^\circ$	5/2	*160 322.56*		
		7/2	*160 577.33*		
		9/2	*160 880.67*		
		11/2	*161 240.69*		
$3d^2(^1G)4d$	$g\ ^2G$	7/2	161 017.78	92	5 $(^3F)\ ^2G$
		9/2	161 085.59	92	5
$3d^2(^1G)4d$	$e\ ^2I$	11/2	161 051.82	100	
		13/2	161 101.91	100	
$3d^2(^3F)5p$	$w\ ^2F^\circ$	5/2	*161 166.33*		
		7/2	*161 588.54*		
$3d^2(^3F)5p$	$w\ ^4D^\circ$	1/2	*161 491.07*		
		3/2	*161 570.12*		
		5/2	*161 924.00*		
		7/2	*162 385.82*		
$3d^2(^3F)5p$	$w\ ^2D^\circ$	3/2	*161 885.32*		
		5/2	*162 305.28*		
$3d^2(^3F)5p$	$x\ ^2G^\circ$	7/2	*162 336.36*		
		9/2	*162 760.84*		

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%) First	Leading components (%) Second
$3d^2(^1G)4d$	$f\ ^2H$	9/2	162 513.19	93	7 $(^3F)\ ^2H$
		11/2	162 543.12	93	7
$3d^2(^1G)5s$	$h\ ^2G$	9/2	164 398.44		
		7/2	164 399.32		
$3d^2(^1G)4d$	$i\ ^2F$	7/2	165 208.47	66	25 $(^3P)\ ^2F$
		5/2	165 267.23	66	24
$3d^2(^1D)5p$	$v\ ^2F^\circ$	5/2	171 614.7		
		7/2	171 809.8		
$3d^2(^1D)5p$	$w\ ^2P^\circ$	3/2	171 717.3		
		1/2	171 863.5		
$3d^2(^1D)5p$	$v\ ^2D^\circ$	3/2	171 983.8		
		5/2	172 112.3		
$3d^2(^3P)5p$	$y\ ^4S^\circ$	3/2	172 804.9		
$3d^2(^3F)4f$	$^4H^\circ$	7/2	173 246.54	77	
		9/2	173 367.21	76	
		11/2	173 517.63	64	27 $(^3F)\ ^4I^\circ$
		13/2	173 788.14	58	38 $(^3F)\ ^4I^\circ$
$3d^2(^3F)4f$	$^2G^\circ$	7/2	173 388.5?	61	
		9/2	173 670.02	56	
$3d^2(^3P)5p$	$v\ ^4D^\circ$	1/2	173 458.5		
		3/2	173 556.6		
		5/2	173 741.4		
		7/2	173 966.3		
$3d^2(^3F)4f$	$^4I^\circ$	9/2	173 534.92	64	
		11/2	173 773.28	65	23 $(^3F)\ ^4H^\circ$
		13/2	174 045.8	56	41 $(^3F)\ ^4H^\circ$
		15/2	174 223.7	100	
$3d^2(^3F)4f$	$^4G^\circ$	5/2	173 568.27	71	
		7/2	173 786.11	59	
		9/2	173 990.35	46	36 $(^3F)\ ^2H^\circ$
		11/2	174 237.76	76	
$3d^2(^3F)4f$	$^2F^\circ$	5/2	173 659.5	41	29 $(^3F)\ ^4F^\circ$
		7/2	174 259.15	53	20
$3d^2(^3F)4f$	$^4F^\circ$	7/2	173 905.49	27	32 $(^3F)\ ^2F^\circ$
		5/2	174 059.6	30	30 $(^3F)\ ^4P^\circ$
		9/2	174 367.6	79	
$3d^2(^3F)4f$	$^4D^\circ$	5/2	173 954.6	20	29 $(^3F)\ ^2F^\circ$
		3/2	174 069.3	23	35 $(^3F)\ ^2P^\circ$
		7/2	174 458.96	66	29 $(^3F)\ ^4F^\circ$

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^2(^3F)4f$	$^2H°$	9/2	*174 170.6*	41	36 $(^3F)\ ^2G°$
		11/2	*174 500.46*	67	23 $(^3F)\ ^2I°$
$3d^2(^3F)4f$	$^2I°$	11/2	*174 192.88*	55	26 $(^3F)\ ^2H°$
		13/2	*174 720.37*	95	
$3d^2(^3F)4f$	$^2D°$	3/2	*174 207.7*	37	27 $(^3F)\ ^4S°$
		5/2	*174 467.3*	32	31 $(^3F)\ ^4D°$
$3d^2(^3P)5p$	$y\ ^4P°$	1/2	*174 507.3*		
		3/2	*174 696.4*		
		5/2	*174 938.9*		
$3d^2(^1G)5p$	$w\ ^2G°$	7/2	*178 053.05*		
		9/2	*178 085.62*		
$3d^2(^1G)5p$	$y\ ^2H°$	9/2	*179 467.60*		
		11/2	*179 631.11*		
$3d^2(^1G)5p$	$u\ ^2F°$	7/2	*179 855.04*		
		5/2	*179 889.40*		
$3d^2(^3F)5d$	$f\ ^4H$	7/2	181 650.16		
		9/2	181 826.54		
		11/2	182 077.54		
		13/2	182 444.06		
$3d^2(^3F)5d$	$f\ ^4G$	9/2	182 035.67		
		11/2	182 287.66		
$3d^2(^3F)5d$	$g\ ^4G$	5/2	182 168.8		
		7/2	182 517.8		
$3d^2(^3F)6s$	$h\ ^4F$	3/2	183 316.75		
		5/2	183 445.06		
		7/2	183 699.40		
		9/2	184 047.67		
$3d^2(^3F)5d$	$i\ ^2G$	7/2	183 760.91		
		9/2	184 087.90		
$3d^2(^3F)6s$	$j\ ^2F$	5/2	183 999.50		
		7/2	184 476.36		
$3d^2(^1D)4f$	$^2F°$	5/2	*184 104.9*		
		7/2	*184 304.4*		
$3d^2(^3F)5d$	$g\ ^2H$	9/2	184 237.44		
		11/2	184 648.09		
$3d^2(^1D)4f$	$^2H°$	11/2	*184 403.2?*	98	
		9/2	*184 413.0*	98	

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d^2(^1D)4f$	$^2G°$	7/2	*184 558.3*	96	
		9/2	*184 589.6*	98	
$3d^2(^3F)5d$	$i\ ^4F$	9/2	184 613.01		
$3d^2(^3P)4f$	$^4D°$	7/2	*186 457.5*	90	
$3d^2(^3P)4f$	$^4G°$	9/2	*186 604.4?*	90	
		11/2	*186 732.9?*	98	
$3d^2(^3P)4f$	$^2G°$	7/2	*186 861.6?*	90	
		9/2	*186 989.2?*	90	
$3d^2(^3P)4f$	$^4F°$	7/2	*187 369.6?*	96	
		9/2	*187 382.9?*	97	
$3d^2(^1G)4f$	$^2H°$	9/2	*191 345.6*	100	
		11/2	*191 348.25*	100	
$3d^2(^1G)4f$	$^2I°$	13/2	*191 540.37*	100	
		11/2	*191 542.50*	100	
$3d^2(^1G)4f$	$^2G°$	9/2	*191 644.8?*	100	
		7/2	*191 742.7*	100	
$3d^2(^1G)4f$	$^2K°$	15/2	*192 359.4?*	100	
		13/2	*192 362.3?*	100	
$3d^2(^3F)5f$	$^4I°$	13/2	*196 473.86*		
		15/2	*196 823.96*		
$3d^2(^3P)6s$	$h\ ^4P$	3/2	196 517.1?		
		5/2	196 707.4		
$3d^2(^3F_2)5g$	$^2[5]$	9/2	196 753.60		
		11/2	196 755.63		
$3d^2(^3F_2)5g$	$^2[6]$	11/2	196 811.7		
		13/2	196 814.4		
$3d^2(^3F_3)5g$	$^2[5]$	9/2	197 075.29		
		11/2	197 076.68		
$3d^2(^3F_3)5g$	$^2[4]$	9/2	197 089.5?		
		7/2	197 089.6		
$3d^2(^3F_3)5g$	$^2[6]$	11/2	197 092.6		
		13/2	197 093.3		
$3d^2(^3F_3)5g$	$^2[7]$	15/2	197 141.14		
		13/2	197 142.21		

V III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%) First	Second
$3d^2(^3F_4)5g$	$^2[6]$	11/2	197 477.25		
		13/2	197 477.56		
$3d^2(^3F_4)5g$	$^2[5]$	9/2	197 482.10		
		11/2	197 482.67		
$3d^2(^3F_4)5g$	$^2[7]$	15/2	197 507.64		
		13/2	197 510.77		
$3d^2(^3F_4)5g$	$^2[8]$	17/2	197 559.40		
		15/2	197 562.98		
$3d^2(^1G)6s$	$j\ ^2G$	7/2	201 733.1?		
		9/2	201 735.22		
$3d^2(^3F)7s$	$j\ ^4F$	7/2	201 836.5?		
		9/2	202 209.3?		
$3d^2(^3F_4)6g$	$^2[8]$	17/2	209 668.2		
$3d^2(^3P_2)5g$	$^2[6]$	13/2	210 193.8?		
		11/2	210 196.07?		
$3d^2(^3F_4)7g$	$^2[8]$	17/2	216 964.5		
V IV ($^3F_2$)	*Limit*	....	**236 410**		

V IV

Ca I isoelectronic sequence $Z = 23$

Ground state: $1s^22s^22p^63s^23p^63d^2\ ^3F_2$

Ionization energy = 376 730 cm^{-1} (46.709 eV)

The initial analysis was due to White (1929), who reported levels of $3d^2$, $3d4d$, and all the levels of the $3d4s$ and $3d4p$ configurations.

The spectrum has been completely reobserved from 675 to 5940 Å by Iglesias and Velasco and analysed by Iglesias (1968), whose results are given here. She has added the $^1S_0$ term of $3d^2$, all the terms but one of $3d4d$, $3d5d$, and $3d4f$, and all the terms of $3d5s$, $3d6s$, and $3d5p$. The two terms of $3d5g$ exhibit pair coupling. The percentage compositions for $3d4f$ were calculated by Spector (1970). He has interchanged Iglesias's designations of $3d4f\ ^1F^\circ_3$ and $^3D^\circ_3$. The compositions of levels of $3d4d + 3d5s$, $3d5d + 3d6s$, and $3d4p$ are quoted from Wyart.

The ionization energy was derived by Iglesias from the three member $3dns$ series, with an estimated uncertainty of 0.005 eV, ($\pm$ 40 cm^{-1}).

References

Iglesias, L. (1969), J. Res. Nat. Bur. Stand. **72A,** 295.
Spector, N. (1970), Optica Pura y Aplicada **3,** 33.
White, H. E. (1929), Phys. Rev. **33,** 538.
Wyart, J.-F. (1975), Physica Scripta **12,** 33.

V IV

Configuration	Term	J	Level (cm^{-1})	Leading components (%) First	Second
$3d^2$	^3F	2	0.0		
		3	325.4		
		4	734.7		
$3d^2$	^1D	2	10 959.3		
$3d^2$	^3P	0	13 122.8		
		1	13 239.2		
		2	13 458.3		
$3d^2$	^1G	4	18 391.2		
$3d^2$	^1S	0	42 462.1		
$3d\,4s$	^3D	1	96 196.1		
		2	96 412.1		
		3	96 798.0		
$3d\,4s$	^1D	2	100 200.7		
$3d\,4p$	$^1D^\circ$	2	*144 273.1*	96	
$3d\,4p$	$^3D^\circ$	1	*146 117.7*	99	
		2	*146 429.3*	95	
		3	*146 855.1*	93	
$3d\,4p$	$^3F^\circ$	2	*147 135.2*	94	
		3	*147 656.5*	94	
		4	*148 369.2*	100	
$3d\,4p$	$^3P^\circ$	1	*151 427.0*	98	
		0	*151 449.1*	100	
		2	*151 567.3*	99	
$3d\,4p$	$^1F^\circ$	3	*153 918.7*	99	

V IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d\,4p$	$^1P^\circ$	1	*155 565.5*	98	
$3d\,4d$	^1F	3	215 957.7	97	
$3d\,4d$	^3D	1	216 905.0	94	6 ^1P
		2	217 108.0	100	
		3	217 350.0	98	
$3d\,4d$	^3G	3	217 836.3	99	
		4	218 100.0	100	
		5	218 463.6	100	
$3d\,4d$	^1P	1	217 990.7	93	6 ^3D
$3d\,4d$	^3S	1	220 343.5	99	
$3d\,4d$	^3F	2	222 794.6	99	
		3	223 033.0	100	
		4	223 304.6	100	
$3d\,4d$	^1D	2	225 804.1	95	4 ^3P
$3d\,4d$	^3P	0	226 521.6	100	
		1	226 617.1	100	
		2	226 796.3	96	4 ^1D
$3d\,4d$	^1G	4	227 712.5	100	
$3d\,4d$	^1S	0	234 121.8	100	
$3d\,5s$	^3D	1	236 148.6	100	
		2	236 322.4	94	6 ^1D
		3	236 766.9	100	
$3d\,5s$	^1D	2	237 638.8	94	6 ^3D
$3d\,5p$	$^1D^\circ$	2	*254 468.8*		
$3d\,5p$	$^3D^\circ$	1	*254 824.1*		
		2	*255 146.8*		
		3	*255 445.5*		
$3d\,5p$	$^3F^\circ$	2	*255 463.3*		
		3	*255 747.6*		
		4	*256 251.7*		
$3d\,5p$	$^3P^\circ$	0	*256 739.9*		
		1	*256 781.8*		
		2	*257 143.2*		
$3d\,5p$	$^1F^\circ$	3	*257 690.8*		

V IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d\,5p$	$^1P°$	1	*258 288.8*		
$3d\,4f$	$^1G°$	4	*263 111.4*	77	
$3d\,4f$	$^3F°$	2	*263 593.0*	90	
		3	*263 608.3*	77	
		4	*264 113.1*	55	29 $^3H°$
$3d\,4f$	$^3H°$	4	*263 822.4*	56	21 $^3F°$
		5	*264 161.8*	77	
		6	*264 845.7*	100	
$3d\,4f$	$^3G°$	3	*263 902.3*	72	
		4	*264 401.9*	72	
		5	*264 591.9*	79	
$3d\,4f$	$^1D°$	2	*264 482.8*	76	
$3d\,4f$	$^3D°$	3	*264 902.2*	50	34 $^1F°$
		1	*265 019.7*	90	
		2	*265 067.4*	74	
$3d\,4f$	$^1F°$	3	*265 271.6*	55	42 $^3D°$
$3d\,4f$	$^3P°$	2	*265 879.2*	85	
		1	*265 879.2*	90	
$3d\,4f$	$^1H°$	5	*266 600.3*	98	
$3d\,5d$	^1F	3	283 459.4	89	6 ^3D
$3d\,5d$	^3D	1	283 722.7	84	16 ^1P
		2	283 940.4	99	
		3	284 226.7	78	13 ^3G
$3d\,5d$	^3G	3	284 101.1	83	16 ^3D
		4	284 340.1	99	
		5	284 699.3	100	
$3d\,5d$	^1P	1	284 365.7	80	16 ^3D
$3d\,5d$	^3S	1	285 298.6	95	4 ^1P
$3d\,5d$	^3F	2	285 798.9	97	
		3	286 056.9	98	
		4	286 286.5	99	
$3d\,5d$	^1D	2	287 221.4	83	14 ^3P
$3d\,5d$	^3P	2	287 733.4	86	14 ^1D
$3d\,5d$	^1G	4	288 127.6	99	

V IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3d\,6s$	^3D	1	291 796.0	100	
		2	291 918.1	85	15 ^1D
		3	292 417.6	100	
$3d\,6s$	^1D	2	292 766.7	84	15 ^3D
$3d(^2D_{3/2})5g$	$^2[7/2]$	3	306 323.1		
		4	306 327.7		
$3d(^2D_{5/2})5g$	$^2[9/2]$	5	306 871.0		
		4	306 876.3		
V v ($^2D_{3/2}$)	*Limit*	....	376 730		

V v

K I isoelectronic sequence $Z = 23$

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

Ionization energy = 526 532 cm^{-1} (65.2822 eV)

The early work of Gibbs and White (1929) revealed six low-lying doublet terms arising from the $3p^6 3d$, $4s$, $4p$, $4f$, $5s$, and $6s$ configurations. The first identifications of lines due to $3p^5 3d^2$ were given by Gabriel, Fawcett, and Jordan (1966).

The compilation is from the recent paper by Van Deurzen (1977). Earlier work by Van Deurzen, Conway, and Davis (1974) and by Ekberg (1974) is incorporated in the paper. Van Deurzen has observed the entire spectrum from 200 to 8500 Å with a vacuum sliding spark. The uncertainty of many of the level values is estimated to be a few units in the second decimal place relative to $3p^6 4p\ ^2P^\circ_{3/2} = 207660.00 \pm 0.3$ cm^{-1}, which reflects the larger uncertainty of the $3d$–$4p$ transitions at 483 Å.

Van Deurzen (1977) calculated the ionization energy from *ng*, *nh*, and *ni* series members by means of a polarization formula and assigned it a value 526532.0 ± 1.4 cm^{-1}.

References

Ekberg, J. O. (1974), Physica Scripta **9**, 96.

Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1966), Proc. Phys. Soc. **87**, 825.

Gibbs, R. C., and White, H. E. (1929), Phys. Rev. **33**, 157.

Van Deurzen, C. H. H., Conway, J. G., and Davis, S. P. (1974), J. Opt. Soc. Am. **64**, 498.

Van Deurzen, C. H. H. (1977), J. Opt. Soc. Am. **67**, 476.

V v

Configuration	Term	J	Level (cm^{-1})
$3p^6(^1S)3d$	^2D	3/2	0.00
		5/2	624.87
$3p^6(^1S)4s$	^2S	1/2	148 143.35
$3p^6(^1S)4p$	$^2P^\circ$	1/2	*206 393.72*
		3/2	*207 660.00*
$3p^6(^1S)4d$	^2D	3/2	293 902.86
		5/2	294 047.24
$3p^5(^2P^\circ)3d^2(^1G)$	$^2F^\circ$	5/2	*319 106.19*
		7/2	*320 731.60*
$3p^6(^1S)5s$	^2S	1/2	328 217.30
$3p^5(^2P^\circ)3d^2(^1D)$	$^2F^\circ$	7/2	*332 198.1*
		5/2	*337 012.59*
$3p^6(^1S)4f$	$^2F^\circ$	7/2	*349 252.40*
		5/2	*349 675.57*
$3p^6(^1S)5p$	$^2P^\circ$	1/2	*351 500.51*
		3/2	*352 018.34*
$3p^6(^1S)5d$	^2D	3/2	387 977.07
		5/2	388 043.69
$3p^5(^2P^\circ)3d^2(^3F)$	$^2F^\circ$	5/2	*396 135.24*
		7/2	*397 993.66*
$3p^6(^1S)6s$	^2S	1/2	403 855.12

V v—Continued

Configuration	Term	J	Level (cm^{-1})
$3p^6(^1S)6p$	$^2P^\circ$	1/2	*415 420.10*
		3/2	*415 675.69*
$3p^6(^1S)5g$	^2G	7/2	416 360.29
		9/2	416 361.78
$3p^6(^1S)5f$	$^2F^\circ$	5/2	*417 699.10*
		7/2	*418 187.47*
$3p^6(^1S)6d$	^2D	3/2	434 303.77
		5/2	434 340.92
$3p^5(^2P^\circ)3d^2(^3P)$	$^2P^\circ$	1/2	*438 018.3*
		3/2	*439 442.7*
$3p^6(^1S)7s$	^2S	1/2	443 074.72
$3p^5(^2P^\circ)3d^2\,(^3F)$	$^2D^\circ$	5/2	*444 153.7*
		3/2	*444 620.8*
$3p^6(^1S)6f$	$^2F^\circ$	5/2	*449 370.81*
		7/2	*449 422.47*
$3p^6(^1S)7p$	$^2P^\circ$	1/2	*449 586.71*
		3/2	*449 772.79*
$3p^6(^1S)6g$	^2G	7/2	450 024.54
		9/2	450 025.20
$3p^6(^1S)6h$	$^2H^\circ$	9/2,11/2	*450 247.99*
$3p^6(^1S)7d$	^2D	5/2	460 719.7
$3p^6(^1S)8s$	^2S	1/2	466 065.79
$3p^6(^1S)7f$	$^2F^\circ$	5/2	*469 706.4*
		7/2	*469 721*
$3p^6(^1S)7g$	^2G	7/2	470 333.35
		9/2	470 333.75
$3p^6(^1S)7h$	$^2H^\circ$	9/2,11/2	*470 488.77*
$3p^6(^1S)7i$	^2I	11/2,13/2	470 524.11
$3p^53d(^3F^\circ)4s$	$^2F^\circ$	7/2	*475 531*
		5/2	*478 566*
$3p^6(^1S)8f$	$^2F^\circ$	5/2	*483 019*
		7/2	*483 039*
$3p^6(^1S)8i$	^2I	11/2,13/2	483 650.82

V v—Continued

Configuration	Term	J	Level (cm^{-})
$3p^6(^1S)9f$	$^2F°$	5/2	*492 144.3*
		7/2	*492 201.8*
$3p^53d(^1F°)4s$	$^2F°$	5/2	*496 296*
		7/2	*497 556*
$3p^53d(^3D°)4s$	$^2D°$	5/2	*500 117*
		3/2	*500 502*
V VI ($^1S_0$)	*Limit*	....	**526 532**

V VI

Ar I isoelectronic sequence $Z = 23$

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

Ionization energy = 1 033 400 cm^{-1} (128.13 eV)

Most of the analysis given here has been done by Ekberg (1976), based on measurements of the spectrum from 100 to 2500 Å. The earlier papers, which are concerned mainly with resonance lines, are referred to in his work. An uncertainty of ± 2.5 cm^{-1} is assigned to the level values. He has calculated the percentage compositions for the levels and designated those of the $3p^53d$, $4p$ and $3s3p^63d$ configurations in *LS* coupling. The *jl* scheme is used for $3p^54s$, $5s$, $4d$, and $4f$. His two $3p^55d$ levels have been redesignated as $3s3p^64p$ levels by Kastner, Crooker, Behring, and Cohen (1977). They have classified seven resonance lines observed in absorption near 100 Å as transitions to the $3s3p^64p$ to $8p$ series and determined the ionization energy.

References

Ekberg, J. O. (1976), Physica Scripta **13**, 111.

Kastner, S. O., Crooker, A.M., Behring, W. E., and Cohen, L. (1977), Phys. Rev. **A16**, 577.

V VI

Configuration	Term	J	Level (cm^{-1})	Leading components (%) First	Second
$3s^23p^6$	^1S	0	0.0		
$3s^23p^53d$	$^3P°$	0	*308 149.8*	100	
		1	*309 394.8*	100	
		2	*311 977.9*	99	
$3s^23p^53d$	$^3F°$	4	*322 773.6*	100	
		3	*324 958.0*	98	
		2	*327 214.9*	97	
$3s^23p^53d$	$^1D°$	2	*345 139.4*	81	17 $^3D°$
$3s^23p^53d$	$^3D°$	3	*345 516.5*	77	23 $^1F°$
		1	*347 899.9*	100	
		2	*348 325.3*	81	17 $^1D°$
$3s^23p^53d$	$^1F°$	3	*350 644.5*	76	22 $^3D°$
$3s^23p^53d$	$^1P°$	1	*445 435.6*	100	
$3s3p^63d$	^3D	1	549 538.0	100	
		2	549 863.6	100	
		3	550 384.6	100	
$3s3p^63d$	^1D	2	566 433.0	100	
$3s^23p^5(^2P°_{3/2})4s$	$^2[3/2]°$	2	*546 284.0*	100	
		1	*549 298.8*	82	18 $(^2P°_{1/2})\ ^2[1/2]°$
$3s^23p^5(^2P°_{1/2})4s$	$^2[1/2]°$	0	*553 820.1*	100	
		1	*557 636.1*	82	18 $(^2P°_{3/2})\ ^2[3/2]°$
$3s^23p^54p$	^3S	1	602 974.3	96	
$3s^23p^54p$	^3D	3	612 289.7	100	
		2	612 392.8	71	24 ^1D
		1	615 177.8	63	22 ^1P

V VI—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3s^23p^54p$	^3P	2	617 490.0	57	40 ^1D
		0	621 757.1	98	
		1	623 594.5	66	30 ^1P
$3s^23p^54p$	^1P	1	620 509.2	48	36 ^3D
$3s^23p^54p$	^1D	2	622 724.5	38	36 ^1D
$3s^23p^54p$	^1S	0	641 800.3	98	
$3s^23p^5(^2P^\circ_{3/2})4d$	$^2[1/2]^\circ$	0	*707 280.3*	100	
		1	*708 044.6*	73	21 $(^2P^\circ_{3/2})\ ^2[3/2]^\circ$
$3s^23p^5(^2P^\circ_{3/2})4d$	$^2[3/2]^\circ$	2	*709 747.4*	83	16 $(^2P^\circ_{1/2})\ ^2[3/2]^\circ$
		1	*716 760.4*	78	20 $(^2P^\circ_{3/2})\ ^2[1/2]^\circ$
$3s^23p^5(^2P^\circ_{3/2})4d$	$^2[7/2]^\circ$	4	*710 695.2*	100	
		3	*711 426.2*	92	6 $(^2P^\circ_{3/2})\ ^2[5/2]^\circ$
$3s^23p^5(^2P^\circ_{3/2})4d$	$^2[5/2]^\circ$	2	*713 742.3*	86	13 $(^2P^\circ_{1/2})\ ^2[5/2]^\circ$
		3	*714 667.9*	86	8 $(^2P^\circ_{3/2})\ ^2[7/2]^\circ$
$3s^23p^5(^2P^\circ_{1/2})4d$	$^2[5/2]^\circ$	2	*720 074.9*	86	13 $(^2P^\circ_{3/2})\ ^2[5/2]^\circ$
		3	*720 836.0*	91	8 $(^2P^\circ_{3/2})\ ^2[7/2]^\circ$
$3s^23p^5(^2P^\circ_{1/2})4d$	$^2[3/2]^\circ$	2	*721 187.6*	83	16 $(^2P^\circ_{3/2})\ ^2[3/2]^\circ$
		1	*723 421.6*	93	7 $(^2P^\circ_{3/2})\ ^2[1/2]^\circ$
$3s^23p^5(^2P^\circ_{3/2})5s$	$^2[3/2]^\circ$	2	*770 494.5*	100	
		1	*771 723.1*	98	
$3s^23p^5(^2P^\circ_{3/2})4f$	$^2[3/2]$	1	777 549.4		
		2	778 194.1		
$3s^23p^5(^2P^\circ_{1/2})5s$	$^2[1/2]^\circ$	1	*778 944.0*	98	
$3s^23p^5(^2P^\circ_{3/2})4f$	$^2[5/2]$	3	779 550.9		
$3s^23p^5(^2P^\circ_{3/2})4f$	$^2[9/2]$	5	781 295.9		
		4	782 345.4		
$3s^23p^5(^2P^\circ_{3/2})4f$	$^2[7/2]$	3	783 852.1		
		4	785 705.4		
$3s^23p^5(^2P^\circ_{1/2})4f$	$^2[7/2]$	4	791 839.6		
$3s3p^64p$	$^3P^\circ$	1	*841 980*		
$3s3p^64p$	$^1P^\circ$	1	*849 170*		
$3s3p^65p$	$^3P^\circ$	1	*1 017 100*		

V VI—Continued

Configuration	Term	J	Level (cm^{-1})	Leading components (%)	
				First	Second
$3s3p^65p$	$^1P°$	1	*1 021 120*		
V VII ($^2P°_{3/2}$)	*Limit*	....	**1 033 400**		
$3s3p^66p$	$^1P°$	1	*1 102 540*		
$3s3p^67p$	$^1P°$	1	*1 148 030*		
$3s3p^68p$	$^1P°$	1	*1 175 490*		

V VII

Cl I isoelectronic sequence $Z = 23$

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^5\ ^2P^\circ_{3/2}$

Ionization energy = 1 215 000 cm^{-1} (150.6 eV)

All the known levels are derived from transitions to the $3s^2 3p^5\ ^2P^\circ$ ground term. Edlén (1937) identified lines originating from all levels of the $3s^2 3p^4 4s$ configuration. Earlier, Weissberg and Kruger (1936) had reported lines from the ^2P term of this configuration as well as from the ^2S term of $3s3p^6$. The transitions from $3s^2 3p^4 3d$ were identified by Gabriel, Fawcett, and Jordan (1966) and by Fawcett and Gabriel (1966). Those from $3s^2 3p^4 4d$ were given by Fawcett, Peacock, and Cowan (1968) and by Fawcett, Cowan, and Hayes (1972). Line identifications in the $3p^4 4d$–$3p^4 4f$ transition array were also given in the latter paper but cannot be used to derive energy levels because they do not embrace levels known with respect to the ground term.

The recent measurements of the $3p^5$–$3s3p^6$ doublet by Smitt, Svensson, and Outred (1976) were used to determine the ground term interval, with an uncertainty of ± 1.4 cm^{-1}.

The ionization energy is an extrapolated value by Lotz (1967).

References

Edlen, B. (1937), Z. Phys. **104**, 407.
Fawcett, B. C., and Gabriel, A. H. (1966), Proc. Phys. Soc. **88**, 262.
Fawcett, B. C., Peacock, N. J., and Cown, R. D. (1968), J. Phys. **B1**, 295.
Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5**, 2143.
Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1965), Nature **206**, 390.
Lotz, W. J. (1967), J. Opt. Soc. Am. **57**, 873.
Smitt, R., Svensson, L. A., and Outred, M. (1976), Physica Scripta **13**, 293.
Weissberg, S. G., and Kruger, P. G. (1936), Phys. Rev. **49**, 872.

V VII

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p^5$	$^2P^\circ$	3/2	*0*
		1/2	*7668*
$3s3p^6$	^2S	1/2	219 162
$3s^2 3p^4(^1D)3d$	^2S	1/2	421 050
$3s^2 3p^4(^1D)3d$	^2P	3/2	435 970
		1/2	438 770
$3s^2 3p^4(^1D)3d$	^2D	5/2	444 130
		3/2	450 550
$3s^2 3p^4(^3P)4s$	^4P	5/2	608 640
		3/2	612 810
		1/2	615 490
$3s^2 3p^4(^3P)4s$	^2P	3/2	620 650
		1/2	625 570
$3s^2 3p^4(^1D)4s$	^2D	5/2	638 540
		3/2	638 710
$3s^2 3p^4(^1S)4s$	^2S	1/2	671 570
$3s^2 3p^4(^3P)4d$	^2D	5/2	793 650
		3/2	794 570
$3s^2 3p^4(^1P)4d$	^2S	1/2	812 550
$3s^2 3p^4(^1D)4d$	^2P	3/2	815 660

V VII—Continued

Configuration	Term	J	Level (cm^{-1})
$3s^23p^4(^1D)4d$	^2D	5/2	820 010
		3/2	820 440
$3s^23p^4(^1S)4d$	^2D	5/2	853 200
V VIII ($^3P_2$)	*Limit*	....	**1 215 000**

V VIII

S I isoelectronic sequence $Z = 23$

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

Ionization energy = 1 399 000 cm^{-1} (173.4 eV)

Edlén (1937) observed and identified the $3p^4$–$3p^3s$ array which occurs between 135 and 148 Å. He identified singlets and triplets and two intercombinations. The present values for the levels of the ground configuration and $3s3p^5$ were measured by Smitt, Svensson, and Outred (1976).

The $3p^3 3d$ configuration was reported by Gabriel, Fawcett, and Jordan (1966) and by Fawcett and Gabriel (1966).

The $3p^3 4d$ terms were identified by Fawcett, Cowan, and Hayes (1972). They also observed nine transitions in the $3d$–$4f$ array that are not connected with the present system of levels.

The ionization energy is an extrapolated value by Lotz (1967).

References

Edlen, B. (1937), Z. Phys. **104**, 188.

Fawcett, B. C., and Gabriel, A. H. (1966), Proc. Phys. Soc. (London) **88**, 262.

Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5**, 2143.

Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1966), Proc. Phys. Soc. **87**, 825.

Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.

Smitt, R., Svensson, L. A., and Outred, M. (1976), Physica Scripta **13**, 293.

V VIII

Configuration	Term	J	Level (cm^{-1})
$3s^23p^4$	^3P	2	0.0
		1	6007.8
		0	7579.6
$3s^23p^4$	^1D	2	27 072
$3s^23p^4$	^1S	0	60 641
$3s3p^5$	$^3P^\circ$	2	*217 486.3*
		1	*222 405.6*
		0	*225 241.6*
$3s3p^5$	$^1P^\circ$	1	*278 200*
$3s^2 3p^3(^2D^\circ)3d$	$^3P^\circ$	2	*416 330*
$3s^23p^3(^4S^\circ)3d$	$^3D^\circ$	3	*434 560*
		2	*438 300*
		1	*440 800*
$3s^23p^3(^2D^\circ)3d$	$^1D^\circ$	2	*450 780*
$3s^23p^3(^2D^\circ)3d$	$^1F^\circ$	3	*464 380*
$3s^23p^3(^4S^\circ)4s$	$^3S^\circ$	1	*687 260*
$3s^23p^3(^2D^\circ)4s$	$^3D^\circ$	1	*710 600*
		2	*710 910*
		3	*711 990*
$3s^23p^3(^2D^\circ)4s$	$^1D^\circ$	2	*718 430*
$3s^23p^3(^2P^\circ)4s$	$^3P^\circ$	0	*734 250*
		1	*734 890*
		2	*736 640*

V VIII—Continued

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p^3(^2P°)4s$	$^1P°$	1	*742 720*
$3s^2 3p^3(^4S°)4d$	$^3D°$	2	*872 410*
		3	*872 680*
		1	*872 780*
$3s^2 3p^3(^2D°)4d$	$^3P°$	2	*903 350*
$3s^2 3p^3(^2D°)4d$	$^3D°$	3	*904 570*
		2	*905 990*
$3s^2 3p^3(^2D°)4d$	$^1D°$	2	*907 350*
$3s^2 3p^3(^2D°)4d$	$^1F°$	3	*909 920*
$3s^2 3p^3(^4S°)4d$	$^1P°$	1	*938 450*
V IX ($^4S°_{3/2}$)	*Limit*	....	**1 398 600**

V IX

P I isoelectronic sequence $Z = 23$

Ground state: $1s^22s^22p^63s^23p^3\ ^4S^\circ_{3/2}$

Ionization energy = 1 660 000 cm^{-1} (205.8 eV)

The levels of the $3s^23p^3$–$3s3p^4$ array are from Smitt, Svensson, and Outred (1976) who improved the measurements and extended the classifications of the earlier work of Fawcett and Peacock (1967) and Fawcett (1970, 1971). No intersystem transitions have been observed and the quartet-doublet separation is based on calculations by Smitt et al. The absolute value of x is probably only a few cm^{-1}.

The $3p^23d$ configuration is from Fawcett (1971), who greatly extended the earlier identifications of Gabriel, Fawcett, and Jordan (1966) and Fawcett, Gabriel, and Saunders (1967).

The $3p^24s$ configuration is from the paper by Fawcett, Cowan, and Hayes (1972), who also identified two unconnected multiplets in the $3d$–$4f$ array, and from the early work of Kruger and Pattin (1937).

The ionization energy is from Lotz (1967).

References

Fawcett, B. C. and Peacock, N. J. (1967), Proc. Phys. Soc. **91,** 973.

Fawcett, B. C., Gabriel, A. H., and Saunders, P. A. H. (1967), Proc. Phys. Soc. **90,** 863.

Fawcett, B. C. (1970), J. Phys. **B3,** 1732.

Fawcett, B. C. (1971), J. Phys. **B4,** 1577.

Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5,** 2143.

Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1965), Nature **206,** 390.

Kruger, P. G., and Pattin, H. S. (1937), Phys. Rev. **52,** 621.

Lotz, W. (1967), J. Opt. Soc. Am. **57,** 873.

Smitt, R., Svensson, L. A., and Outred, M. (1976), Physica Scripta **13,** 293.

V IX

Configuration	Term	J	Level (cm^{-1})
$3s^23p^3$	$^4S^\circ$	3/2	*0*
$3s^23p^3$	$^2D^\circ$	3/2	*34 708*+x
		5/2	*36 319*+x
$3s^23p^3$	$^2P^\circ$	1/2	*59 028*+x
		3/2	*61 224*+x
$3s3p^4$	^4P	5/2	214 067
		3/2	218 814
		1/2	221 174
$3s3p^4$	^2D	3/2	265 160+x
		5/2	265 835+x
$3s3p^4$	^2P	3/2	305 664+x
		1/2	309 210+x
$3s3p^4$	^2S	1/2	319 184+x
$3s^23p^2(^3P)3d$	^2P	3/2	398 530+x
		1/2	404 560+x
$3s^23p^2(^3P)3d$	^4P	5/2	408 350
		3/2	409 060
		1/2	410 540
$3s^23p^2(^1D)3d$	^2D	5/2	438 070+x
		3/2	438 420+x
$3s^23p^2(^1D)3d$	^2P	1/2	452 470+x
		3/2	456 150+x

V IX—Continued

Configuration	Term	J	Level (cm^{-1})
$3s^23p^2(^3P)3d$	^2F	7/2	460 550+x
$3s^23p^2(^3P)3d$	^2D	5/2	477 370+x
$3s^23p^2(^3P)4s$	^4P	1/2	789 070
		3/2	792 690
		5/2	797 320
$3s^23p^2(^3P)4s$	^2P	1/2	802 220+x
		3/2	807 570+x
$3s^23p^2(^1D)4s$	^2D	5/2	823 290+x
		3/2	823 570+x
V X ($^3P_0$)	*Limit*	....	**1 660 000**

V X

Si I isoelectronic sequence $Z = 23$

Ground state: $1s^2 2s^2 2p^6 3s^2 3p^2\ ^3P_0$

Ionization energy = 1 859 000 cm^{-1} (230.5 eV)

The levels of the $3s^23p^2$–$3s3p^3$ array are from Smitt, Svensson, and Outred (1976), who improved the measurements and extended the classifications of Fawcett and Peacock (1967) and Fawcett (1970, 1971). The connection between the singlet and triplet systems was observed in their work.

The levels of $3s^23p3d$ are from Fawcett, Gabriel, and Saunders (1967) and Fawcett (1971). Those of $3s^23p4s$ and $3s^23p4d$ are due to Fawcett, Cowan, and Hayes (1972).

The ionization energy was obtained by extrapolation by Lotz (1967).

References

Fawcett, B. C., and Peacock, N. J. (1967), Proc. Phys. Soc. **91**, 973.
Fawcett, B. C., Gabriel, A. H., and Saunders, P. A. H. (1967), Proc. Phys. Soc. **90**, 863.
Fawcett, B. C. (1970), J. Phys. **B3**, 1732.
Fawcett, B. C. (1971), J. Phys. **B4**, 1577.
Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5**, 2143.
Lotz, W. J. (1967), J. Opt. Soc. Am. **57**, 873.
Smitt, R., Svensson, L. A., and Outred, M. (1976), Physica Scripta **13**, 293.

V X

Configuration	Term	J	Level (cm^{-1})
$3s^23p^2$	^{3}P	0	0
		1	4180
		2	9421
$3s^23p^2$	^{1}D	2	32 509
$3s^23p^2$	^{1}S	0	67 751
$3s3p^3$	^{3}D°	1	*220 984*
		2	*221 072*
		3	*222 104*
$3s3p^3$	^{3}P°	0	*253 936*
		1	*254 147*
		2	*254 337*
$3s3p^3$	^{1}D°	2	*279 969*
$3s3p^3$	^{3}S°	1	*327 902*
$3s3p^3$	^{1}P°	1	*341 335*
$3s^23p3d$	^{3}P°	2	*385 790*
		1	*391 340*
$3s^23p3d$	^{3}D°	1	*399 130*
		2	*400 740*
		3	*401 210*
$3s^23p3d$	^{1}F°	3	*440 090*
$3s^23p4s$	^{3}P°	1	*865 200*
		2	*873 100*
$3s^23p4s$	^{1}P°	1	*878 700*

V x—Continued

Configuration	Term	J	Level (cm^{-1})
$3s^23p4d$	$^3D^\circ$	3	*1 070 600*
$3s^23p4d$	$^1F^\circ$	3	*1 085 600*
V XI ($^2P^\circ_{1/2}$)	*Limit*	....	**1 859 000**

V XI

Al I isoelectronic sequence $Z = 23$

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

Ionization energy = 2 062 000 cm^{-1} (255.7 eV)

The $3p$–$4d$ transitions were identified by Edlen (1936). Thirty years later new observations of this spectrum by Gabriel, Fawcett, and Jordan (1966) resulted in the discovery of the $3p$–$3d$ lines.

The doublet terms of $3s3p^2$ were first observed by Fawcett and Peacock (1967) in a laser-produced plasma. They were remeasured by Fawcett (1970), who also observed the ^4P–$^4S^\circ$ multiplet of the $3s3p^2$–$3p^3$ array. The present values of the ground term and the doublet terms of $3s3p^2$ are from Smitt, Svensson, and Outred (1976).

Calculated spectra enabled Fawcett, Cowan, Kononov, and Hayes (1972) to identify the $3d$–$4f$ and $3p$–$4s$ lines from a theta-pinch spectrum. They also identified the $3s3p^2\ ^4P$–$3s3p4s\ ^4P^\circ$ and $3s3p3d\ ^4F^\circ$–$3s3p4f\ ^4G$ multiplets, the second of which has not been connected to the present system of levels.

Since no intersystem transitions have been observed, we have based the quartet system on the $3s3p^2\ ^4P_{5/2}$ level, the position of which is estimated from our extrapolation beyond the sequence Al I–P III. The uncertainty in our extrapolation is about ± 2000 cm^{-1}.

The value for the ionization energy was obtained by extrapolation by Lotz (1967).

References

Edlén, B. (1936), Z. Phys. **103,** 536.
Fawcett, B. C., and Peacock, N. J. (1967), Proc. Phys. Soc. **91,** 973.
Fawcett, B. C. (1970), J. Phys. **B3,** 1732.
Fawcett, B. C., Cowan, R. D., Kononov, E. Y., and Hayes, R. W. (1972), J. Phys. **B5,** 1255.
Gabriel, A. H., Fawcett, B. C., and Jordan, C. (1966), Proc. Phys. Soc. **87,** 825.
Lotz, W. (1967), J. Opt. Soc. Am. **57,** 873.
Smitt, R., Svenson, L. A., and Outred, M. (1976), Physica Scripta **13,** 293.

V XI

Configuration	Term	J	Level (cm^{-1})
$3s^2 3p$	$^2P^\circ$	1/2	*0*
		3/2	*9696*
$3s3p^2$	^4P	1/2	166 300+x
		3/2	169 600+x
		5/2	175 000+x
$3s3p^2$	^2D	3/2	232 973
		5/2	233 778
$3s3p^2$	^2S	1/2	288 914
$3s3p^2$	^2P	1/2	306 801
		3/2	311 890
$3s^2 3d$	^2D	3/2	376 920
		5/2	377 680
$3p^3$	$^4S^\circ$	3/2	*453 640*+x
$3s^2 4s$	^2S	1/2	939 500
$3s3p4s$	$^4P^\circ$	3/2	*1 118 400*+x
		5/2	*1 124 300*+x
$3s^2 4d$	^2D	3/2	1 147 240
		5/2	1 147 770
$3s^2 4f$	$^2F^\circ$	5/2	*1 215 300*
		7/2	*1 215 500*
V XII ($^1S_0$)	*Limit*	....	**2 062 000**

V XII

Mg I isoelectronic sequence $Z = 23$

Ground state: $1s^22s^22p^63s^2$ $^1S_0$

Ionization energy = 2 485 000 cm^{-1} (308.1 eV)

Edlén (1936) reported three unconnected systems of levels for this ion: the resonance line $3s^2\,{}^1S_0$–$3s4p\,{}^1P^\circ_1$; the triplet system of $3s3p$–$3s4s$, $3s4d$, $3s5d$ and the triplets of $3s3d$–$3s4f$, $3s5f$. The triplets were unified by the work of Fawcett (1970), and Fawcett, Cowan, and Hayes (1972) who identified the $3s3p\,{}^3P^\circ$–$3s3d\,{}^3D$ multiplet. Fawcett and Peacock (1967) reported the $3s^2\,{}^1S_0$–$3s3p\,{}^1P^\circ_1$ line. The triplet system remains unconnected to the ground state but its position is estimated by an interpolated value for $3s3p\,{}^3P^\circ_1$ by Ekberg (1971) which is used here.

The $3p^2\,{}^3P$ and $3s3p\,{}^1P^\circ$ terms were reported by Fawcett and Peacock (1967). Fawcett (1970) provided the ^1S and ^1D of $3p^2$ and the known terms of $3p3d$.

Fawcett, Cowan, and Hayes (1972) found the singlets of $3s3d$, $3s4d$, and $3s4f$. Their publication was accompanied by a supplementary report which provides extensions of the analysis. Here they identified the $3p4s\,{}^3P^\circ$, the $3p4f$ and $3p4d$ configurations, the $3s5s$ to $3s7s\,{}^3S$ series, the $3s5p$ to $3s10p\,{}^1P^\circ$ series, the $3s6d$ to $3s8d\,{}^3D_3$ series, and the $3s6f$ to $3s8f\,{}^3F^\circ_4$ series.

The terms of $3p4f$ given here are from Fawcett, Cowan, Kononov, and Hayes (1972).

We determined the quoted ionization energy from the $3s\,nf$ series, with an uncertainty of ± 3000 cm^{-1}.

References

Edlén, B. (1936), Z. Phys. **103**, 536.
Ekberg, J. O. (1971), Physica Scripta, **4**, 101.
Fawcett, B. C., and Peacock, N. J. (1967), Proc. Phys. Soc. **91**, 973.
Fawcett, B. C. (1970), J. Phys. **B3**, 1732.
Fawcett, B. C., Cowan, R. D., Kononov, E. Y., and Hayes, R. W. (1972), J. Phys. **B5**, 1255.
Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5**, 2143 and Supplementary Publication No. SUP70005 (National Lending Library, Boston Spa, Yorkshire, LS237BQ, G.B.)

V XII

Configuration	Term	J	Level (cm^{-1})
$3s^2$	^1S	0	0
$3s3p$	$^3P^\circ$	0	*186 460*+x
		1	*189 550*+x
		2	*196 710*+x
$3s3p$	$^1P^\circ$	1	*281 600*
$3p^2$	^3P	0	444 300+x
		1	448 900+x
		2	457 400+x
$3p^2$	^1D	2	445 740
$3p^2$	^1S	0	524 840
$3s3d$	^3D	1	542 190+x
		2	542 520+x
		3	543 130+x
$3s3d$	^1D	2	613 280
$3p3d$	$^3F^\circ$	2	*742 400*+x
		3	*747 200*+x
		4	*752 800*+x
$3p3d$	$^3D^\circ$	3	*793 200*+x

V XII—Continued

Configuration	Term	J	Level (cm^{-1})
$3p3d$	$^1P°$	1	*816 300*
$3s4s$	^3S	1	1 210 600+x
$3s4s$	^1S	0	1 227 300
$3s4p$	$^1P°$	1	*1 310 500*
$3s4d$	^3D	1	1 422 630+x
		2	1 422 950+x
		3	1 423 510+x
$3s4d$	^1D	2	1 426 200
$3p4s$	$^3P°$	0	*1 445 200*+x
		2	*1 456 100*+x
$3s4f$	$^3F°$	3	*1 478 670*+x
		2	*1 478 690*+x
		4	*1 478 720*+x
$3s4f$	$^1F°$	3	*1 492 100*
$3p4p$	^3D	3	1 542 200+x
$3p4p$	^3P	1	1 543 400+x
		2	1 548 600+x
$3p4p$	^3S	1	1 550 600+x
$3p4d$	$^1F°$	3	*1 640 800*
$3p4d$	$^3D°$	2	*1 656 000*+x
		1	*1 656 200*+x
		3	*1 660 300*+x
$3p4d$	$^3F°$	3	*1 660 100*
$3p4d$	$^3P°$	2	*1 676 600*+x
$3p4f$	^3G	3	1 698 600+x
		4	1 702 700+x
		5	1 710 200+x
$3p4f$	^3F	4	1 711 200+x
$3s5s$	^3S	1	1 714 900+x
$3p4f$	^3D	3	1 720 600+x
$3s5p$	$^1P°$	1	*1 765 100*

V XII—Continued

Configuration	Term	J	Level (cm^{-1})
$3s5d$	^3D	1	1 816 400+x
		2	1 816 760+x
		3	1 817 010+x
$3s5d$	^1D	2	1 822 000
$3s5f$	$^3F°$	4	*1 842 510*+x
$3s6s$	^3S	1	1 956 700+x
$3s6p$	$^1P°$	1	*1 997 800*
$3s6d$	^3D	2	2 024 600+x
		3	2 024 800+x
$3s6f$	$^3F°$	4	*2 040 000*+x
$3s7s$	^3S	1	2 108 200+x
$3s7p$	$^1P°$	1	*2 131 600*
$3s7d$	^3D	3	2 149 500+x
$3s7f$	$^3F°$	4	*2 158 100*+x
$3s8p$	$^1P°$	1	*2 218 700*
$3s8d$	^3D	3	2 228 200+x
$3s8f$	$^3F°$	4	*2 235 400*+x
$3s9p$	$^1P°$	1	*2 271 000*
$3s10p$	$^1P°$	1	*2 306 400*
V XIII ($^2S_{1/2}$)	*Limit*	....	**2 485 000**

V XIII

Na I isoelectronic sequence $Z = 23$

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

Ionization energy = 2 712 300 cm^{-1} (336.28 eV)

The $3p$ and $3d$ levels are determined from the observations of Fawcett, Cowan, and Hayes (1972) at 320 and 430 Å. The $4s$, $4p$, $4d$, $4f$, $5p$, $5d$, and $5f$ levels are from the observations of Edlen (1936) between 50 and 100 Å. The levels of $6s$ to $11s$, $10d$, $10f$, and $11f$ are from Fawcett, Cowan, and Hayes. The $2p^5 3s^2\ ^2P°$ was observed by Feldman and Cohen (1967) at 24 Å. The remaining levels are from the measurements and assignments of Cohen and Behring (1976) from 39 to 62 Å.

The ionization energy is determined from the nd and nf series by Cohen and Behring.

References

Cohen, L., and Behring, W. E. (1976), J. Opt. Soc. Am. **66,** 899.
Edlén, B. (1936), Z. Phys. **100,** 621.
Fawcett, B. C., Cowan, R. D., and Hayes, R. W. (1972), J. Phys. **B5,** 2143.
Feldman, U., and Cohen, L. (1967), J. Opt. Soc. Am **57,** 1128.

V XIII

Configuration	Term	J	Level (cm^{-1})
$2p^6(^1S)3s$	^2S	1/2	0
$2p^6(^1S)3p$	$^2P°$	1/2	*225 530*
		3/2	*236 570*
$2p^6(^1S)3d$	^2D	3/2	544 640
		5/2	545 980
$2p^6(^1S)4s$	^2S	1/2	1 300 490
$2p^6(^1S)4p$	$^2P°$	1/2	*1 388 410*
		3/2	*1 392 780*
$2p^6(^1S)4d$	^2D	3/2	1 505 900
		5/2	1 506 480
$2p^6(^1S)4f$	$^2F°$	5/2	*1 549 430*
		7/2	*1 549 740*
$2p^6(^1S)5s$	^2S	1/2	1 846 100
$2p^6(^1S)5p$	$^2P°$	1/2	*1 889 360*
		3/2	*1 891 430*
$2p^6(^1S)5d$	^2D	3/2	1 946 230
		5/2	1 946 500
$2p^6(^1S)5f$	$^2F°$	5/2	*1 967 880*
		7/2	*1 967 990*
$2p^6(^1S)6s$	^2S	1/2	2 127 000
$2p^6(^1S)6p$	$^2P°$	1/2	*2 151 400*
		3/2	*2 152 400*
$2p^6(^1S)6d$	^2D	3/2	2 182 800
		5/2	2 183 000

V XIII—Continued

Configuration	Term	J	Level (cm^{-1})
$2p^6(^1S)6f$	$^2F°$	5/2	*2 194 900*
		7/2	*2 195 100*
$2p^6(^1S)7s$	^2S	1/2	2 290 400
$2p^6(^1S)7p$	$^2P°$	1/2,3/2	*2 305 700*
$2p^6(^1S)7d$	^2D	3/2	2 324 700
		5/2	2 325 000
$2p^6(^1S)7f$	$^2F°$	5/2	*2 332 500*
		7/2	*2 332 800*
$2p^6(^1S)8s$	^2S	1/2	2 393 000
$2p^6(^1S)8p$	$^2P°$	1/2,3/2	*2 404 100*
$2p^6(^1S)8d$	^2D	3/2	2 416 300
		5/2	2 416 500
$2p^6(^1S)8f$	$^2F°$	5/2,7/2	*2 421 500*
$2p^6(^1S)9s$	^2S	1/2	2 462 800
$2p^6(^1S)9p$	$^2P°$	1/2,3/2	*2 470 500*
$2p^6(^1S)9d$	^2D	3/2,5/2	2 479 000
$2p^6(^1S)9f$	$^2F°$	7/2	*2 483 200*
$2p^6(^1S)10s$	^2S	1/2	2 508 600
$2p^6(^1S)10p$	$^2P°$	1/2,3/2	*2 517 600*
$2p^6(^1S)10d$	^2D	5/2	2 522 800
$2p^6(^1S)10f$	$^2F°$	7/2	*2 526 400*
$2p^6(^1S)11s$	^2S	1/2	2 547 800
$2p^6(^1S)11p$	$^2P°$	1/2,3/2	*2 552 300*
$2p^6(^1S)11d$	^2D	3/2	2 556 000
		5/2	2 556 600
$2p^6(^1S)11f$	$^2F°$	7/2	*2 560 400*
V XIV ($^1S_0$)	*Limit*	....	**2 712 300**
$2p^53s^2$	$^2P°$	3/2	*4 079 000*
		1/2	*4 132 000*

V XIV

Ne I isoelectronic sequence $Z = 23$

Ground state: $1s^22s^22p^6\ ^1S_0$

Ionization energy = 7 227 000 cm^{-1} (896.0 eV)

Only resonance between 15 and 24 Å are classified by this system of energy levels. Edlen and Tyren (1936) identified transitions from $2p^53s$ and $3d$ and extrapolated an ionization potential which agrees well with the present value. Fawcett (1965) observed five more transitions from $2p^53d$ and $4d$ and from $2s2p^63p\ ^1P^\circ_1$. Feldman and Cohen (1967) observed nine transitions, including four of those observed by Fawcett. We have adopted their more accurate values in preference to those of Fawcett.

We have preferred the use of *jj*-coupling designations for the $2p^5ns$ levels and *jl*-coupling designations for the $2p^5nd$ levels.

Kastner, Behring, and Cohen (1975) identified transitions between $2p^53p$ and $2p^54d$, but there is no connection with the levels given here.

We derived the ionization energy from the $2s^22p^5(^2P^\circ_{3/2})nd\ ^2[3/2]^\circ$ series for n = 3, 4, and 5.

References

Edlen, B., and Tyrén, F. (1936), Z. Phys. **101**, 206.
Fawcett, B. C. (1965), Proc. Phys. Soc. **86**, 1087.
Feldman, U. and Cohen, L. (1967), Astrophys. J. **149**, 265.
Kastner, S. O., Behring, W. E., and Cohen, L. (1975), Astrophys. J. **199**, 777.

V XIV

Configuration	Term	J	Level (cm^{-1})
$2s^22p^6$	^1S	0	0
$2s^22p^5(^2P^\circ_{3/2})3s$	$(3/2,1/2)^\circ$	1	*4 202 700*
$2s^22p^5(^2P^\circ_{1/2})3s$	$(1/2,1/2)^\circ$	1	*4 257 100*
$2s^22p^5(^2P^\circ_{3/2})3d$	$^2[1/2]^\circ$	1	*4 696 000*
$2s^22p^5(^2P^\circ_{3/2})3d$	$^2[3/2]^\circ$	1	*4 757 800*
$2s^22p^5(^2P^\circ_{1/2})3d$	$^2[3/2]^\circ$	1	*4 827 200*
$2s2p^63p$	$^3P^\circ$	1	*5 299 000*
$2s2p^63p$	$^1P^\circ$	1	*5 324 000*
$2s^22p^5(^2P^\circ_{3/2})4s$	$(3/2,1/2)^\circ$	1	*5 632 000*
$2s^22p^5(^2P^\circ_{1/2})4s$	$(1/2,1/2)^\circ$	1	*5 690 000*
$2s^22p^5(^2P^\circ_{3/2})4d$	$^2[1/2]^\circ$	1	*5 794 000*
$2s^22p^5(^2P^\circ_{3/2})4d$	$^2[3/2]^\circ$	1	*5 850 000*
$2s^22p^5(^2P^\circ_{1/2})4d$	$^2[3/2]^\circ$	1	*5 904 000*
$2s^22p^5(^2P^\circ_{3/2})5d$	$^2[3/2]^\circ$	1	*6 350 000*
$2s^22p^5(^2P^\circ_{1/2})5d$	$^2[3/2]^\circ$	1	*6 407 000*
V XV ($^2P^\circ_{3/2}$)	*Limit*	....	**7 227 000**

V XV

F I isoelectronic sequence $Z = 23$

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

Ionization energy = 7 870 000 cm^{-1} (976 eV)

The first work on this spectrum, by Fawcett (1965), was continued by Cohen, Feldman, and Kastner (1968), who classified many lines of the $2s^2 2p^5$–$2s^2 2p^4\,3s$ and $3d$ transition arrays between 19 and 23 Å. This work was revised and extended by Feldman, Doschek, Cowan, and Cohen (1973), from whose wavelengths nearly all of the $3s$ and $3d$ levels are determined. The ground term $2s^2 2p^5\ ^2P^\circ$ interval obtained by Fawcett (1971) from his identification of the $2s^2 2p^5$–$2s 2p^6$ doublet at ~120 Å is in agreement with the value provided by Feldman et al. (1973) from much shorter wavelength data. We used the new measurements of this doublet by Doschek, Feldman, Cowan, and Cohen (1974) to derive the levels.

The $2s2p^5 3s\ ^2P^\circ$ term is from Feldman et al. (1973).

The ionization energy was obtained by extrapolation by Lotz (1967).

References

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

Doschek, G. A., Feldman, U., Cowan, R. D., and Cohen, L. (1974), Ap. J. **188**, 417.

Fawcett, B. C. (1965), Proc. Phys. Soc. **86**, 1087.

Fawcett, B. C. (1971), J. Phys. **B4**, 981.

Feldman, U., Doschek, G. A., Cowan, R. D., and Cohen, L. (1973), J. Opt. Soc. Am. **63**, 1445.

Lotz, W. J. (1967), J. Opt. Soc. Am. **57**, 873.

V XV

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^5$	$^2P^\circ$	3/2	*0*
		1/2	*58 100*
$2s2p^6$	^2S	1/2	878 100
$2s^2 2p^4(^3P)3s$	^4P	5/2	4 506 000
		3/2	4 528 000
		1/2	4 556 000
$2s^2 2p^4(^3P)3s$	^2P	3/2	4 564 000
		1/2	4 587 000
$2s^2 2p^4(^1D)3s$	^2D	5/2	4 636 000
		3/2	4 638 000
$2s^2 2p^4(^1S)3s$	^2S	1/2	4 757 000
$2s^2 2p^4(^3P)3d$	^4D	3/2	5 023 000
$2s^2 2p^4(^3P)3d$	^4P	1/2	5 028 000
		3/2	5 039 000
		5/2	5 055 000
$2s^2 2p^4(^3P)3d$	^4F	5/2	5 039 000
$2s^2 2p^4(^3P)3d$	^2P	1/2	5 045 000
		3/2	5 082 000
$2s^2 2p^4(^3P)3d$	^2D	3/2	5 061 000
		5/2	5 090 000
$2s^2 2p^4(^3P)3d$	^2F	5/2	5 070 000
$2s^2 2p^4(^1D)3d$	^2P	1/2	5 141 000
		3/2	5 163 000

V XV—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^22p^4(^1D)3d$	^2S	1/2	5 143 000
$2s^22p^4(^1D)3d$	^2D	5/2	5 164 000
		3/2	5 182 000
$2s^22p^4(^1S)3d$	^2D	5/2	5 255 000
		3/2	5 266 000
$2s2p^5(^3P^\circ)3s$	$^2P^\circ$	3/2	*5 347 000*
		1/2	*5 380 000*
V XVI ($^3P_2$)	*Limit*	....	**7 870 000**

V XVI

O I isoelectronic sequence $Z = 23$

Ground state: $1s^2 2s^2 2p^4\ ^3P_2$

Ionization energy = 8 550 000 cm^{-1} (1060 eV)

The observed spectrum of V XVI consists of the strong transition array $2s^2 2p^4$–$2s2p^5$, which lies between 108 and 141 Å, and the arrays $2p^4$–$2p^3 3s$ at 20 Å and $2p^4$–$2p^3 3d$ at 18 Å. The $^1S_0$ due to $2p^6$ radiates to $2s2p^5\ ^1P^\circ_1$ at 138 Å. The arrays at 18 Å and 20 Å were first observed by Goldsmith, Feldman, and Cohen (1971). The $J = 0$ and 1 levels of the ground term could not be resolved at these wavelengths. Fawcett (1971) then observed the $2s^2 2p^4$–$2s2p^5$ array above 100 Å and resolved the ground term. Doschek, Feldman, Cowan, and Cohen (1974) reobserved this array with higher resolution. We have determined the levels of the $2s^2 2p^4$ and $2s2p^5$ configurations from their measurements.

The $2p^6\ ^1S_0$ level is from Fawcett, Galanti, and Peacock (1974b) and was confirmed by Doschek, Feldman, Davis, and Cowan (1975).

The $2p^3 3s$ levels are from Doschek, Feldman, and Cohen (1973) and Goldsmith, Feldman, and Cohen (1971).

The $2p^3 3d$ levels are from Goldsmith, Feldman, and Cohen (1971), from Fawcett, Galanti, and Peacock (1974a), and from Fawcett and Hayes (1975). The $^3D^\circ_2$ and $^3D^\circ_1$ levels of $2p^3(^2P^\circ)3d$ are not given because of conflicting assignments of lines.

Since no intersystem transitions have been observed, we based the singlet system on Edlén's (1972) extrapolated value for $2p^4\ ^1D$. Its uncertainty is probably ± 100 cm^{-1}.

The ionization energy is from Lotz's (1967) extrapolation.

References

Doschek, G. A., Feldman, U., and Cohen, L. (1973), J. Opt. Soc. Am. **63,** 1463.

Doschek, G. A., Feldman, U., Cowan, R. D., and Cohen, L. (1974), Astrophys. J. **188,** 417.

Doschek, G. A., Feldman, U., Davis, J., and Cowan, R. D. (1975), Phys. Rev. **A12,** 980.

Edlén, B. (1972), Sol. Phys. **24,** 356.

Fawcett, B. C. (1971), J. Phys. **B4,** 981.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974a), J. Phys. **B7,** L106.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974b), J. Phys. **B7,** 1149.

Fawcett, B. C., and Hayes, R. W. (1975), Mon. Not. R. Astr. Soc. **170,** 185.

Goldsmith, S., Feldman, U., and Cohen, L. (1971), J. Opt. Soc. Am. **61,** 615.

Lotz, W. J. (1967), J. Opt. Soc. Am. **57,** 873.

V XVI

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^4$	^3P	2	0
		1	48 990
		0	49 980
$2s^2 2p^4$	^1D	2	121 550+x
$2s^2 2p^4$	^1S	0	238 220+x
$2s2p^5$	$^3P^\circ$	2	*761 770*
		1	*798 930*
		0	*822 980*
$2s2p^5$	$^1P^\circ$	1	*1 046 100*+x
$2p^6$	^1S	0	1 769 800+x
$2s^2 2p^3(^4S^\circ)3s$	$^3S^\circ$	1	*4 891 000*
$2s^2 2p^3(^2D^\circ)3s$	$^3D^\circ$	2	*4 980 000*
		1	*4 981 000*
		3	*4 996 000*
$2s^2 2p^3(^2D^\circ)3s$	$^1D^\circ$	2	*5 013 000*+x
$2s^2 2p^3(^2P^\circ)3s$	$^3P^\circ$	2	*5 068 000*

V XVI—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^22p^3(^2P°)3s$	$^1P°$	1	*5 113 000+x*
$2s^22p^3(^4S°)3d$	$^3D°$	2	*5 343 000*
		3	*5 351 000*
$2s^22p^3(^2D°)3d$	$^3D°$	2	*5 457 000*
		3	*5 475 000*
$2s^22p^3(^2D°)3d$	$^1D°$	2	*5 489 000+x*
$2s^22p^3(^2D°)3d$	$^3P°$	2	*5 476 000*
$2s^22p^3(^2D°)3d$	$^1F°$	3	*5 520 000+x*
$2s^22p^3(^2P°)3d$	$^3P°$	2	*5 488 000*
$2s^22p^3(^2P°)3d$	$^3D°$	3	*5 553 000*
$2s^22p^3(^2P°)3d$	$^1F°$	3	*5 604 000+x*
$2s^22p^3(^2P°)3d$	$^1D°$	2	*5 640 000+x*
V XVII ($^4S°_{3/2}$)	*Limit*	....	**8 549 000**

V XVII

N I isoelectronic sequence $Z = 23$

Ground state: $1s^22s^22p^3\ {}^4S^\circ_{3/2}$

Ionization energy = 9 420 000 cm^{-1} (1168 eV)

The strong transition array $2s^22p^3$–$2s2p^4$ was identified by Fawcett (1971) and confirmed by Doschek, Feldman, Cowan, and Cohen (1974), by Fawcett, Galanti, and Peacock (1974b), and by Feldman, Doschek, Cowan, and Cohen (1975). The levels are derived from the data of Doschek et al. (1974) and Feldman et al. (1975). The position of the doublets relative to the ground state is based on the estimated position of $2s^22p^3\ {}^2D^\circ_{3/2}$ by Fawcett (1975).

The $2p^5\ {}^2P^\circ$ term was found by Fawcett, Galanti, and Peacock (1974b) and confirmed by Doschek, Feldman, Davis, and Cowan (1975), and by Fawcett and Hayes (1975).

The $2p^23d$ terms are from Fawcett, Galanti, and Peacock (1974a), and Fawcett and Hayes (1975).

The ionization energy is from Lotz's extrapolation.

References

Doschek, G. A., Feldman, U., Cowan, R. D., and Cohen, L. (1974), Astrophys. J. **188**, 417.

Doschek, G. A., Feldman, U., Davis, J., and Cowan, R. D. (1975), Phys. Rev. **A12**, 980.

Fawcett, B. C. (1971), J. Phys. **B4**, 981.

Fawcett, B. C. (1975), At. Data Nucl. Data Tables **16**, 135.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974a), J. Phys. **B7**, L106.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974b), J. Phys. **B7**, 1149.

Fawcett, B. C., and Hayes, R. W. (1975), Mon. Not. R. Astr. Soc. **170**, 185.

Feldman, U., Doschek, G. A. Cowan, R. D., and Cohen, L. (1975), Astrophys. J. **196**, 613.

Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.

V XVII

Configuration	Term	J	Level (cm^{-1})
$2s^22p^3$	$^4S^\circ$	3/2	*0*
$2s^22p^3$	$^2D^\circ$	3/2	*117 300*+x
		5/2	*136 680*+x
$2s^22p^3$	$^2P^\circ$	1/2	*207 830*+x
		3/2	*236 950*+x
$2s2p^4$	^4P	5/2	627 860
		3/2	666 270
		1/2	681 520
$2s2p^4$	^2D	3/2	863 310+x
		5/2	869 250+x
$2s2p^4$	^2S	1/2	996 280+x
$2s2p^4$	^2P	3/2	1 035 200+x
		1/2	1 089 710+x
$2p^5$	$^2P^\circ$	3/2	*1 632 900*+x
		1/2	*1 694 560*+x
$2s^22p^2(^3P)3d$	^4P	5/2	5 794 100
		3/2	5 828 200
$2s^22p^2(^3P)3d$	^2F	5/2	5 784 900+x
		7/2	5 839 200+x
$2s^22p^2(^3P)3d$	^2D	5/2	5 892 700+x

V XVII—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2(^1D)3d$	^2F	7/2	5 930 800+x
$2s^2 2p^2(^1D)3d$	^2D	5/2	5 954 500+x
V XVIII ($^3P_0$)	*Limit*	....	**9 420 000**

V XVIII

C I isoelectronic sequence $Z = 23$

Ground state: $1s^2 2s^2 2p^2\ ^3P_0$

Ionization energy = 10 160 000 cm^{-1} (1260 eV)

The levels of the $2s^2 2p^2$ and $2s2p^3$ configurations are determined from the line classifications of Fawcett, Galanti, and Peacock (1974), who observed the $2s^2 2p^2$–$2s2p^3$ transition array between 111 and 176 Å. The $^3D^\circ_1$ level of the upper configuration was subsequently revised by Fawcett (1975).

The $2p^4\ ^3P$ term is from Fawcett (1975). All levels of higher configurations are from the measurements of Goldsmith, Feldman, Crooker, and Cohen (1972).

No intersystem combinations have been observed. Goldsmith et al. extrapolated the position of $2p^2\ ^1D_2$ to 163 000 cm^{-1}. Fawcett (1975) obtained an extrapolated value of 161 000 cm^{-1}. We have used the mean of these values as the reference value for the singlet system. Goldsmith et al. identified two quintet transitions but they are not connected to the triplet system.

The ionization energy is Lotz's (1967) extrapolation.

References

Fawcett, B. C. (1975), Atomic Data and Nucl. Data Tables **16**, 135.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974), J. Phys. **B7**, 1149.

Goldsmith, S., Feldman, U., Crooker, A., and Cohen, L. (1972) J. Opt. Soc. Am. **62**, 260.

Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.

V XVIII

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2$	^3P	0	0
		1	37 890
		2	68 300
$2s^2 2p^2$	^1D	2	162 000+x
$2s^2 2p^2$	^1S	0	269 400+x
$2s2p^3$	$^3D^\circ$	2	*623 820*
		1	*625 940*
		3	*635 160*
$2s2p^3$	$^3P^\circ$	0	*733 110*
		1	*735 290*
		2	*743 470*
$2s2p^3$	$^3S^\circ$	1	*897 500*
$2s2p^3$	$^1D^\circ$	2	*909 500*+x
$2s2p^3$	$^1P^\circ$	1	*1 015 100*+x
$2p^4$	^3P	2	1 359 100
		1	1 410 800
$2s^2 2p3s$	$^3P^\circ$	1	*5 725 000*
		2	*5 786 000*
$2s^2 2p3s$	$^1P^\circ$	1	*5 806 300*+x
$2s^2 2p3d$	$^3D^\circ$	2	*6 127 000*
		3	*6 157 000*
$2s^2 2p3d$	$^3P^\circ$	1	*6 165 000*
		2	*6 174 000*

V XVIII—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^22p3d$	$^1P^\circ$	1	*6 216 100*+x
$2s^22p3d$	$^1F^\circ$	3	*6 234 800*+x
$2s2p^2(^2D)3s$	^3D	2	6 323 400
$2s2p^2(^4P)3d$	^3F	3	6 500 000
$2s2p^2(^2D)3d$	^3F	4	6 674 500
V XIX ($^2P^\circ_{1/2}$)	*Limit*	....	**10 160 000**

V XIX

B I isoelectronic sequence $Z = 23$

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

Ionization energy = 10 930 000 cm^{-1} (1355 eV)

The $2s^2 2p$–$2s2p^2$ transition array was first observed by Fawcett, Galanti, and Peacock (1974b). Their identification of the $2s2p^2\ ^2D$ term has been revised by Fawcett and Hayes (1975).

The terms of $2s^2 3d$, $2s2p3p$, and $2s2p(^3P^\circ)3d$ are from Fawcett, Galanti, and Peacock (1974a). The level of $2s2p(^1P^\circ)3d$ is from Fawcett and Hayes (1975). They also observed the quartet $2s2p^2\ ^4P$–$2p^3\ ^4S^\circ$ but these terms have not been connected to the doublet system.

The ionization energy is from Lotz (1967).

References

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974a), J. Phys. **B7**, L106.
Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974b), J. Phys. **B7**, 1149.
Fawcett, B. C., and Hayes, R. W. (1975), Mon. Not. R. Astr. Soc. **170**, 185.
Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.

V XIX

Configuration	Term	*J*	Level (cm^{-1})
$2s^2 2p$	$^2P^\circ$	1/2	*0*
		3/2	*68 610*
$2s2p^2$	^2D	3/2	597 590
		5/2	605 320
$2s2p^2$	^2S	1/2	716 370
$2s2p^2$	^2P	1/2	788 850
		3/2	802 560
$2s^2 3d$	^2D	3/2	6 426 700
		5/2	6 437 200
$2s2p(^3P^\circ)3p$	^2P	3/2	6 590 500
$2s2p(^3P^\circ)3p$	^2D	5/2	6 718 000
$2s2p(^1P^\circ)3p$	^2D	5/2	6 901 000
$2s2p(^3P^\circ)3d$	$^2F^\circ$	5/2	*6 844 900*
		7/2	*6 885 100*
$2s2p(^1P^\circ)3d$	$^2F^\circ$	7/2	*7 059 000*
V XX ($^1S_0$)	*Limit*	....	**10 930 000**

V XX

Be I isoelectronic sequence $Z = 23$

Ground state: $1s^2 2s^2\ ^1S_0$ Ionization energy = 11 990 000 cm^{-1} (1486 eV)

The intersystem resonance line, $2s^2\ ^1S_0$–$2s2p\ ^3P^\circ_1$, has not been observed. An extrapolated value for $2s2p\ ^3P^\circ_2$ on which to base the triplet system has been taken from Kononov, Koshelev, and Podobedova (1974). Three transitions to this level from higher ^3P and ^3D levels were observed by Fawcett, Galanti, and Peacock (1974a), and one from a ^3S level by Aglitskii, Boiko, Pikuz, Safronova, and Faenov (1976).

The singlet resonance transition from $2s2p\ ^1P^\circ_1$ was observed by Fawcett, Galanti, and Peacock (1974b) at 160 Å. The $2s3p$ and $2s3d$ singlet terms were established from observations at 15 Å by Fawcett and Hayes (1975). The $2p3p$ singlets are from Aglitskii et al.

New measurements were obtained by Bromage, Cowan, Fawcett, and Ridgeley (1977), who also extended the analysis to include levels of $2s4p$ and $2s4d$. Transitions to $2p^2$ have been identified but no connection of $2p^2$ with the lower levels has been observed. The present level scheme is derived from this paper.

The ionization energy is from Lotz (1967).

References

Aglitskii, E. V., Boiko, V. A., Pikuz, S. A., Safronova, U. I., and Faenov, A. Y. (1976), Physical Institute (Moscow) Preprint No. 9.

Bromage, G. E., Cowan, R. D., Fawcett, B. C., and Ridgeley, A. (1978), J. Opt. Soc. Am. **68**, 48.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974a), J. Phys. **B7**, L106.

Fawcett, B. C., Galanti, M., and Peacock, N. J. (1974b), J. Phys. **B7**, 1149.

Fawcett, B. C., and Hayes, R. W. (1975), Mon. Not. Roy. Astr. Soc. **170**, 185.

Kononov, E. Y., Koshelev, K. N., and Podobedova, L. I. (1974), Opt. Spectrosc. **37**, 1.

Lotz, W. (1967), J. Opt. Soc. Am. **57**, 873.

V XX

Configuration	Term	J	Level (cm^{-1})
$2s^2$	^1S	0	0
$2s2p$	$^3P^\circ$	2	*375 000*+x
$2s2p$	$^1P^\circ$	1	*625 000*
$2s3p$	$^3P^\circ$	1	*6 944 000*
$2s3p$	$^1P^\circ$	1	*6 964 000*
$2s3d$	^3D	3	7 052 000+x
$2s3d$	^1D	2	7 107 000
$2p3p$	^1P	1	7 323 000
$2p3p$	^3S	1	7 372 000+x
$2p3p$	^3D	3	7 378 000+x
$2p3p$	^3P	2	7 403 000+x
$2p3p$	^1D	2	7 451 000
$2s4p$	$^1P^\circ$	1	*9 140 000*
$2s4d$	^3D	3	9 218 000+x
$2s4d$	^1D	2	9 235 000
$2p4p$	^3D	3	9 602 000+x
V XXI ($^2S_{1/2}$)	*Limit*	....	**11 990 000**

V XXI

Li I isoelectronic sequence $Z = 23$

Ground state: $1s^22s\ ^2S_{1/2}$

Ionization energy = 12 668 000 cm^{-1} (1570.7 eV)

The $2s$–$3p$, $2s$–$4p$, $2p$–$3s$, $2p$–$3d$, and $2p$–$4d$ transitions were reported by Goldsmith, Feldman, Oren, and Cohen (1972). They extrapolated the value of the $2p\ ^2P^\circ_{1/2}$ level used here. Aglitskii, Boiko, Pikuz, and Faenov (1974) confirmed the lines identified by Goldsmith et al. (1972) and added the $5p$ to $7p$ and $5d$ to $8d$ terms. They also derived the ionization energy from the $nd\ ^2D_{3/2}$ Rydberg series, where $n = 3$ to 8.

The doubly excited levels were obtained by Aglitskii, Boiko, Zakharov, Pikuz, and Faenov (1974) from lines observed at 2.4 Å in a laser-produced plasma.

References

Aglitskii, E. V., Boiko, V. A., Zakharov, S. M., Pikuz, S. A., and Faenov, A. Y. (1974), J. E. T. P. Letters **19**, 8.

Aglitskii, E. V., Boiko, V. A., Pikuz, S. A., and Faenov, A. Y. (1974), Kvantovaya Elektron. (Moscow) **1**, 1731.

Goldsmith, S., Feldman, U., Oren, L., and Cohen, L. (1972), Astrophys. J. **174**, 209.

V XXI

Configuration	Term	J	Level (cm^{-1})
$1s^22s$	^2S	1/2	0
$1s^22p$	$^2P^\circ$	1/2	*340 500*+x
		3/2	*416 600*+x
$1s^23s$	^2S	1/2	7 115 700+x
$1s^23p$	$^2P^\circ$	1/2	*7 209 800*
		3/2	*7 231 700*
$1s^23d$	^2D	3/2	7 268 900+x
		5/2	7 276 300+x
$1s^24p$	$^2P^\circ$	1/2,3/2	*9 603 400*
$1s^24d$	^2D	3/2	9 627 300+x
		5/2	9 630 600+x
$1s^25p$	$^2P^\circ$	1/2,3/2	*10 693 000*
$1s^25d$	^2D	3/2	10 721 000+x
		5/2	10 722 000+x
$1s^26p$	$^2P^\circ$	1/2,3/2	*11 308 000*
$1s^26d$	^2D	3/2,5/2	11 316 000+x
$1s^27p$	$^2P^\circ$	1/2,3/2	*11 660 000*
$1s^27d$	^2D	3/2	11 671 000+x
		5/2	11 675 000+x
$1s^28d$	^2D	5/2	11 907 000+x
		3/2	11 911 000+x

V XXI—Continued

Configuration	Term	J	Level (cm^{-1})
V XXII ($^1S_0$)	***Limit***	....	**12 668 000**
$1s(^2S)2s2p(^1P^\circ)$	$^2P^\circ$	1/2,3/2	*41 829 000*
$1s2p^2$	^2D	3/2	41 985 000+x
		5/2	42 002 000+x
$1s2p^2$	^2P	3/2	42 097 000+x
$1s2p^2$	^2S	1/2	42 279 000+x

V XXII

He I isoelectronic sequence $Z = 23$

Ground state: $1s^2\ ^1S_0$

Ionization energy = 55 262 800 cm^{-1} (6851.77 eV)

The theoretical values calculated by Ermolaev and Jones (1974) for the singlet and triplet S and P terms of this two-electron ion are more accurate than the observed values, and we have quoted them up to $n = 4$. The uncertainty of the ionization energy and level values is estimated to be of the order of ± 60 cm^{-1}. For comparison, the $1s^2$–$1s2p$ transition of this ion has been observed by Aglitskii et al. (1974) in a laser-produced plasma. They place $1s2p\ ^3P^\circ_1$ at 41 770 000 cm^{-1} and $1s2p\ ^1P^\circ_1$ at 41 980 000 cm^{-1}.

References

Ermolaev, A. M., and Jones, M. (1974), J. Phys. **B7**, 199.
Aglitskii, E. V., Boiko, V. A., Zakharov, S. M., Pikuz, S. A., and Faenov, A. Y. (1974), Sov. Quantum Electronics **1**, 908.

V XXII

Configuration	Term	J	Level (cm^{-1})
$1s^2$	^1S	0	0
$1s2s$	^3S	1	41 573 150
$1s2p$	$^3P^\circ$	0	*41 774 810*
		1	*41 786 750*
		2	*41 853 280*
$1s2s$	^1S	0	41 791 780
$1s2p$	$^1P^\circ$	1	*41 986 020*
$1s3s$	^3S	1	49 238 420
$1s3p$	$^3P^\circ$	0	*49 294 070*
		1	*49 297 400*
		2	*49 317 410*
$1s3s$	^1S	0	49 296 140
$1s3p$	$^1P^\circ$	1	*49 353 420*
$1s4s$	^3S	1	51 890 590
$1s4p$	$^3P^\circ$	0	*51 913 730*
		1	*51 915 120*
		2	*51 923 580*
$1s4s$	^1S	0	51 913 970
$1s4p$	$^1P^\circ$	1	*51 938 260*
V XXIII ($^2S_{1/2}$)	*Limit*	....	55 262 820

V XXIII

H I isoelectronic sequence $Z = 23$

Ground state: 1*s* $^2S_{1/2}$

Ionization energy = 58 443 500 cm^{-1} (7246.13 eV)

The theoretical values calculated by Erikson for terms of this hydrogen-like ion are much more accurate than any observed values and they are given below. The binding energy of the 1*s* electron is given with an uncertainty of ±200 cm^{-1}; the levels measured from the ground state taken as zero will also have this uncertainty.

Reference

Erikson, G. W. (1977), J. Phys. Chem. Ref. Data **6**, 831.

V XXIII

Configuration	Term	*J*	Level (cm^{-1})
1*s*	^{2}S	1/2	0
2*p*	^{2}P°	1/2	*43 801 100*
		3/2	*43 905 400*
2*s*	^{2}S	1/2	43 804 200
3*p*	^{2}P°	1/2	*51 947 400*
		3/2	*51 978 300*
3*s*	^{2}S	1/2	51 948 300
3*d*	^{2}D	3/2	51 978 200
		5/2	51 988 400
4*p*	^{2}P°	1/2	*54 794 300*
		3/2	*54 807 400*
4*s*	^{2}S	1/2	54 794 700
4*d*	^{2}D	3/2	54 807 300
		5/2	54 811 600
4*f*	^{2}F°	5/2	*54 811 600*
		7/2	*54 813 800*
	Limit	....	**58 443 500**