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W. C. Martin, Romuald Zalubas, and Arlene Musgrove

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Energy Levels of Sulfur, S I Through S XVI

W. C. Martin, Romuald Zalubas[a], and Arlene Musgrove

Center for Atomic, Molecular, and Optical Physics, National Measurement Laboratory,
National Institute of Standards and Technology, Gaithersburg, MD 20899

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Energy level data are given for the atom and all positive ions of sulfur ($Z=16$). These data have been critically compiled, mainly from published and unpublished material on measurements and analyses of the optical spectra. We have derived or recalculated the levels for a number of the ions. In addition to the level values in cm^{-1} and the parity, the J value and the configuration and term assignments are listed if known. Leading percentages from the calculated eigenvectors are tabulated or quoted wherever available. Ionization energies are given for all spectra.

Key words: atomic energy levels; atomic ions; atomic spectra; electron configurations; ionization potentials; sulfur.

Contents

1. Introduction

This compilation is one of a series being published by the NIST Atomic Energy Levels Data Center. Earlier publications in this series include critical compilations of energy level data for Na I–XI, Mg I–XII, Al I–XIII, Si I–XIV [Martin and Zalubas, 1981, 1980, 1979, 1983, respectively], and P I–XV [Martin, Zalubas, and Musgrove, 1985]. Compilations of the energy levels for all spectra of the iron-period elements K through Ni [Sugar and Corliss, 1985] and for Mo I–XLII and Cu I–XXIX [Sugar and Musgrove, 1988, 1990] have also been published.

Since the general methods used in these compilations were outlined previously [Martin and Zalubas, 1979, 1980], our explanation here is confined mainly to the tables and the material preceding them. The levels for the sulfur spectra have been compiled from data available to us through October, 1989.

The basic data listed after the main heading for each spectrum include the appropriate isoelectronic sequence (for ions), the configuration and term designation of the ground-state level, and the wavenumber corresponding to the principal ionization energy. The ionization energy is also given in electron-volt (eV) units, an equivalence of 1 eV to $8065.5410 \pm 0.0024\ \mathrm{cm}^{-1}$ being used for the conversion [Cohen and Taylor, 1987].

We have tried to describe our use of the data from the references for each spectrum in sufficient detail to make apparent the sources for at least all major groups of levels. More complete references are given in several bibliographic publications [Moore, 1968, Hagan and Martin, 1972, Hagan, 1977, Zalubas and Albright, 1980, Musgrove and Zalubas, 1985]. We have also used a bibliographic database of references published since December 1983 maintained by the AEL Data Center. Our starting point in collecting the references was Moore's Atomic Energy Levels, Vol. I.

The symbols following the references indicate type of data or other content according to a code explained in the *Bibliography on Atomic Energy Levels and Spectra* publications [Hagan and Martin, 1972]. These symbols are especially useful for references otherwise listed without comment. We note that "EL," "CL," and "IP" refer to energy levels, classified lines, and ionization potentials, respectively, "SF" refers to evaluated series constants, and "PT" and "AT" refer to theoretical results.

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[a] Present address: 908 Roswell Drive, Silver Spring, MD 20901.

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The spectroscopic notations used in energy-level compilations of the AEL Data Center have been described fully [Martin, Zalubas, and Hagan, 1978]. This reference also describes the format of the tables in detail and includes material on coupling schemes, eigenvector percentages, allowed terms, and the Zeeman effect. In general we use the notation and conventions outlined there without comment.

The levels are given in units of cm^{-1} with respect to the ground level at zero. Odd-parity levels are printed in italics. The assignment of a set of levels to a term is indicated by grouping the levels and by listing the configuration and term for only the first (lowest) level of the group. Levels within terms are listed in order of position, and terms are listed in order of lowest levels.

The "Leading percentages" column normally gives one or two percentages from a calculated eigenvector for the level. All percentages are rounded off to the nearest percent, and the % symbol is omitted. If the level has a name (under "Configuration" and "Term"), a first percentage not followed by a term symbol is for this name component. A first percentage followed by a term symbol normally represents the largest component in the eigenvector of a level for which no particular name is appropriate, the configuration and parentage for this component being shown under "Configuration." Any variation from these conventions is made obvious by the notation and is mentioned in the comments.

2. Acknowledgments

In compiling and evaluating the data given here, we have used a considerable amount of unpublished material kindly supplied by a number of colleagues. We should like to thank T. Brage, K. T. Cheng, L. Cohen, R. D. Cowan, G. W. F. Drake, L. Engström, B. C. Fawcett, C. F. Fischer, M. R. Haas, P. Indelicato, V. Kaufman, P. J. Mohr, J. E. Pettersson, and U. I. Safronova, all of whom have communicated unpublished results. Dr. Cowan has been especially generous in carrying out several calculations especially for this compilation.

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References for the Introduction

Cohen, E. R. and Taylor, B. N. [1987], Rev. Mod. Phys. **59**, 1121–1148.

Hagan, L. [1977], *Bibliography on Atomic Energy Levels and Spectra, July 1971 through June 1975*, Natl. Bur. Stand. (U.S.) Spec. Publ. 363, Suppl. 1, 186 pp.

Hagan, L., and Martin, W. C. [1972], *Bibliography on Atomic Energy Levels and Spectra, July 1968 through June 1971*, Natl. Bur. Stand. (U.S.) Spec. Publ. 363, 103 pp.

Martin, W. C., and Zalubas, R. [1979], J. Phys. Chem. Ref. Data **8**, 817–864.

Martin, W. C., and Zalubas, R. [1980], J. Phys. Chem. Ref. Data **9**, 1–58.

Martin, W. C., and Zalubas, R. [1981], J. Phys. Chem. Ref. Data **10**, 153–195.

Martin, W. C., and Zalubas, R. [1983], J. Phys. Chem. Ref. Data **12**, 323–380.

Martin, W. C., Zalubas, R., and Hagan, L. [1978], *Atomic Energy Levels — The Rare-Earth Elements*, Natl. Stand. Ref. Data Ser., Natl. Bur. Stand. (U.S.) 60, 422 pp.

Martin, W. C., Zalubas, R., and Musgrove, A. [1985], J. Phys. Chem. Ref. Data **14**, 751–802.

Moore, C. E. [1949], *Atomic Energy Levels*, Circ. Natl. Bur. Stand. (U.S.) 467, Vol. I, 309 pp.; [1952], Vol. II, 227 pp.; [1958], Vol. III, 245 pp.; [1971] reprinted in three volumes as Natl. Stand. Ref. Data Ser., Natl. Bur. Stand. (U.S.), 35.

Moore, C. E. [1968], Natl. Bur. Stand. (U.S.), Spec. Publ. 306, Sec. 1, 80 pp.

Musgrove, A., and Zalubas, R. [1985], *Bibliography on Atomic Energy Levels and Spectra, July 1979 through December 1983*, Natl. Bur. Stand. (U.S.) Spec. Publ. 363, Suppl. 3.

Sugar, J. and Corliss, C. [1985], J. Phys. Chem. Ref. Data **14**, Suppl. 2.

Sugar, J., and Musgrove, A. [1988], J. Phys. Chem. Ref. Data **17**, 155–239.

Sugar, J., and Musgrove, A. [1990], J. Phys. Chem. Ref. Data **19**, in press.

Zalubas, R., and Albright, A. [1980], *Bibliography on Atomic Energy Levels and Spectra, July 1975 through June 1979*, Natl. Bur. Stand. (U.S.) Spec. Publ. 363, Suppl. 2, 119 pp.

S I

$Z=16$

Ground state $1s^2 2s^2 2p^6 3s^2 3p^4\ {}^3\mathrm{P}_2$

Ionization energy 83 559.1 ± 1.0 cm^{-1} (10.36001 ± 0.00012 eV)

Levels Below the Principal Ionization Limit

A large extension of the analysis of this spectrum was given in the 1933 papers by Frerichs, by Ruedy, and by Meissner *et al.* No more recent observations are available for most of the S I lines in the wavelength range covered by Frerichs (4150–11 500 Å) and by Meissner *et al.* (3400–8700 Å). Edlén [1949] revised the designations of a number of terms and also located several new levels.

Kaufman's measurements of 114 lines between 1157 and 2169 Å superseded previous observations of the vacuum-ultraviolet emission spectrum by Ruedy and by Toresson. The measurements of about 120 lines in the infrared (9212–37 270 Å) by Jakobsson gave an extension of the analysis and accurate connections between the levels of the lower excited configurations.

Eriksson gave the levels of the $3s^2 3p^4$ ground configuration except ${}^3\mathrm{P}_0$ as accurate to $\pm 0.005\ \mathrm{cm}^{-1}$, based on his wavelength measurements for three transitions between these levels. Kaufman's determinations gave the $3s^2 3p^4\ {}^3\mathrm{P}_0$ level accurate to about $\pm 0.016\ \mathrm{cm}^{-1}$, and the uncertainty of his connection between the most accurate levels of the excited configurations and the ground-configuration levels is about $\pm 0.02\ \mathrm{cm}^{-1}$. The relative positions of the excited-configuration levels given to three decimal places were determined by Jakobsson. The relative uncertainty of these levels is less than $0.01\ \mathrm{cm}^{-1}$, and the uncertainty of their values as given here with respect to the $3s^2 3p^4$ levels is about $\pm 0.02\ \mathrm{cm}^{-1}$, Jakobsson's values having been increased by $0.950\ \mathrm{cm}^{-1}$ [Kaufman].

Most of the two-place and one-place odd levels below the $3p^3({}^4\mathrm{S}^\circ)$ limit, as well as the $3p^3({}^2\mathrm{D}^\circ)5s\ {}^1\mathrm{D}^\circ_2$ and $3p^3({}^2\mathrm{P}^\circ)5s\ {}^1\mathrm{P}^\circ_1$ levels, are from Kaufman's list. The uncertainty of these levels is 0.03 to $0.20\ \mathrm{cm}^{-1}$ for the two-place values and $0.3\ \mathrm{cm}^{-1}$ for the one-place values. We evaluated most of the remaining levels using the values for the lower levels given here with experimental wavenumbers of the corresponding transitions from Frerichs and/or from Meissner *et al.* The levels evaluated in this way include those belonging to the odd terms $3s^2 3p^3({}^4\mathrm{S}^\circ)ns\ {}^5\mathrm{S}^\circ$ $(n \geqslant 6)$, $({}^4\mathrm{S}^\circ)nd\ {}^5\mathrm{D}^\circ$ $(n \geqslant 4)$, and $({}^4\mathrm{S}^\circ)7d\ {}^3\mathrm{D}^\circ$ and the even levels of $({}^4\mathrm{S}^\circ)nf$ $(n \geqslant 5)$, $({}^4\mathrm{S}^\circ)np$ $(n=7, 8)$, and $({}^2\mathrm{D}^\circ)4p\ {}^3\mathrm{F}$. Edlén's values for the $({}^4\mathrm{S}^\circ)7p\ {}^3\mathrm{P}$ and $({}^4\mathrm{S}^\circ)8p\ {}^3\mathrm{P}$ levels have been lowered by $0.30\ \mathrm{cm}^{-1}$, this correction being an estimate based on related levels.

We derived values for the ionization energy by fitting Ritz series formulae to the $({}^4\mathrm{S}^\circ)ns\ {}^5\mathrm{S}^\circ$ series $(n=4-10)$, the $({}^4\mathrm{S}^\circ)ns\ {}^3\mathrm{S}^\circ$ series $(n=4-11)$, the $({}^4\mathrm{S}^\circ)nd\ {}^5\mathrm{D}^\circ_4$ series $(n=4-9)$, and the $({}^4\mathrm{S}^\circ)nf\ {}^5\mathrm{F}$ series $(n=4-8)$. The ionization-energy value given here is based on these results, with the uncertainty being estimated from the consistency of the values from the different series and from the range of limit values allowed by acceptable fits to the series.

The eigenvector percentages for the odd levels are from a calculation by Cowan [1984] that included the interactions between the $3s3p^5$, $3s^2 3p^3 ns$, and $3s^2 3p^3 md$ configurations, with $n=4-6$, $m=3-6$ and also seven additional pseudo configurations to mock up the higher md configurations and the ϵd continuum. The energy parameters were scaled from their Hartree-Fock values to improve agreement with experiment. The assignment of the largest $3s3p^5\ {}^3\mathrm{P}^\circ$ eigenvector components to the levels of the ${}^3\mathrm{P}^\circ$ term near $72\,000\ \mathrm{cm}^{-1}$ is supported by all available calculations that include the pertinent configuration interactions with sufficient completeness [Cowan and Hansen, 1981; Cowan, 1984; McGuire, 1986]. Most of the remaining $3s3p^5\ {}^3\mathrm{P}^\circ$ composition is distributed amongst the $3s^2 3p^3({}^2\mathrm{D}^\circ, {}^2\mathrm{P}^\circ)nd$, $\epsilon d\ {}^3\mathrm{P}^\circ$ and $3s^2 3p^3({}^2\mathrm{P}^\circ)ns$, $\epsilon s\ {}^3\mathrm{P}^\circ$ series and continua.

Levels Above the Principal Ionization Limit

Five levels above the $3s^2 3p^3\ {}^4\mathrm{S}^\circ$ limit have been determined within uncertainties of 0.10 to $0.20\ \mathrm{cm}^{-1}$ from relatively sharp emission lines: the $3s^2 3p^3({}^2\mathrm{D}^\circ)5s\ {}^1\mathrm{D}^\circ_2$ and $({}^2\mathrm{P}^\circ)5s\ {}^1\mathrm{P}^\circ_1$ levels are from Kaufman's list, and the $({}^2\mathrm{D}^\circ)3d\ {}^3\mathrm{P}^\circ$ levels were derived by Alder *et al.* from their measurements of the $({}^4\mathrm{S}^\circ)4p\ {}^3\mathrm{P}-({}^2\mathrm{D}^\circ)3d\ {}^3\mathrm{P}^\circ$ multiplet near 4630 Å.

Tondello's observations of the vacuum-ultraviolet absorption spectrum (941–1707 Å) yielded higher series members and autoionization-broadened features not observed in emission. His classifications of the lines included transitions from the $3s^2 3p^4\ {}^1\mathrm{D}$ level as well as from the $3s^2 3p^4\ {}^3\mathrm{P}$ ground-term levels. More recent measurements of the absorption spectrum in the vacuum ultraviolet have been carried out by Sarma and Joshi and by Joshi *et al.* (840–1220 Å); Gibson *et al.* observed the photoionization spectrum in the 925–1200 Å region. Most of the odd-parity terms lying above the $3s^2 3p^3\ {}^4\mathrm{S}^\circ$ limit have been selected from the data of Tondello, Joshi *et al.*, and Gibson *et al.* The measurements of the sharper features were probably accurate within errors of 1 to several cm^{-1}, the corresponding levels being given here to the nearest cm^{-1}. The levels derived from broader features (denoted by the letter "*a*" following the value) are given to the nearest 10 cm^{-1} or, in the case of several of the most strongly autoionizing terms, to the nearest 100 cm^{-1}.

A considerable number of the observed photoabsorption and photoionization resonances have been interpreted differently by different authors. For example, the assignments of the $(^2\mathrm{D}^\circ)nd\ ^3\mathrm{S}^\circ$ and $(^2\mathrm{D}^\circ)ms\ ^3\mathrm{D}^\circ$ series appear to be ambiguous for $n+2=m \geqslant 5$, and the adopted interpretation of the features on which the apparently overlapping $(^2\mathrm{P}^\circ)nd\ ^3\mathrm{P}^\circ$, $^3\mathrm{D}^\circ$ series are based may be in question. The odd-parity term assignments here are generally consistent with calculations by Cowan [1984] and by Tayal [1988], but none of the available calculations is sufficiently accurate to allow definitive interpretation of all features of this complex spectrum. Among the other useful calculations that we have consulted are those by Conneely *et al.* [1970], McGuire [1979], Ho and Henry [1985], and Mendoza and Zeippen [1988]. We have omitted a number of terms based on tentative series identifications or derived from relatively weak and blended features.

Pratt [1988] has applied laser and mass-spectrometric techniques to observe ionization resonances due to two-photon excitation from the S I $3s^23p^4\ ^1\mathrm{D}_2$ level. His method allowed scanning over an upper-level energy range from about 93 600 to 98 900 cm^{-1}, with two-photon transitions being allowed only to upper levels having the same parity as the $^1\mathrm{D}_2$ level (even-parity upper levels). Upper levels having dominant or large singlet eigenvector components were strongly favored; thus the observed lines or features were relatively narrow, autoionization being inhibited by the lack of a singlet continuum below the S II $2s^22p^3(^2\mathrm{D}^\circ)$ limits. Most of the stronger lines were assigned to series belonging to $(^2\mathrm{D}^\circ)nf$ or $(^2\mathrm{D}^\circ)np$ configurations on the basis of quantum-defect behavior. We have tabulated the $(^2\mathrm{D}^\circ_{3/2})nf$ and $(^2\mathrm{D}^\circ_{5/2})nf$ $(n=5-18)$ positions as designated by Pratt, and we also list the members of his strongest $(^2\mathrm{D}^\circ)np$ series for $n=7-12$. Pratt estimated that his measurements are accurate to $\pm 1\ \mathrm{cm}^{-1}$; his energies have been lowered by 0.4 cm^{-1} for consistency with the $3s^23p^4\ ^1\mathrm{D}_2$ level given here.

It should be noted that even the sharpest features observed by Pratt (2.0 to 2.5 cm^{-1} instrumental width) may have unresolved level structure that varies along a "series." This may account in part for apparently irregular quantum-defect behavior corresponding to deviations as large as several cm^{-1} for some series members. Pending more detailed theoretical calculations of these structures, we have omitted the J_1l-coupling designations tentatively suggested by Pratt for the $(^2\mathrm{D}^\circ)np$ series. Additional resonances designated as higher members of this series and also the positions for lines assigned to three weaker $(^2\mathrm{D}^\circ)np$ series are given by Pratt.

References

Alder, J. F., Bombelka, R. M., and Kirkbright, G. F. [1978], J. Phys. B **11**, 235–238. EL CL

Conneely, M. J., Smith, K., and Lipsky, L. [1970], J. Phys. B **3**, 493–512. AT

Cowan, R. D. [1984], unpublished material. AT

Cowan, R. D., and Hansen, J. E. [1981], J. Opt. Soc. Am. **71**, 60–63. AT

Edlén, B. [1942], Phys. Rev. **62**, 434–435. EL CL

Edlén, B. [1949], material published in Moore, C. E. [1949], *Atomic Energy Levels*, Circ. Natl. Bur. Stand. (U.S.) 467, Vol. I.

Eriksson, K. B. S. [1978], Astrophys. J. **222**, 398–399. EL CL

Frerichs, R. [1933], Z. Phys. **80**, 150–160. EL CL IP

Gibson, S. T., Greene, J. P., Ruscic, B., and Berkowitz, J. [1986], J. Phys. B **19**, 2825–2840. EL CL

Ho, Y. K., and Henry, R. J. W. [1985], Astrophys. J. **290**, 424–427. AT

Jakobsson, L. R. [1967], Ark. Fys. **34**, 19–31. EL CL

Joshi, Y. N., Mazzoni, M., Nencioni, A., Parkinson, W. H., and Cantu, A. [1987], J. Phys. B **20**, 1203–1213. EL CL

Kaufman, V. [1982], Phys. Scr. **26**, 439–442. EL CL IP

Kaufman, V., and Radziemski, Jr., L. J. [1969], J. Opt. Soc. Am. **59**, 227–228, and unpublished results of the calculations described therein. PT

McGuire, E. J. [1979], Phys. Rev. A **19**, 1978–1998. PT AT

McGuire, E. J. [1986], Phys. Rev. A **33**, 1492–1510. AT

Meissner, K. W., Bartelt, O., and Eckstein, L. [1933], Z. Phys. **86**, 54–81. EL CL IP SF

Mendoza, C., and Zeippen, C. J. [1988], J. Phys. B **21**, 259–266. AT

Moore, C. E. [1949], *Atomic Energy Levels*, Circ. Natl. Bur. Stand. (U.S.) 467, Vol. I; [1971] reprinted as Natl. Stand. Ref. Data Ser., Natl. Bur. Stand. (U.S.) 35, Vol. I, 309 pp. EL

Pratt, S. T. [1988], Phys. Rev. A **38**, 1270–1278. EL CL

Ruedy, J. E. [1933], Phys. Rev. **44**, 757–760. EL CL IP

Sarma, V. N., and Joshi, Y. N. [1984], Physica (Utrecht) **123C**, 349–352. CL

Tayal, S. S. [1988], Phys. Rev. A **38**, 729–736. AT

Tondello, G. [1972], Astrophys. J. **172**, 771–783. EL CL

Toresson, Y. G. [1960], Ark. Fys. **18**, 417–420. EL CL IP

S I

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p^4$	$^3\mathrm{P}$	2	0.000	
		1	396.055	
		0	573.640	
$3s^23p^4$	$^1\mathrm{D}$	2	9 238.609	
$3s^23p^4$	$^1\mathrm{S}$	0	22 179.954	

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^3(^4S^\circ)4s$	$^5S^\circ$	2	*52 623.640*	100		
$3s^23p^3(^4S^\circ)4s$	$^3S^\circ$	1	*55 330.811*	100		
$3s^23p^3(^4S^\circ)4p$	^5P	1	63 446.065			
		2	63 457.142			
		3	63 475.051			
$3s^23p^3(^4S^\circ)4p$	^3P	1	64 888.964			
		0	64 891.386			
		2	64 892.582			
$3s^23p^3(^2D^\circ)4s$	$^3D^\circ$	1	*67 816.351*	96	3	$3s^23p^3(^4S^\circ)3d$ $^3D^\circ$
		2	*67 825.188*	96	3	"
		3	*67 842.867*	96	3	"
$3s^23p^3(^4S^\circ)3d$	$^5D^\circ$	4	*67 877.635*	97	1	$3s^23p^3(^4S^\circ)4d$ $^5D^\circ$
		0	*67 884.158*	97	1	"
		1	*67 885.535*	97	1	"
		2	*67 887.805*	97	1	"
		3	*67 890.016*	97	1	"
$3s^23p^3(^2D^\circ)4s$	$^1D^\circ$	2	*69 237.886*	99		
$3s^23p^3(^4S^\circ)3d$	$^3D^\circ$	1	*70 164.658*	95	3	$3s^23p^3(^2D^\circ)4s$ $^3D^\circ$
		2	*70 166.195*	95	3	"
		3	*70 173.968*	96	3	"
$3s^23p^3(^4S^\circ)5s$	$^5S^\circ$	2	*70 702.790*	100		
$3s^23p^3(^4S^\circ)5s$	$^3S^\circ$	1	*71 351.399*	99		
$3s3p^5$	$^3P^\circ$	2	*72 023.495*	58	15	$3s^23p^3(^2D^\circ)3d$ $^3P^\circ$
		1	*72 382.328*	57	15	"
		0	*72 571.630*	57	15	"
$3s^23p^3(^4S^\circ)5p$	^5P	1	73 911.259			
		2	73 914.928			
		3	73 920.961			
$3s^23p^3(^4S^\circ)5p$	^3P	2	74 268.547			
		1	74 269.600			
		0	74 271.651			
$3s^23p^3(^4S^\circ)4d$	$^5D^\circ$	4	*74 973.14*	95	2	$3s^23p^3(^4S^\circ)3d$ $^5D^\circ$
		3	*74 974.10*	95	2	"
		2	*74 975.19*	95	2	"
		1	*74 976.06*	95	2	"
		0	*74 976.61*	95	2	"
$3s^23p^3(^4S^\circ)4d$	$^3D^\circ$	1	*75 951.95*	98		
		2	*75 952.35*	98		
		3	*75 956.53*	98		
$3s^23p^3(^4S^\circ)6s$	$^5S^\circ$	2	*76 464.06*	100		

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^3(^4S^\circ)4f$	^5F	4	76 654.767			
		5	76 654.769			
		3	76 654.794			
		2	76 654.811			
		1	76 654.847			
$3s^23p^3(^4S^\circ)4f$	^3F	4	76 656.324			
		3	76 656.330			
		2	76 656.358			
$3s^23p^3(^4S^\circ)6s$	$^3S^\circ$	1	*76 720.65*	100		
$3s^23p^3(^2P^\circ)4s$	$^3P^\circ$	0	*77 135.52*	95	3	$3s3p^5\ ^3P^\circ$
		1	*77 150.14*	94	3	"
		2	*77 181.15*	95	3	"
$3s^23p^3(^4S^\circ)6p$	^5P	1	77 850.740			
		2	77 853.234			
		3	77 856.446			
$3s^23p^3(^2D^\circ)4p$	^1P	1	77 854.906			
$3s^23p^3(^4S^\circ)6p$	^3P	2	77 890.532			
		0	77 902.208			
		1	77 913.543			
$3s^23p^3(^2D^\circ)4p$	^3D	2	78 152.071			
		1	78 152.336			
		3	78 203.180			
$3s^23p^3(^4S^\circ)5d$	$^5D^\circ$	4	*78 270.10*	94	2	$3s^23p^3(^4S^\circ)4d\ ^5D^\circ$
		3	*78 270.52*	94	2	"
		2	*78 270.99*	94	2	"
		1		94	2	"
		0		94	2	"
$3s^23p^3(^2P^\circ)4s$	$^1P^\circ$	1	*78 288.44*	76	16	$3s^23p^3(^2D^\circ)3d\ ^1P^\circ$
$3s^23p^3(^2D^\circ)4p$	^3F	2	78 409.89			
		3	78 435.81			
		4	78 463.04			
$3s^23p^3(^2D^\circ)4p$	^1F	3	78 639.923			
$3s^23p^3(^4S^\circ)5d$	$^3D^\circ$	2	*78 691.37*	98	1	$3s^23p^3(^2D^\circ)3d\ ^3D^\circ$
		3	*78 691.80*	98	1	"
		1	*78 692.53*	98	1	"
$3s^23p^3(^4S^\circ)7s$	$^5S^\circ$	2	*79 058.04*			
$3s^23p^3(^4S^\circ)5f$	^5F	5–1	79 142.81			
$3s^23p^3(^4S^\circ)5f$	^3F	4,3,2	79 143.93			
$3s^23p^3(^4S^\circ)7s$	$^3S^\circ$	1	*79 185.35*			
$3s^23p^3(^2D^\circ)4p$	^3P	2	79 375.80			
		1	79 405.30			
		0	79 418.01			

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^3(^4S^\circ)7p$	^5P	1				
		2				
		3	79 785.52			
$3s^23p^3(^4S^\circ)6d$	$^5D^\circ$	4	*79 992.15*	95	2	$3s^23p^3(^4S^\circ)5d$ $^5D^\circ$
		3	*79 992.32*	95	2	″
		2	*79 992.50*	95	2	″
		1		95	2	″
		0		95	2	″
$3s^23p^3(^4S^\circ)7p$	^3P	2	80 112.93			
		1	80 120.21			
		0	80 123.86			
$3s^23p^3(^4S^\circ)6d$	$^3D^\circ$	3	*80 182.16*	98	1	$3s^23p^3(^2D^\circ)3d$ $^3D^\circ$
		2	*80 183.83*	98	1	″
		1	*80 185.60*	98	1	″
$3s^23p^3(^4S^\circ)8s$	$^5S^\circ$	2	*80 449.10*			
$3s^23p^3(^4S^\circ)6f$	^5F	5–1	80 494.31			
$3s^23p^3(^4S^\circ)6f$	^3F	4,3,2	80 495.24			
$3s^23p^3(^4S^\circ)8s$	$^3S^\circ$	1	*80 521.46*			
$3s^23p^3(^4S^\circ)7d$	$^5D^\circ$	4	*80 995.28*			
$3s^23p^3(^4S^\circ)8p$	^3P	0,1	80 995.60			
		2	80 996.03			
$3s^23p^3(^4S^\circ)7d$	$^3D^\circ$	3	*81 080.29*			
		2	*81 082.46*			
		1	*81 084.67*			
$3s^23p^3(^4S^\circ)9s$	$^5S^\circ$	2	*81 281.56*			
$3s^23p^3(^4S^\circ)7f$	^5F	5–1	81 308.84			
$3s^23p^3(^4S^\circ)7f$	^3F	4,3,2	81 309.57			
$3s^23p^3(^4S^\circ)9s$	$^3S^\circ$	1	*81 326.81*			
$3s^23p^3(^2D^\circ)3d$	$^1P^\circ$	1	*81 438.30*	58	23	$3s^23p^3(^2P^\circ)4s$ $^1P^\circ$
$3s^23p^3(^4S^\circ)8d$	$^5D^\circ$	4	*81 628.70*			
$3s^23p^3(^4S^\circ)8d$	$^3D^\circ$	3	*81 663.05*			
		2	*81 665.61*			
		1	*81 667.93*			
$3s^23p^3(^4S^\circ)10s$	$^5S^\circ$	2	*81 819.20*			
$3s^23p^3(^4S^\circ)8f$	^5F	5–1	81 837.6			
$3s^23p^3(^4S^\circ)10s$	$^3S^\circ$	1	*81 849.68*			
$3s^23p^3(^4S^\circ)9d$	$^5D^\circ$	4	*82 053.74*			

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentag
$3s^23p^3(^4S^\circ)9d$	$^3D^\circ$	3	*82 061.70*	
		2	*82 063.40*	
		1	*82 067.22*	
$3s^23p^3(^4S^\circ)11s$	$^3S^\circ$	1	*82 208.17*	
$3s^23p^3(^4S^\circ)10d$	$^3D^\circ$	3	*82 350.77*	
		2	*82 352.35*	
		1	*82 353.25*	
$3s^23p^3(^4S^\circ)10d$	$^5D^\circ$	4	*82 353.1*	
$3s^23p^3(^4S^\circ)11d$	$^3D^\circ$	3	*82 561.9*	
		2	*82 563.6*	
		1	*82 564.4*	
$3s^23p^3(^2D^\circ)3d$	$^1F^\circ$	3	*82 604.41*	
$3s^23p^3(^4S^\circ)12d$	$^3D^\circ$	3	*82 723.2*	
		2	*82 725.0*	
		1		
$3s^23p^3(^4S^\circ)13d$	$^3D^\circ$	3	*82 849.0*	
		2	*82 850.3*	
		1		
$3s^23p^3(^4S^\circ)14d$	$^3D^\circ$	3	*82 948.7*	
…………	…………	…………	…………	
S II ($^4S^\circ_{3/2}$)	*Limit*		*83 559.1*	
$3s^23p^3(^2D^\circ)3d$	$^3D^\circ$	1,2,3	*83 700a*	
$3s^23p^3(^2D^\circ)3d$	$^3S^\circ$	1	*85 430a*	
$3s^23p^3(^2D^\circ)3d$?	$^1D^\circ$?	2	*85 614*	
$3s^23p^3(^2D^\circ)5s$	$^3D^\circ$	1,2,3	*85 680a*	
$3s^23p^3(^2D^\circ)5s$	$^1D^\circ$	2	*86 108.08*	
$3s^23p^3(^2D^\circ)3d$	$^3P^\circ$	0	*86 473.17*	
		1	*86 484.57*	
		2	*86 503.21*	
$3s^23p^3(^2D^\circ)4d$	$^3D^\circ$	1,2,3	*90 400a*	
$3s^23p^3(^2D^\circ)4d$	$^3S^\circ$	1	*91 190a*	
$3s^23p^3(^2D^\circ)4d$	$^1D^\circ$	2	*91 276*	
$3s^23p^3(^2D^\circ)6s$	$^3D^\circ$	1,2,3	*91 380a*	
$3s^23p^3(^2D^\circ)4d$	$^3P^\circ$	0	*91 469?*	
		1	*91 486*	
		2	*91 519*	
$3s^23p^3(^2D^\circ)6s$	$^1D^\circ$	2	*91 545?*	
$3s^23p^3(^2D^\circ)5d$	$^3D^\circ$	1,2,3	*93 410a*	

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p^3(^2D^\circ)5d$	$^3S^\circ$	1	*93 824*	
$3s^23p^3(^2D^\circ)5d$	$^1D^\circ$	2	*93 870*	
$3s^23p^3(^2D^\circ)7s$	$^3D^\circ$	1,2,3	*93 984*	
$3s^23p^3(^2D^\circ_{3/2})5f$			93 996.4	
$3s^23p^3(^2D^\circ_{5/2})5f$			94 032.6	
$3s^23p^3(^2D^\circ)7s$	$^1D^\circ$	2	*94 035*	
$3s^23p^3(^2P^\circ)3d$	$^3D^\circ$	1,2,3	*94 180a*	
$3s^23p^3(^2P^\circ)3d$	$^3P^\circ$	0,1,2	*94 381*	
$3s^23p^3(^2D^\circ)5d$	$^3P^\circ$	1,2	*94 414*	
$3s^23p^3(^2D^\circ)7p$			94 875.5	
$3s^23p^3(^2D^\circ)6d$	$^3D^\circ$	1,2,3	*95 100a*	
$3s^23p^3(^2P^\circ)5s$	$^3P^\circ$	0	*95 181?*	
		2	*95 198*	
		1	*95 208*	
$3s^23p^3(^2D^\circ)6d$	$^3S^\circ$	1	*95 256a*	
$3s^23p^3(^2D^\circ)6d$	$^1D^\circ$	2	*95 299*	
$3s^23p^3(^2D^\circ_{3/2})6f$			95 349.1	
$3s^23p^3(^2D^\circ)8s$	$^3D^\circ$	1,2,3	*95 350*	
$3s^23p^3(^2D^\circ_{5/2})6f$			95 383.4	
$3s^23p^3(^2D^\circ)6d$	$^3P^\circ$	1,2	*95 625*	
$3s^23p^3(^2P^\circ)5s$	$^1P^\circ$	1	*95 638.95*	
$3s^23p^3(^2P^\circ)3d$	$^1P^\circ$	1	*95 873.5*	
$3s^23p^3(^2D^\circ)8p$			95 880.9	
$3s^23p^3(^2D^\circ)7d$	$^3D^\circ$	1,2,3	*96 006a*	
$3s^23p^3(^2D^\circ)7d$	$^3S^\circ$	1	*96 099*	
$3s^23p^3(^2D^\circ)7d$	$^1D^\circ$	2	*96 133*	
$3s^23p^3(^2D^\circ_{3/2})7f$			96 160.0	
$3s^23p^3(^2D^\circ_{5/2})7f$			96 194.2	
$3s^23p^3(^2D^\circ)9s$	$^3D^\circ$	1,2,3	*96 204*	
$3s^23p^3(^2D^\circ)7d$	$^3P^\circ$	1,2	*96 312*	
$3s^23p^3(^2D^\circ)9p$			96 513.2	

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p^3(^2D^\circ)8d$	$^3D^\circ$	1,2,3	*96 618a*	
$3s^23p^3(^2D^\circ)8d$	$^3S^\circ$	1	*96 649*	
$3s^23p^3(^2D^\circ)8d$	$^1D^\circ$	2	*96 677*	
$3s^23p^3(^2D^\circ_{3/2})8f$			96 689.1	
$3s^23p^3(^2D^\circ)10s$	$^3D^\circ$	1,2,3	*96 716*	
$3s^23p^3(^2D^\circ_{5/2})8f$			96 721.7	
$3s^23p^3(^2D^\circ)10p$			96 937.0	
$3s^23p^3(^2D^\circ)9d$	$^3D^\circ$	1,2,3	*97 012a*	
$3s^23p^3(^2D^\circ_{3/2})9f$			97 052.7	
$3s^23p^3(^2D^\circ_{5/2})9f$			97 085.1	
$3s^23p^3(^2D^\circ)11s$	$^3D^\circ$	1,2,3	*97 089*	
$3s^23p^3(^2D^\circ)11p$			97 232.0	
$3s^23p^3(^2D^\circ)10d$	$^3D^\circ$	1,2,3	*97 276a*	
$3s^23p^3(^2D^\circ_{3/2})10f$			97 309.8	
$3s^23p^3(^2D^\circ)12s$	$^3D^\circ$	1,2,3	*97 327*	
$3s^23p^3(^2D^\circ_{5/2})10f$			97 342.7	
$3s^23p^3(^2D^\circ)12p$			97 455.1	
$3s^23p^3(^2D^\circ_{3/2})11f$			97 505.0	
$3s^23p^3(^2D^\circ)13s$	$^3D^\circ$	1,2,3	*97 523*	
$3s^23p^3(^2D^\circ_{5/2})11f$			97 536.4	
$3s^23p^3(^2D^\circ_{3/2})12f$			97 649.6	
$3s^23p^3(^2D^\circ)14s$	$^3D^\circ$	1,2,3	*97 665*	
$3s^23p^3(^2D^\circ_{5/2})12f$			97 680.3	
$3s^23p^3(^2D^\circ_{3/2})13f$			97 761.6	
$3s^23p^3(^2D^\circ)15s$	$^3D^\circ$	1,2,3	*97 778*	
$3s^23p^3(^2D^\circ_{5/2})13f$			97 794.0	
$3s^23p^3(^2D^\circ_{3/2})14f$			97 851.4	
$3s^23p^3(^2D^\circ)16s$	$^3D^\circ$	1,2,3	*97 870*	
$3s^23p^3(^2D^\circ_{5/2})14f$			97 885.0	
$3s^23p^3(^2D^\circ_{3/2})15f$			[97 925.4]	

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p^3(^2D^\circ)17s$	$^3D^\circ$	1,2,3	*97 940*	
$3s^23p^3(^2D^\circ_{5/2})15f$			97 956.8	
$3s^23p^3(^2D^\circ_{3/2})16f$			97 985.5	
$3s^23p^3(^2D^\circ)18s$	$^3D^\circ$	1,2,3	*98 000*	
$3s^23p^3(^2D^\circ_{5/2})16f$			98 017.0	
$3s^23p^3(^2D^\circ_{3/2})17f$			98 034.3	
$3s^23p^3(^2D^\circ)19s$	$^3D^\circ$	1,2,3	*98 052*	
$3s^23p^3(^2D^\circ_{5/2})17f$			98 065.9	
$3s^23p^3(^2D^\circ_{3/2})18f$			98 074.5	
$3s^23p^3(^2D^\circ)20s$	$^3D^\circ$	1,2,3	*98 093*	
$3s^23p^3(^2D^\circ_{5/2})18f$			98 106.2	
$3s^23p^3(^2D^\circ)21s$	$^3D^\circ$	1,2,3	*98 126*	
$3s^23p^3(^2D^\circ)22s$	$^3D^\circ$	1,2,3	*98 155*	
S II ($^2D^\circ_{3/2}$)	*Limit*		*98 412.0*	
S II ($^2D^\circ_{5/2}$)	*Limit*		*98 443.8*	
$3s^23p^3(^2P^\circ)4d$	$^3P^\circ$	0,1,2	*100 300a*	
$3s^23p^3(^2P^\circ)4d$	$^3D^\circ$	1,2,3	*100 540a*	
$3s^23p^3(^2P^\circ)6s$	$^3P^\circ$	0,1,2	*101 000a*	
$3s^23p^3(^2P^\circ)5d$	$^3P^\circ$	0,1,2	*103 190a*	
$3s^23p^3(^2P^\circ)5d$	$^3D^\circ$	1,2,3	*103 370a*	
$3s^23p^3(^2P^\circ)7s$	$^3P^\circ$	0,1,2	*103 600a*	
$3s^23p^3(^2P^\circ)6d$	$^3P^\circ$	0,1,2	*104 740a*	
$3s^23p^3(^2P^\circ)6d$	$^3D^\circ$	1,2,3	*104 870a*	
$3s^23p^3(^2P^\circ)8s$	$^3P^\circ$	0,1,2	*105 000a*	
$3s^23p^3(^2P^\circ)7d$	$^3P^\circ$	0,1,2	*105 660a*	
$3s^23p^3(^2P^\circ)7d$	$^3D^\circ$	1,2,3	*105 740a*	
$3s^23p^3(^2P^\circ)9s$	$^3P^\circ$	0,1,2	*105 880a*	
$3s^23p^3(^2P^\circ)8d$	$^3P^\circ$	0,1,2	*106 246*	
$3s^23p^3(^2P^\circ)8d$	$^3D^\circ$	1,2,3	*106 310a*	
$3s^23p^3(^2P^\circ)10s$	$^3P^\circ$	0,1,2	*106 370a*	

S I — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p^3(^2P^\circ)9d$	$^3P^\circ$	0,1,2	*106 614*	
$3s^23p^3(^2P^\circ)10d$	$^3P^\circ$	0,1,2	*106 930*	
$3s^23p^3(^2P^\circ)11d$	$^3P^\circ$	0,1,2	*107 120*	
$3s^23p^3(^2P^\circ)12d$	$^3P^\circ,^3D^\circ$		*107 287*	
$3s^23p^3(^2P^\circ)13d$	$^3P^\circ,^3D^\circ$		*107 401*	
$3s^23p^3(^2P^\circ)14d$	$^3P^\circ,^3D^\circ$		*107 513*	
$3s^23p^3(^2P^\circ)15d$	$^3P^\circ,^3D^\circ$		*107 584*	
$3s^23p^3(^2P^\circ)16d$	$^3P^\circ,^3D^\circ$		*107 645*	
S II ($^2P^\circ_{1/2}$)	*Limit*		*108 084.0*	
S II ($^2P^\circ_{3/2}$)	*Limit*		*108 130.7*	

S II

$Z=16$

P I isoelectronic sequence

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

Ionization energy 188 232.7 ± 2.0 cm^{-1} (23.337 89 ± 0.000 25 eV)

The analysis of this spectrum was recently extended by Pettersson, who measured 867 lines in the range 558–9564 Å. He found new energy levels for the $3s3p^4$ and $3s^23p^24s-7s$, $4p-5p$, $3d-7d$, $4f-7f$, and $5g$ configurations. The levels of the excited configurations are from Pettersson's tables. The $3s^23p^3$ ${}^2D^\circ$ and ${}^2P^\circ$ levels are from measurements of forbidden transitions to the ground level observed in astronomical spectra; the corresponding uncertainties are about ±0.05 cm^{-1} for the ${}^2D^\circ$ levels [weighted averages of measurements from Bowen, 1955; Trauger *et al.*, 1980; Brown, 1983] and ±0.20 cm^{-1} for the ${}^2P^\circ$ levels [Bowen]. Pettersson's estimates of the uncertainties of his wavelength determinations indicate that the connection between the $3s^23p^3$ levels and the excited-configuration levels should be accurate to about ±0.5 cm^{-1}, and the relative uncertainties within the excited-configuration system should be mainly in the range ±0.05 to ±0.3 cm^{-1}.

Pettersson derived the ionization energy using the $3s^23p^2({}^3P_2)nf\ {}^2[5]^\circ_{11/2}$ series ($n=4-7$) and the $({}^3P_2)\ 5g\ {}^2[6]_{13/2}$ level. His estimated uncertainty of ±2 cm^{-1} for the S III (${}^3P_2$) limit would also apply to the (${}^3P_0$) principal limit and to the (${}^3P_1$) limit.

The high configurational and *LS*-coupling purities of the $3s^23p^3$ ground-configuration levels are evident from the leading percentages as tabulated (to the nearest percent) from a calculation of $3s^23p^3+3p^5$ by Cowan, but we mention here Cowan's more precise percentages for these important levels. The eigenvectors for the $3s^23p^3$ ${}^2P^\circ$ levels each have a 1.48% $3p^5$ ${}^2P^\circ$ contribution, and there is a 0.45% mutual intermediate-coupling mixture of $3s^23p^3$ ${}^2P^\circ_{3/2}$ and ${}^2D^\circ_{3/2}$. A 0.035% ${}^4S^\circ_{3/2}$, ${}^2P^\circ_{3/2}$ mixing accounts for most of the impurity of the ${}^4S^\circ_{3/2}$ ground-level eigenvector.

Pettersson calculated the levels of the $3s^23p^24p+3s^23p^25p$ and $3s^23p^24f+3s^23p^25f$ configurations including the indicated configuration interactions. The leading percentages for the levels of these configurations given here are from his calculations, which included least-squares level fitting. The first percentage given for the $3p^24f$ and $3p^25f$ levels pertains to the J_1l-coupling scheme that best names these levels, the largest percentage in the *LS* scheme being given after the word "or".

The eigenvector percentages given for even-parity levels are from a calculation by Cowan that included the interactions between $3s3p^4$, $3s^23p^23d-6d$, $3s^23p^24s-7s$, and several higher $3s^23p^2nd$ and ϵd mock configurations. As noted by Pettersson in discussing an earlier, less complete calculation, the compositions of some of the eigenvectors show strong mixtures, "especially in the doublet system." Practically all of the $3s3p^4$ ${}^2P$ composition is distributed amongst eigenvectors having mainly $3s^23p^2nd$ character. The term most appropriate for the $3s3p^4$ ${}^2P$ designation (near 145 500 cm^{-1}) is near the "unperturbed" $3s3p^4$ ${}^2P$ position obtained from a calculation omitting the configuration interactions, and retains ~35% $3s3p^4$ ${}^2P$ character. Interaction with $3s3p^4$ ${}^2P$ is mainly responsible for a large downward displacement of the $3s^23p^2({}^3P)3d$ ${}^2P$ term (near 106 000 cm^{-1}, with 17% $3s3p^4$ ${}^2P$ composition), a large upward displacement of the $({}^3P)4d$ ${}^2P$ term (near 159 000 cm^{-1}, with ~24% $3s3p^4$ ${}^2P$ composition), and smaller upward displacements of other higher $3s^23p^2nd$ levels. The term names as given here, which are consistent with this interpretation based on Cowan's recent calculations, involve an interchange of the previous $3s3p^4$ ${}^2P$ and $3s^23p^2$ $({}^3P)4d$ ${}^2P$ designations. The nominal $3s^23p^2$ $({}^3P)3d$ ${}^2F$ and $({}^1D)3d$ ${}^2F$ terms, given here as designated by Pettersson, have eigenvectors with almost equal mixtures of these two ${}^2F$ terms.

The overall agreement between Cowan's predicted even levels and the experimental positions is quite satisfactory. The $3s^23p^2({}^1D)3d$ ${}^2S_{1/2}$ level given by Pettersson at 151 651.72 cm^{-1} is an exception, the calculated position being 22 cm^{-1} below the $({}^3P)5s$ ${}^4P_{1/2}$ level (experimental value 150 258.51 cm^{-1}). The eigenvectors belonging mainly to $({}^1D)3d$ ${}^2S_{1/2}$ and $3s3p^4$ ${}^2S_{1/2}$ have strong mutual mixtures, as may be seen from the percentages for the $3s3p^4$ ${}^2S_{1/2}$ level at 119 783.77 cm^{-1}. The nominal $({}^1D)3d$ ${}^2S_{1/2}$ eigenvector also has a 21% $({}^3P)5s$ ${}^4P_{1/2}$ component, however, because of the accidental closeness of the calculated positions of these two levels; since this mixture would not occur for the relatively large experimental separation of the $({}^1D)3d$ ${}^2S_{1/2}$ and $({}^3P)5s$ ${}^4P_{1/2}$ levels given by Pettersson, we have omitted the calculated percentages for both levels.

References

Aymar, M. [1973], Physica (Utrecht) **66**, 364–379. AT

Bloch, L., and Bloch, E. [1929], Ann. Phys. (Paris) [10]12, 1–22. EL CL

Bowen, I. S. [1955], Astrophys. J. **121**, 306–311. CL

Brown, R. A. [1983], Astrophys. J. **268**, L47–L50. W

Cowan, R. D. [1984], unpublished material. AT

Gilles, M. [1931], Ann. Phys. (Paris) [10]15, 19–410. EL CL ZE IP

Ho, Y. K., and Henry, R. J. W. [1983], Astrophys. J. 267, 886–890. AT

Hunter, A. [1934], Philos. Trans. R. Soc. London, Ser. A 233, 303–326. EL CL IP

Ingram, S. B. [1928], Phys, Rev. 32, 172–178. EL CL IP

Pettersson, J. E. [1983], Phys. Scr. 28, 421–434. EL CL IP SF PT AT. Pettersson supplied the eigenvectors obtained from his calculations of the $3p^3(4p + 5p)$ and $(4f + 5f)$ configurations for this compilation.

Trauger, J. T., Münch, G., and Roesler, F. L. [1980], Astrophys. J. 236, 1035–1042. W

S II

Configuration	Term	J	Level (cm⁻¹)	Leading percentages		
$3s^23p^3$	$^4S^\circ$	$^3/_2$	*0.00*	100		
$3s^23p^3$	$^2D^\circ$	$^3/_2$	*14 852.94*	100		
		$^5/_2$	*14 884.73*	100		
$3s^23p^3$	$^2P^\circ$	$^1/_2$	*24 524.83*	99	1	$3p^5\ ^2P^\circ$
		$^3/_2$	*24 571.54*	98	1	"
$3s3p^4$	^4P	$^5/_2$	79 395.39	85	13	$3s^23p^2(^3P)3d\ ^4P$
		$^3/_2$	79 756.83	85	13	"
		$^1/_2$	79 962.61	85	13	"
$3s3p^4$	^2D	$^3/_2$	97 890.74	67	26	$3s^23p^2(^1D)3d\ ^2D$
		$^5/_2$	97 918.86	67	26	"
$3s^23p^2(^3P)3d$	^2P	$^3/_2$	105 599.06	72	17	$3s3p^4\ ^2P$
		$^1/_2$	106 044.24	71	17	"
$3s^23p^2(^3P)4s$	^4P	$^1/_2$	109 560.69	99		
		$^3/_2$	109 831.59	99		
		$^5/_2$	110 268.60	100		
$3s^23p^2(^3P)3d$	^4F	$^3/_2$	110 177.02	98	1	$3s^23p^2(^3P)4d\ ^4F$
		$^5/_2$	110 313.40	98	1	"
		$^7/_2$	110 508.71	98	1	"
		$^9/_2$	110 766.56	98	1	"
$3s^23p^2(^3P)4s$	^2P	$^1/_2$	112 937.57	95	2	$3s^23p^2(^3P)3d\ ^2P$
		$^3/_2$	113 461.54	96	1	"
$3s^23p^2(^3P)3d$	^4D	$^1/_2$	114 162.30	99	1	$3s^23p^2(^3P)4d\ ^4D$
		$^3/_2$	114 200.54	99	1	"
		$^5/_2$	114 231.04	98	1	"
		$^7/_2$	114 279.33	97	1	$3s^23p^2(^1D)3d\ ^2F$
$3s^23p^2(^3P)3d$	^2F	$^5/_2$	114 804.37	49	49	$3s^23p^2(^1D)3d\ ^2F$
		$^7/_2$	115 285.61	47	49	"
$3s3p^4$	^2S	$^1/_2$	119 783.77	62	37	$3s^23p^2(^1D)3d\ ^2S$
$3s^23p^2(^1D)4s$	^2D	$^3/_2$	121 528.72	98	1	$3s^23p^2(^3P)3d\ ^2D$
		$^5/_2$	121 530.02	99		
$3s^23p^2(^3P)4p$	$^2S^\circ$	$^1/_2$	*125 485.29*	98	2	$3s^23p^2(^3P)5p\ ^2S^\circ$
$3s^23p^2(^1D)3d$	^2G	$^7/_2$	127 127.10	100		
		$^9/_2$	127 128.35	100		

S II — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^2(^3P)4p$	$^4D^\circ$	1/2	*127 825.08*	99		
		3/2	*127 976.34*	98	1	$3s^23p^2(^3P)4p$ $^4P^\circ$
		5/2	*128 233.20*	98	1	"
		7/2	*128 599.16*	99		
$3s^23p^2(^3P)4p$	$^4P^\circ$	1/2	*129 787.83*	99		
		3/2	*129 858.18*	89	8	$3s^23p^2(^3P)4p$ $^4S^\circ$
		5/2	*130 134.16*	94	4	$3s^23p^2(^3P)4p$ $^2D^\circ$
$3s^23p^2(^3P)3d$	^4P	5/2	130 602.21	85	10	$3s3p^4$ ^4P
		3/2	130 818.85	85	11	"
		1/2	130 948.94	85	11	"
$3s^23p^2(^3P)4p$	$^2D^\circ$	3/2	*130 641.11*	88	10	$3s^23p^2(^1D)4p$ $^2D^\circ$
		5/2	*131 187.19*	88	9	"
$3s^23p^2(^3P)4p$	$^4S^\circ$	3/2	*131 028.85*	89	9	$3s^23p^2(^3P)4p$ $^4P^\circ$
$3s^23p^2(^3P)4p$	$^2P^\circ$	1/2	*133 268.68*	91	6	$3s^23p^2(^1D)4p$ $^2P^\circ$
		3/2	*133 399.97*	90	8	"
$3s^23p^2(^3P)3d$	^2D	3/2	133 360.86	82	10	$3s^23p^2(^1S)3d$ ^2D
		5/2	133 814.84	83	9	"
$3s^23p^2(^1S)4s$	^2S	1/2	136 328.79	95	2	$3s^23p^2(^1D)3d$ ^2S
$3s^23p^2(^1D)3d$	^2F	5/2	138 509.17	42	44	$3s^23p^2(^3P)3d$ ^2F
		7/2	138 527.98	42	44	"
$3s^23p^2(^1D)3d$	^2P	1/2	139 844.99	90	3	$3s^23p^2(^3P)3d$ ^2P
		3/2	140 016.77	90	4	$3s3p^4$ ^2P
$3s^23p^2(^1D)4p$	$^2F^\circ$	5/2	*140 230.10*	97	3	$3s^23p^2(^1D)4p$ $^2D^\circ$
		7/2	*140 319.23*	100		
$3s^23p^2(^1D)4p$	$^2D^\circ$	5/2	*140 708.89*	86	10	$3s^23p^2(^3P)4p$ $^2D^\circ$
		3/2	*140 750.34*	88	10	"
$3s^23p^2(^1D)4p$	$^2P^\circ$	1/2	*143 488.95*	91	6	$3s^23p^2(^3P)4p$ $^2P^\circ$
		3/2	*143 623.56*	89	8	"
$3s^23p^2(^1D)3d$	^2D	5/2	144 009.42	64	14	$3s^23p^2(^1S)3d$ ^2D
		3/2	144 142.16	64	14	$3s3p^4$ ^2D
$3s3p^4$	^2P	3/2	145 505.74	35	42	$3s^23p^2(^3P)4d$ ^2P
		1/2	145 877.66	36	42	"
$3s^23p^2(^1S)3d$	^2D	5/2	148 886.57	64	14	$3s^23p^2(^3P)4d$ ^2D
		3/2	148 900.91	64	15	"
$3s^23p^2(^3P)5s$	^4P	1/2	150 258.51			
		3/2	150 531.31	98	2	$3s^23p^2(^3P)5s$ ^2P
		5/2	150 996.41	99	1	$3s^23p^2(^3P)4d$ ^4P
$3s^23p^2(^3P)5s$	^2P	1/2	151 383.81	97	1	$3s^23p^2(^3P)4d$ ^2P
		3/2	151 910.83	96	2	$3s^23p^2(^3P)5s$ ^4P
$3s^23p^2(^1D)3d$	^2S	1/2	151 651.72			

S II — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s^23p^2(^3P)4d$	^4F	$^3/_2$	151 959.69	96		2	$3s^23p^2(^3P)4d\ ^4D$
		$^5/_2$	152 094.64	95		3	″
		$^7/_2$	152 305.00	94		4	″
		$^9/_2$	152 615.46	98		1	$3s^23p^2(^3P)3d\ ^4F$
$3s^23p^2(^3P)4d$	^4D	$^1/_2$	153 153.90	99		1	$3s^23p^2(^3P)3d\ ^4D$
		$^3/_2$	153 201.95	97		2	$3s^23p^2(^3P)4d\ ^4F$
		$^5/_2$	153 283.07	95		3	″
		$^7/_2$	153 413.74	95		4	″
$3s^23p^2(^3P)4d$	^4P	$^5/_2$	155 818.71	94		2	$3s3p^4\ ^4P$
		$^3/_2$	156 029.54	94		2	″
		$^1/_2$	156 148.48	94		2	″
$3s^23p^2(^3P)4d$	^2F	$^5/_2$	156 121.70	78		12	$3s^23p^2(^1D)4d\ ^2F$
		$^7/_2$	156 604.17	79		11	″
$3s^23p^2(^1S)4p$	$^2P^\circ$	$^1/_2$	*156 167.04*	85		5	$3s^23p^2(^3P)5p\ ^2S^\circ$
		$^3/_2$	*156 276.83*	92		5	$3s^23p^2(^1D)5p\ ^2P^\circ$
$3s^23p^2(^3P)5p$	$^4D^\circ$	$^1/_2$	*156 829.75*	95		4	$3s^23p^2(^3P)5p\ ^2S^\circ$
		$^3/_2$	*156 939.50*	92		6	$3s^23p^2(^3P)5p\ ^4P^\circ$
		$^5/_2$	*157 173.69*	92		6	″
		$^7/_2$	*157 558.77*	99			
$3s^23p^2(^3P)5p$	$^4P^\circ$	$^3/_2$	*157 579.68*	55		37	$3s^23p^2(^3P)5p\ ^4S^\circ$
		$^1/_2$	*157 677.32*	95		3	$3s^23p^2(^3P)5p\ ^2S^\circ$
		$^5/_2$	*158 038.60*	90		7	$3s^23p^2(^3P)5p\ ^4D^\circ$
$3s^23p^2(^3P)5p$	$^4S^\circ$	$^3/_2$	*158 118.75*	51		37	$3s^23p^2(^3P)5p\ ^4P^\circ$
$3s^23p^2(^3P)5p$	$^2D^\circ$	$^3/_2$	*158 215.59*	86		9	$3s^23p^2(^3P)5p\ ^4S^\circ$
		$^5/_2$	*158 715.46*	94		4	$3s^23p^2(^3P)5p\ ^4P^\circ$
$3s^23p^2(^3P)4d$	^2P	$^3/_2$	158 828.31	43		22	$3s3p^4\ ^2P$
		$^1/_2$	159 283.66	50		25	″
$3s^23p^2(^3P)4d$	^2D	$^5/_2$	159 492.83	73		9	$3s^23p^2(^3P)5d\ ^2D$
		$^3/_2$	159 495.94	62		8	$3s^23p^2(^3P)5d\ ^2P$
$3s^23p^2(^3P_0)4f$	$^2[3]^\circ$	$^5/_2$	*160 104.11*	95	or	44	$3s^23p^2(^3P)4f\ ^4G^\circ$
		$^7/_2$	*160 128.90*	91	or	57	$3s^23p^2(^3P)4f\ ^4D^\circ$
$3s^23p^2(^3P_1)4f$	$^2[3]^\circ$	$^5/_2$	*160 258.03*	99	or	52	$3s^23p^2(^3P)4f\ ^4G^\circ$
		$^7/_2$	*160 284.24*	93	or	41	″
$3s^23p^2(^3P_1)4f$	$^2[4]^\circ$	$^9/_2$	*160 442.67*	94	or	74	$3s^23p^2(^3P)4f\ ^4G^\circ$
		$^7/_2$	*160 483.16*	90	or	57	$3s^23p^2(^3P)4f\ ^2G^\circ$
$3s^23p^2(^3P_1)4f$	$^2[2]^\circ$	$^3/_2$	*160 462.24*	86	or	46	$3s^23p^2(^3P)4f\ ^2D^\circ$
		$^5/_2$	*160 467.51*	84	or	70	$3s^23p^2(^3P)4f\ ^4D^\circ$
$3s^23p^2(^3P_2)4f$	$^2[1]^\circ$	$^3/_2$?	*160 733.68*	99	or	52	$3s^23p^2(^3P)4f\ ^4D^\circ$
		$^1/_2$?		99	or	100	″
$3s^23p^2(^3P_2)4f$	$^2[5]^\circ$	$^{11}/_2$	*160 828.69*	99	or	100	$3s^23p^2(^3P)4f\ ^4G^\circ$
		$^9/_2$	*160 920.95*	98	or	80	$3s^23p^2(^3P)4f\ ^2G^\circ$

S II — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s^23p^2(^3P_2)4f$	$^2[2]^\circ$	$3/2$	*161 221.05*	85	or	88	$3s^23p^2(^3P)4f\ ^4F^\circ$
		$5/2$	*161 253.47*	70	or	74	″
$3s^23p^2(^3P_2)4f$	$^2[4]^\circ$	$7/2$	*161 329.65*	80	or	88	$3s^23p^2(^3P)4f\ ^4F^\circ$
		$9/2$	*161 360.19*	94	or	91	″
$3s^23p^2(^3P_2)4f$	$^2[3]^\circ$	$5/2$	*161 386.45*	79	or	76	$3s^23p^2(^3P)4f\ ^2F^\circ$
		$7/2$	*161 454.96*	79	or	91	″
$3s^23p^2(^1D)5s$	^2D	$5/2$	161 733.10	99		1	$3s^23p^2(^1D)4d\ ^2D$
		$3/2$	161 737.99	99		1	″
$3s^23p^2(^1D)4d$	^2G	$7/2$	164 181.17	87		10	$3s^23p^2(^1D)4d\ ^2F$
		$9/2$	164 268.79	100			
$3s^23p^2(^1D)4d$	^2F	$5/2$	164 232.36	65		25	$3s^23p^2(^3P)5d\ ^2F$
		$7/2$	164 337.61	59		19	″
$3s^23p^2(^3P)6s$	^4P	$1/2$	165 719.23	95		5	$3s^23p^2(^3P)6s\ ^2P$
		$3/2$	165 991.35	95		5	″
		$5/2$	166 479.82	99		1	$3s^23p^2(^3P)5d\ ^4P$
$3s^23p^2(^1D)4d$	^2P	$1/2$	166 151.61	80		17	$3s^23p^2(^3P)5d\ ^2P$
		$3/2$	166 185.47	63		18	″
$3s^23p^2(^3P)6s$	^2P	$1/2$	166 331.19	94		5	$3s^23p^2(^3P)6s\ ^4P$
		$3/2$	166 862.71	93		4	″
$3s^23p^2(^3P)5d$	^4F	$3/2$	166 591.08	79		13	$3s^23p^2(^1D)4d\ ^2P$
		$5/2$	166 709.27	87		11	$3s^23p^2(^3P)5d\ ^4D$
		$7/2$	166 918.27	85		13	″
		$9/2$	167 269.15	98		1	$3s^23p^2(^3P)4d\ ^4F$
$3s^23p^2(^3P)5d$	^4D	$1/2$	167 254.84	98		1	$3s^23p^2(^1D)4d\ ^2P$
		$3/2$	167 291.84	91		5	$3s^23p^2(^3P)5d\ ^4F$
		$5/2$	167 364.98	83		11	″
		$7/2$	167 575.23	86		13	″
$3s^23p^2(^1D)4d$	^2D	$3/2$	167 472.42	83		6	$3s^23p^2(^3P)5d\ ^2D$
		$5/2$	167 506.39	80		7	″
$3s^23p^2(^3P)5d$	^4P	$5/2$	168 217.10	89		5	$3s^23p^2(^3P)5d\ ^4D$
		$3/2$	168 397.89	94		3	″
		$1/2$	168 490.43	96		1	$3s^23p^2(^3P)6d\ ^4P$
$3s^23p^2(^1D)5p$	$^2F^\circ$	$5/2$	*168 443.14*	98		1	$3s^23p^2(^1D)5p\ ^2D^\circ$
		$7/2$	*168 473.48*	100			
$3s^23p^2(^1D)4d$	^2S	$1/2$	169 109.54	80		6	$3s^23p^2(^1D)5d\ ^2S$
$3s^23p^2(^3P)5d$	^2F	$5/2$	169 283.54	62		15	$3s^23p^2(^1D)4d\ ^2F$
		$7/2$	169 702.32	72		14	″
$3s^23p^2(^3P)5d$	^2P	$3/2$	169 340.39	37		28	$3s^23p^2(^3P)5d\ ^2D$
		$1/2$	169 687.52	66		12	$3s^23p^2(^1D)4d\ ^2P$
$3s^23p^2(^3P)5d$	^2D	$3/2$	169 922.27	49		24	$3s^23p^2(^3P)5d\ ^2P$
		$5/2$	170 015.23	70		6	$3s^23p^2(^3P)6d\ ^2D$

S II — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s^23p^2(^3P_0)5f$	$^2[3]^\circ$	$5/2$	*170 254.81*	97	or	61	$3s^23p^2(^3P)5f\ ^4G^\circ$
		$7/2$	*170 298.18*	97	or	29	$3s^23p^2(^3P)5f\ ^4D^\circ$
$3s^23p^2(^3P_1)5f$	$^2[3]^\circ$	$5/2$	*170 497.03*	98	or	49	$3s^23p^2(^3P)5f\ ^2D^\circ$
		$7/2$	*170 504.91*	97	or	58	$3s^23p^2(^3P)5f\ ^4D^\circ$
$3s^23p^2(^3P_1)5f$	$^2[4]^\circ$	$9/2$	*170 587.24*	97	or	66	$3s^23p^2(^3P)5f\ ^4G^\circ$
		$7/2$	*170 620.00*	93	or	50	$3s^23p^2(^3P)5f\ ^2G^\circ$
$3s^23p^2(^3P_0)5g$	$^2[4]$	$7/2$	170 621.45				
		$9/2$	170 621.87				
$3s^23p^2(^3P_1)5f$	$^2[2]^\circ$	$3/2$	*170 647.95*	95	or	36	$3s^23p^2(^3P)5f\ ^2D^\circ$
		$5/2$	*170 663.13*	93	or	56	$3s^23p^2(^3P)5f\ ^4D^\circ$
$3s^23p^2(^3P_1)5g$	$^2[4]$	$7/2$	170 872.25				
		$9/2$	170 872.45				
$3s^23p^2(^3P_1)5g$	$^2[5]$	$11/2$	170 935.64				
		$9/2$	170 936.19				
$3s^23p^2(^3P_1)5g$	$^2[3]$	$5/2$	170 950.25				
		$7/2$	170 950.51				
$3s^23p^2(^1D_2)4f$	$^2[4]^\circ$	$9/2$	*170 965.87*	50	or	50	$3s^23p^2(^1D)4f\ ^2G^\circ$
		$7/2$	*171 007.91*	97	or	97	"
$3s^23p^2(^3P_2)5f$	$^2[1]^\circ$	$3/2?$	*171 000.19*	99	or	50	$3s^23p^2(^3P)5f\ ^4D^\circ$
		$1/2?$		99	or	100	"
$3s^23p^2(^3P_2)5f$	$^2[5]^\circ$	$11/2$	*171 015.64*	99	or	100	$3s^23p^2(^3P)5f\ ^4G^\circ$
		$9/2$	*171 125.40*	49	or	48	$3s^23p^2(^1D)4f\ ^2G^\circ$
$3s^23p^2(^3P_2)5f$	$^2[2]^\circ$	$3/2$	*171 182.67*	94	or	70	$3s^23p^2(^3P)5f\ ^4F^\circ$
		$5/2$	*171 204.27*	82	or	57	"
$3s^23p^2(^1D_2)4f$	$^2[3]^\circ$	$5/2$	*171 188.98*	99	or	100	$3s^23p^2(^1D)4f\ ^2F^\circ$
		$7/2$	*171 189.39*	99	or	100	"
$3s^23p^2(^3P_2)5f$	$^2[4]^\circ$	$7/2$	*171 263.87*	79	or	81	$3s^23p^2(^3P)5f\ ^4F^\circ$
		$9/2$	*171 281.29*	96	or	83	"
$3s^23p^2(^3P_2)5f$	$^2[3]^\circ$	$5/2$	*171 304.92*	85	or	64	$3s^23p^2(^3P)5f\ ^2F^\circ$
		$7/2$	*171 358.13*	77	or	84	"
$3s^23p^2(^3P_2)5g$	$^2[6]$	$13/2$	171 420.85				
		$11/2$	171 421.02				
$3s^23p^2(^3P_2)5g$	$^2[5]$	$11/2$	171 495.44				
		$9/2$					
$3s^23p^2(^1D_2)4f$	$^2[2]^\circ$	$3/2,5/2$	*171 778.83*	99	or	100	$3s^23p^2(^1D)4f\ ^2D^\circ$
$3s^23p^2(^1D_2)4f$	$^2[5]^\circ$	$9/2,11/2$	*171 821.87*	99	or	100	$3s^23p^2(^1D)4f\ ^2H^\circ$
$3s^23p^2(^1D_2)4f$	$^2[1]^\circ$	$1/2,3/2$	*172 363.71*	99	or	100	$3s^23p^2(^1D)4f\ ^2P^\circ$

S II — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s^23p^2(^3P)7s$	^4P	$^1/_2$	173 316.83	89		10	$3s^23p^2(^3P)7s\ ^2P$
		$^3/_2$	173 595.77	92		8	"
		$^5/_2$	174 098.10	98		1	$3s^23p^2(^3P)6d\ ^4F$
$3s^23p^2(^3P)7s$	^2P	$^1/_2$	173 749.01	89		10	$3s^23p^2(^3P)7s\ ^4P$
		$^3/_2$	174 274.52	84		7	"
$3s^23p^2(^3P)6d$	^4D	$^1/_2$		96		2	$3s^23p^2(^3P)6d\ ^2P$
		$^3/_2$	174 329.31	76		9	$3s^23p^2(^3P)6d\ ^4F$
		$^5/_2$	174 360.92	61		20	"
		$^7/_2$		75		24	"
$3s^23p^2(^3P)6d$	^4F	$^3/_2$		88		9	$3s^23p^2(^3P)6d\ ^4D$
		$^5/_2$		75		20	"
		$^7/_2$		74		23	"
		$^9/_2$	174 529.27	99		1	$3s^23p^2(^3P)5d\ ^4F$
$3s^23p^2(^3P)6d$	^4P	$^5/_2$	174 892.75	78		17	$3s^23p^2(^3P)6d\ ^4D$
		$^3/_2$	175 019.78	80		8	$3s^23p^2(^3P)6d\ ^2P$
		$^1/_2$	175 083.51	95		2	$3s^23p^2(^3P)6d\ ^4D$
$3s^23p^2(^3P_2)6f$	$^2[5]^\circ$	$^{11}/_2$	*176 559.84*				
		$^9/_2$	*176 614.70*				
$3s^23p^2(^3P_2)6f$	$^2[4]^\circ$	$^7/_2$	*176 701.13*				
		$^9/_2$	*176 712.51*				
$3s^23p^2(^1D)6s$	^2D	$^5/_2$	177 076.28	99		1	$3s^23p^2(^1D)5d\ ^2D$
		$^3/_2$	177 077.02	99		1	"
$3s^23p^2(^1D)5d$	^2G	$^7/_2$	178 173.39	89		9	$3s^23p^2(^1D)5d\ ^2F$
		$^9/_2$	178 240.64				
$3s^23p^2(^3P)7d$	^4D	$^1/_2$					
		$^3/_2$					
		$^5/_2$	178 344.36				
		$^7/_2$					
$3s^23p^2(^3P)7d$	^4P	$^5/_2$	178 848.96				
		$^3/_2$	178 915.20				
		$^1/_2$	178 969.32				
$3s^23p^2(^3P_2)7f$	$^2[5]^\circ$	$^{11}/_2$	*179 899.86*				
		$^9/_2$					
$3s^23p^2(^1D_2)5f$	$^2[4]^\circ$	$^7/_2,^9/_2$	*181 340.51*	99	or	100	$3s^23p^2(^1D)5f\ ^2G^\circ$
$3s^23p^2(^1D_2)5f$	$^2[3]^\circ$	$^5/_2,^7/_2$	*181 457.92*	99	or	100	$3s^23p^2(^1D)5f\ ^2F^\circ$
$3s^23p^2(^1D_2)5f$	$^2[5]^\circ$	$^9/_2,^{11}/_2$	*181 732.04*	99	or	100	$3s^23p^2(^1D)5f\ ^2H^\circ$
$3s^23p^2(^1D_2)5f$	$^2[2]^\circ$	$^3/_2,^5/_2$	*181 770.40*	99	or	100	$3s^23p^2(^1D)5f\ ^2D^\circ$
$3s^23p^2(^1D_2)5f$	$^2[1]^\circ$	$^1/_2,^3/_2$	*182 120.47*	99	or	100	$3s^23p^2(^1D)5f\ ^2P^\circ$
$3s^23p^2(^1D)7s$	^2D	$^3/_2,^5/_2$	184 642.76	99		1	$3s^23p^2(^1D)6d\ ^2D$
$3s^23p^2(^1S_0)4f$	$^2[3]^\circ$	$^5/_2,^7/_2$	*187 205.63?*	100	or	100	$3s^23p^2(^1S)4f\ ^2F^\circ$

S II — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
S III ($^3P_0$)	*Limit*		188 232.7	
S III ($^3P_1$)	*Limit*		188 531.6	
S III ($^3P_2$)	*Limit*		189 066.0	
S III ($^1D_2$)	*Limit*		199 555	
S III ($^1S_0$)	*Limit*		215 394	

S III

$Z=16$

Si I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^2\ {}^3P_0$

Ionization energy 280 600 cm^{-1} (34.79 eV)

The analysis of this spectrum has been carried out mainly by Ingram [1929], Gilles [1931], Hunter [1934], and Robinson [1937]. Kaufman has obtained more accurate wavelengths for most of the classified lines in the 677–1202 Å region from spectrograms taken with the NIST 10.7-m normal-incidence spectrograph. Smith *et al.* [1984] accurately measured the two $3s^23p^2\ {}^3P_{2,1}-3s3p^3\ {}^5S_2^\circ$ lines, which Moos *et al.* [1983] first identified in the spectrum of the plasma torus associated with Io (a moon of Jupiter).

We evaluated the levels of the $3s^23p^2$ ground configuration from the wavelengths of forbidden lines observed in astronomical nebular spectra. The ${}^3P_0-{}^3P_1$ interval is from Graf [1988] and Colgan *et al.* [1990], and the ${}^3P_1-{}^3P_2$ interval is from Baluteau *et al.* [1976], the estimated uncertainties being ±0.02 and ±0.01 cm^{-1}, respectively. The ${}^1S_0$ and ${}^1D_2$ levels were evaluated by using the ${}^3P_1-{}^1S_0$ and ${}^1D_2-{}^1S_0$ wavenumbers, with respective uncertainties of ±0.7 cm^{-1} [Bowen, 1960] and ±0.1 cm^{-1} [Bowen, 1955].

We have reevaluated the levels of the excited configurations using the available data and the $3s^23p^2$ level values given here. The estimated wavelength uncertainty of the $3s3p^3\ {}^5S_2^\circ$ lines [Smith *et al.*, 1984] indicates an error of less than 0.15 cm^{-1} for this level. The positions of most of the other excited-configuration levels relative to the ground configuration are based on Kaufman's measurements; in most cases the uncertainty is probably less than 1 cm^{-1}. The relative positions *within* the group of higher levels given to two decimal places are from Hunter, and the $3s^23p4s\ {}^1P^\circ$ and $3s^23p5s\ {}^3P^\circ$ levels are also determined relative to this group [Hunter, 1934; Robinson, 1937]. Kaufman's measurements place this entire group of levels 1.0 cm^{-1} higher than the connection adopted by Robinson. The $3s3p^3\ {}^1P_1^\circ$ and $3s^23p5s\ {}^1P_1^\circ$ levels are based on the older measurements of Robinson or Bloch and Bloch and may have errors of several cm^{-1}.

The eigenvector percentages for the $3s3p^3$ and $3s^23p3d$ levels are from Fawcett's calculation, which included the $3s3p^3$, $3s^23p3d$, $3s^23p4s$, $3s3p3d^2$, and $3p^33d$ configurations with their interactions. Fawcett's results support the designation $3s^23p3d\ {}^1D_2^\circ$ for the level at 104 159 cm^{-1}, this change from the former $3s3p^3\ {}^1D_2^\circ$ designation having been proposed by Ho and Henry. Our new tentative value of 151 978.9 cm^{-1} for the nominal $3s3p^3\ {}^1D_2^\circ$ level is based on the classification of a strong line at 710.951 Å [Kaufman, 1971] as the $3s^23p^2\ {}^1D_2-3s3p^3\ {}^1D_2^\circ$ transition. Beyer *et al.* [1973] and Dumont *et al.* [1978] assigned this line to S III on experimental evidence, and the resulting $3s3p^3\ {}^1D_2^\circ$ position is only 762 cm^{-1} below Fawcett's calculated value. The experimental lifetime measured by Dumont *et al.* is roughly consistent with the oscillator strength of the proposed transition as calculated by Fawcett and by Ho and Henry.

We derived the ionization energy by extrapolating the accurately known behavior of the quantum defects for the $3s^23p4s$ and $5s$ series in Si I and P II. The available calculations for Si I, P II, and S III indicate, at most, small perturbations of these series due to configuration interactions. The consistency of the series extrapolations indicates that the adopted ionization energy is probably accurate within a few hundred cm^{-1}. The value here agrees well with the value 280 900 cm^{-1} obtained by Edlén [1964] using a semiempirical isoionic method.

References

Baluteau, J. P., Bussoletti, E., Anderegg, M., Moorwood, A. F. M., and Coron, N. [1976], Astrophys. J. **210**, L45–L48. CL

Beyer, L. M., Maddox, W. E., and Bridwell, L. B. [1973], J. Opt. Soc. Am. **63**, 365–369. CL W

Bloch, L., and Bloch, E. [1935], J. Phys. Radium [7]**6**, 441–450. CL

Bowen, I. S. [1955], Astrophys. J. **121**, 306–311. CL

Bowen, I. S. [1960], Astrophys. J. **132**, 1–17. CL

Colgan, S. W. J., Simpson, J. P., Rubin, R. H., Erickson, E. F., Haas, M. R., and Wolf, J. [1990], submitted to Astrophys. J. EL

Dumont, P. D., Garnir, H. P., and Baudinet-Robinet, Y. [1978], J. Opt. Soc. Am. **68**, 825–829. W

Edlén, B. [1964], in *Encyclopedia of Physics*, S. Flügge, Ed., Vol. **27**, p. 212 (Springer-Verlag, Berlin). IP

Fawcett, B. C. [1987], At. Data Nucl. Data Tables **36**, 129–149. AT PT

Gilles, M. [1931], Ann. Phys. (Paris) [10]**15**, 267–410. EL CL

Graf, P. H. [1988], *A Fabry-Perot for Airborne Infrared Astronomy and the [Si II] Emission from the Galactic Center*, Ph.D Thesis, Cornell Univ., CRSR 889. CL. Graf obtained a wavelength of 33.482±0.002 μm for the S III ${}^3P_0-{}^3P_1$ ground-term interval assuming $V_{LSR}=0$ for the Omega Nebula source. Correction to $V_{LSR}=17$ km/s for the central region of this nebula [E. C. Reifenstein, III *et al.*, 1970, Astron. Astrophys. **4**, 357–377] yields a rest wavelength of 33.480±0.002 μm, in exact agreement with the determination of Colgan *et al.*

Ho, Y. K., and Henry, R. J. W. [1984], Astrophys. J. **282**, 816–819. AT

Hunter, A. [1934], Philos. Trans. R. Soc. London, Ser. A **233**, 303–326. EL CL

Ingram, S. B. [1929], Phys. Rev. **33**, 907–913. EL CL IP

Kaufman, V. [1971], unpublished material. EL CL

Moos, H. W., Durrance, S. T., Skinner, T. E., Feldman, P. D., Bertaux, J. L., and Festou, M. C. [1983], Astrophys. J. **275**, L19–L23. CL

Robinson, H. A., and Shortley, G. H. [1937], Phys. Rev. **52**, 724–725. EL CL

Smith, P. L., Magnusson, C. E., Zetterberg, P. O. [1984], Astrophys. J. **277**, L79–L81. EL CL

S III

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^2$	^{3}P	0	0.00			
		1	298.69			
		2	833.08			
$3s^23p^2$	^{1}D	2	11 322.2			
$3s^23p^2$	^{1}S	0	27 160.5			
$3s3p^3$	^{5}S°	2	*58 671.92*	99		
$3s3p^3$	^{3}D°	1	*84 018.9*	81	16	$3s^23p3d$ ^{3}D°
		2	*84 046.5*	81	16	"
		3	*84 099.1*	81	16	"
$3s3p^3$	^{3}P°	2	*98 744.8*	77	19	$3s^23p3d$ ^{3}P°
		1	*98 765.2*	78	19	"
		0		78	19	"
$3s^23p3d$	^{1}D°	2	*104 158.7*	61	34	$3s3p^3$ ^{1}D°
$3s3p^3$	^{1}P°	1	*136 841.0*	68	28	$3s^23p3d$ ^{1}P°
$3s3p^3$	^{3}S°	1	*138 066.6*	92		
$3s^23p3d$	^{3}P°	0	*143 096.91*	61	21	$3s^23p4s$ ^{3}P°
		1	*143 117.19*	63	21	"
		2	*143 124.93*	66	16	$3s3p^3$ ^{3}P°
$3s^23p4s$	^{3}P°	0	*146 697.19*			
		1	*146 737.54*			
		2	*147 147.00*			
$3s^23p3d$	^{3}D°	1	*147 551.32*	69	14	$3s^23p3d$ ^{3}P°
		2	*147 691.99*	61	21	$3s^23p4s$ ^{3}P°
		3	*147 745.54*	79	16	$3s3p^3$ ^{3}D°
$3s^23p4s$	^{1}P°	1	*148 398.8*			
$3s3p^3$	^{1}D°	2	*151 978.9*?	59	34	$3s^23p3d$ ^{1}D°
$3s^23p4p$	^{3}D	1	169 771.04			
		2	170 068.31			
		3	170 649.94			
$3s^23p4p$	^{3}P	0	172 632.27			
		1	172 786.77			
		2	173 192.73			
$3s^23p4p$	^{3}S	1	174 037.19			
$3s^23p4d$	^{3}F°	2	*204 579.89*			
		3	*205 071.75*			
		4	*205 561.67*			
$3s^23p4d$	^{3}D°	1	*206 539.87*			
		2	*206 672.61*			
		3	*206 911.97*			

S III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p5s$	$^3P^\circ$	0	*209 774.4*	
		1	*209 927.1*	
		2	*210 698.6*	
$3s^23p5s$	$^1P^\circ$	1	*211 327.8*	
……………………	……………	……	……………………	
S IV ($^2P^\circ_{1/2}$)	***Limit***		***280 600***	

S IV

$Z=16$

Al I isoelectronic sequence

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

Ionization Energy 380 870 ± 100 cm^{-1} (47.222 ± 0.012 eV)

The values of all levels above the $3s^2 3p$ ground configuration are taken from an ongoing analysis of S IV by Joelsson *et al.* [1989]. These investigators have observed the spectra of sliding-spark and beam-foil sources over the 100–7000 Å region and classified some 700 lines as S IV transitions. The estimated errors of most of the levels with respect to the $3s^2 3p\ ^2P^\circ$ ground-term levels are less than ±1 cm^{-1}, and the relative values of many of the levels are accurate within ±0.2 cm^{-1} or less.

Joelsson *et al.* obtained a value of 951.2 cm^{-1} for the $3s^2 3p\ ^2P^\circ_{1/2}-{}^2P^\circ_{3/2}$ ground term splitting. This value is consistent with the more accurate value given here, which is from unpublished measurements of the corresponding forbidden line as observed in planetary-nebulae spectra [Lacy, 1989; see Rank *et al.* for details of a less accurate earlier astronomical determination]. The estimated uncertainty of Lacy's value is ±0.01 cm^{-1}.

Joelsson *et al.* derived the quoted ionization energy by assuming a value for the quantum defect of the $3s^2 5g\ ^2G$ term based on extrapolation from Si II and P III.

Reistad and Engström have carried out calculations for the S IV configurations of both parities using matrices that included the major expected configuration interactions. The eigenvector percentages here are from their results. The large $3s^2 nd\ ^2D$ components in the eigenvectors of the $3s3p^2\ ^2D$ and $3s3p4p\ ^2D$ terms are notable, as are the strong $3s3p3d\ ^2D^\circ$ and $^2P^\circ$ contributions to the eigenvectors of the $3p^3\ ^2D^\circ$ and $^2P^\circ$ terms, respectively. Most of the calculated $3s3p(^1P^\circ)3d\ ^2F^\circ$ composition is distributed as large second percentages in the eigenvectors of the three lowest $^2F^\circ$ terms (near 242 000, 257 700, and 277 600 cm^{-1}). The leading percentages for both of the higher two of these terms arise from $3s^2(^1S)4f\ ^2F^\circ$. We have designated these higher two terms only as "$b\ ^1F^\circ$" and "$c\ ^1F^\circ$" and thus omitted both $3s3p(^1P^\circ)3d\ ^2F^\circ$ and $3s^2(^1S)4f\ ^2F^\circ$ as names.

Most of the published calculations for S IV were carried out mainly in connection with oscillator strengths for various lines; some references for such calculations are given below.

References

Aashamar, K., Luke, T. M., and Talman, J. D. [1984], Phys. Scr. **30**, 121–134. AT

Bhadra, K., and Henry, R. J. W. [1980], Astrophys. J. **240**, 368–373. AT

Bhatia, A. K., Doschek, G. A., and Feldman, U. [1980], Astron. Astrophys. **86**, 32–35. EL

Bowen, I. S. [1928], Phys. Rev. **31**, 34–38. EL CL

Bowen, I. S. [1932], Phys. Rev. **39**, 8–15. EL CL

Fischer, C. F. [1981], Phys. Scr. **23**, 38–44. AT

Glass, R. [1979], J. Phys. B **12**, 2953–2964. AT

Joelsson, I., Engström, L., Magnusson, K. E., and Zetterberg, P. O. [1989], unpublished material. EL IP

Lacy, J. H. [1989], unpublished material.

Millikan, R. A., and Bowen, I. S. [1925], Phys. Rev. **25**, 600–605. EL CL IP

Rank, D. M., Holtz, J. Z., Geballe, T. R., and Townes, C. H. [1970], Astrophys. J. **161**, L185–L189. CL

Reistad, N., Engström, L. [1989], Phys. Rev. A **39**, 4518–4524, and unpublished material. PT. The unpublished results used here are from Reistad and Engström's extensions of the calculations as described in the published paper.

Smitt, R., Svensson, L. A., and Outred, M. [1976], Phys. Scr. **13**, 293–307. EL W

S IV

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2(^1S)3p$	$^2P^\circ$	1/2	*0.00*	96	2	$3p^3\ ^2P^\circ$
		3/2	*951.43*	96	2	"
$3s3p^2$	^4P	1/2	71 184.5	99		
		3/2	71 528.2	99		
		5/2	72 074.2	99		
$3s3p^2$	^2D	3/2	94 103.3	82	16	$3s^2(^1S)3d\ ^2D$
		5/2	94 150.3	82	16	"

S IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s3p^2$	^2S	$^1/_2$	123 509.5	97		2	$3s(^2S)3d^2(^1S)\ ^2S$
$3s3p^2$	^2P	$^1/_2$	133 619.6	95		3	$3p^2(^1D)3d\ ^2P$
		$^3/_2$	134 245.6	95		3	″
$3s^2(^1S)3d$	^2D	$^3/_2$	152 133.2	80		15	$3s(^2S)3p^2(^1D)\ ^2D$
		$^5/_2$	152 146.8	80		15	″
$3s^2(^1S)4s$	^2S	$^1/_2$	181 448.2	96		3	$3p^2(^1S)4s\ ^2S$
$3p^3$	$^2D^\circ$	$^3/_2$	*185 055.2*	59		40	$3s3p(^3P^\circ)3d\ ^2D^\circ$
		$^5/_2$	*185 148.0*	59		40	″
$3p^3$	$^4S^\circ$	$^3/_2$	*196 455.4*	99		1	$3p(^2P^\circ)3d^2(^3P)\ ^4S^\circ$
$3s3p(^3P^\circ)3d$	$^4F^\circ$	$^3/_2$	*203 442.1*	100			
		$^5/_2$	*203 632.8*	100			
		$^7/_2$	*203 906.3*	100			
		$^9/_2$	*204 265.7*	100			
$3p^3$	$^2P^\circ$	$^3/_2$	*211 366.6*	63		19	$3s3p(^3P^\circ)3d\ ^2P^\circ$
		$^1/_2$	*211 376.6*	62		19	″
$3s^2(^1S)4p$	$^2P^\circ$	$^1/_2$	*213 514.7*	83		10	$3p^3\ ^2P^\circ$
		$^3/_2$	*213 725.3*	85		8	″
$3s3p(^3P^\circ)3d$	$^4P^\circ$	$^5/_2$	*222 198.3*	98		1	$3s3p(^3P^\circ)3d\ ^4D^\circ$
		$^3/_2$	*222 488.6*	98		1	″
		$^1/_2$	*222 692.4*	99			
$3s3p(^3P^\circ)3d$	$^4D^\circ$	$^1/_2$	*224 342.7*	99			
		$^3/_2$	*224 435.6*	98		1	$3s3p(^3P^\circ)3d\ ^4P^\circ$
		$^5/_2$	*224 539.3*	98		1	″
		$^7/_2$	*224 617.3*	99			
$3s3p(^3P^\circ)3d$	$^2D^\circ$	$^5/_2$	*233 610.4*	43		31	$3s3p(^1P^\circ)3d\ ^2D^\circ$
		$^3/_2$	*233 641.9*	43		31	″
$3s3p(^3P^\circ)3d$	$^2F^\circ$	$^5/_2$	*241 646.0*	66		31	$3s3p(^1P^\circ)3d\ ^2F^\circ$
		$^7/_2$	*242 421.4*	66		32	″
$3s^2(^1S)4d$	^2D	$^3/_2$	255 396.1	95		3	$3p^2(^1S)4d\ ^2D$
		$^5/_2$	255 400.1	95		3	″
	$b\ ^2F^\circ$	$^7/_2$	*257 611.0*	52	$3s^2(^1S)4f\ ^2F^\circ$	26	$3s3p(^1P^\circ)3d\ ^2F^\circ$
		$^5/_2$	*257 742.6*	53	″	26	″
$3s3p(^3P^\circ)4s$	$^4P^\circ$	$^1/_2$	*263 097.3*	99			
		$^3/_2$	*263 448.1*	99			
		$^5/_2$	*264 067.7*	99			
$3s3p(^3P^\circ)3d$	$^2P^\circ$	$^3/_2$	*264 882.8*	74		18	$3p^3\ ^2P^\circ$
		$^1/_2$	*265 055.1*	74		17	″
$3s3p(^3P^\circ)4s$	$^2P^\circ$	$^1/_2$	*270 826.7*	88		4	$3s3p(^3P^\circ)3d\ ^2P^\circ$
		$^3/_2$	*271 436.7*	88		4	$3s^2(^1S)5p\ ^2P^\circ$
$3s^2(^1S)5s$	^2S	$^1/_2$	271 020.9	100			

S IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
	$c\ ^2F^\circ$	7/2	*277 596.0*	44	$3s^2(^1S)4f\ ^2F^\circ$	36	$3s3p(^1P^\circ)3d\ ^2F^\circ$
		5/2	*277 682.9*	43	"	36	"
$3s3p(^1P^\circ)3d$	$^2P^\circ$	3/2	*278 642.4*	81		5	$3p^3\ ^2P^\circ$
		1/2	*278 676.7*	84		5	"
$3s3p(^1P^\circ)3d$	$^2D^\circ$	3/2	*281 093.2*	62		15	$3s3p(^3P^\circ)3d\ ^2D^\circ$
		5/2	*281 231.4*	64		15	"
$3s^2(^1S)5p$	$^2P^\circ$	1/2	*285 122.2*	91		4	$3s3p(^3P^\circ)4s\ ^2P^\circ$
		3/2	*285 296.0*	90		5	"
$3s3p(^3P^\circ)4p$	^2P	1/2	292 569.2	66		32	$3s3p(^3P^\circ)4p\ ^4D$
		3/2	292 893.9	68		30	"
$3s3p(^3P^\circ)4p$	^4D	1/2	293 310.8	68		31	$3s3p(^3P^\circ)4p\ ^2P$
		3/2	293 463.1	70		28	"
		5/2	293 736.6	99			
		7/2	294 282.4	99			
$3s3p(^3P^\circ)4p$	^4P	1/2	297 397.1	99			
		3/2	297 592.7	93		6	$3s3p(^3P^\circ)4p\ ^4S$
		5/2	298 010.3	99			
$3s3p(^3P^\circ)4p$	^4S	3/2	299 369.3	94		6	$3s3p(^3P^\circ)4p\ ^4P$
$3s3p(^3P^\circ)4p$	^2D	3/2	301 109.8	60		39	$3s^2(^1S)5d\ ^2D$
		5/2	301 576.4	51		47	"
$3s^2(^1S)5d$	^2D	3/2	303 337.8	59		38	$3s3p(^3P^\circ)4p\ ^2D$
		5/2	303 480.1	50		46	"
$3s3p(^3P^\circ)4p$	^2S	1/2	308 761.0	90		8	$3s^2(^1S)6s\ ^2S$
$3s3p(^1P^\circ)4s$	$^2P^\circ$	1/2	*308 939.3*	89		6	$3s^2(^1S)6p\ ^2P^\circ$
		3/2	*308 996.2*	90		5	"
$3s^2(^1S)5g$	^2G	9/2	309 920.6				
		7/2	309 920.9				
$3s^2(^1S)5f$	$^2F^\circ$	7/2	*311 354.3*	96		2	$3s3p(^1P^\circ)3d\ ^2F^\circ$
		5/2	*311 356.3*	96		2	"
$3s^2(^1S)6s$	^2S	1/2	311 500.6	91		8	$3s3p(^3P^\circ)4p\ ^2S$
$3p^2(^3P)3d$	^4F	3/2	315 733.7	96		4	$3s3p(^3P^\circ)4f\ ^4F$
		5/2	315 922.5	96		4	"
		7/2	316 182.9	96		4	"
		9/2	316 510.9	96		4	"
$3s^2(^1S)6p$	$^2P^\circ$	1/2	*318 609.3*	94		5	$3s3p(^1P^\circ)4s\ ^2P^\circ$
		3/2	*318 639.2*	94		5	"
$3s^2(^1S)6f$	$^2F^\circ$	5/2	*332 638.6*	97		2	$3s3p(^3P^\circ)4d\ ^2F^\circ$
		7/2	*332 644.6*	97		2	"
$3s^2(^1S)7s$	^2S	1/2	332 965.6	98		2	$3s3p(^1P^\circ)4p\ ^2S$

S IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s3p(^3P^\circ)4d$	$^4D^\circ$	$1/2$	*336 255.3*	99		
		$3/2$	*336 297.0*	96	2	$3s3p(^3P^\circ)4d$ $^4F^\circ$
		$5/2$	*336 356.2*	94	4	"
		$7/2$	*336 536.8*	95	4	"
$3s^2(^1S)7p$	$^2P^\circ$	$1/2$	*336 736.0*	99		
		$3/2$	*336 760.6*	98	1	$3s3p(^3P^\circ)4d$ $^2D^\circ$
$3s3p(^3P^\circ)4d$	$^2D^\circ$	$3/2$	*337 030.8*	79	16	$3s3p(^3P^\circ)4d$ $^4F^\circ$
		$5/2$	*337 308.1*	87	9	"
$3s3p(^3P^\circ)4d$	$^4F^\circ$	$3/2$	*337 501.0*	81	15	$3s3p(^3P^\circ)4d$ $^2D^\circ$
		$5/2$	*337 641.6*	87	8	"
		$7/2$	*337 750.7*	96	4	$3s3p(^3P^\circ)4d$ $^4D^\circ$
		$9/2$	*338 053.1*	100		
$3s3p(^1P^\circ)4p$	^2D	$3/2$	338 882.9	56	29	$3s^2(^1S)7d$ ^2D
		$5/2$	338 972.5	58	30	"
$3s3p(^1P^\circ)4p$	^2P	$1/2$	339 813.7	97	1	$3p^2(^3P)4s$ ^2P
		$3/2$	340 000.5	95	1	"
$3s3p(^3P^\circ)4d$	$^4P^\circ$	$5/2$	*340 407.1*	98		
		$3/2$	*340 684.4*	99		
		$1/2$	*340 851.2*	99		
$3s3p(^3P^\circ)4d$	$^2F^\circ$	$5/2$	*342 171.2*	79	18	$3s^2(^1S)7f$ $^2F^\circ$
		$7/2$	*342 689.4*	74	24	"
$3s3p(^1P^\circ)4p$	^2S	$1/2$	343 826.0	92	2	$3p^2(^1S)4s$ ^2S
$3s3p(^3P^\circ)4f$	^2F	$5/2$	345 239.7	76	13	$3p^2(^3P)3d$ ^2F
		$7/2$	345 368.1	76	13	"
$3s3p(^3P^\circ)4d$	$^2P^\circ$	$3/2$	*345 278.9*	95	2	$3s3p(^3P^\circ)3d$ $^2P^\circ$
		$1/2$	*345 624.7*	95	2	"
$3s3p(^3P^\circ)4f$	^4F	$3/2$	348 948.2	85	11	$3s(^2S)3d^2(^3F)$ ^4F
		$5/2$	348 979.3	85	11	"
		$7/2$	349 041.1	85	11	"
		$9/2$	349 139.1	85	11	"
$3s3p(^3P^\circ)4f$	^4G	$5/2$	352 086.9	100		
		$7/2$	352 230.6	99		
		$9/2$	352 434.7	99		
		$11/2$	352 746.5	100		
$3s3p(^3P^\circ)4f$	^4D	$7/2$	355 665.5	97	3	$3p^2(^3P)3d$ ^4D
		$5/2$	355 942.4	97	3	"
		$3/2$	356 172.2	97	3	"
		$1/2$	356 241.8	97	3	"
$3s3p(^1P^\circ)4d$	$^2D^\circ$	$3/2$	*380 576.4*	98		
		$5/2$	*380 599.1*	98		

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S IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
S V $3s^2(^1S_0)$	*Limit*		380 870			
$3s3p(^1P^\circ)4f$	^2F	$^5/_2$	391 426.5	90	8	$3s(^2S)3d^2(^3F)\ ^2F$
		$^7/_2$	391 442.7	90	8	"
S V $3s3p(^3P^\circ_0)$	*Limit*		*463 894*			
S V $3s3p(^3P^\circ_1)$	*Limit*		*464 263*			
S V $3s3p(^3P^\circ_2)$	*Limit*		*465 025*			
S V $3s3p(^1P^\circ_1)$	*Limit*		*508 021*			

S V

$Z = 16$

Mg I isoelectronic sequence

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

Ionization energy 585 514.1 ± 3.0 cm^{-1} (72.5945 ± 0.0004 eV)

The original observations and analysis of S V by Bowen and Millikan [1925] and Bowen [1932] were significantly extended in several papers published during the period 1970–1978 (see Dynefors and Martinson, [1978] and references therein). More recently Joelsson, Zetterberg, and Magnusson [1981] obtained a much more complete description of this spectrum using a sliding vacuum-spark source. The levels here are from their paper, which gives about 385 classified lines covering the region 187–6729 Å.

Joelsson *et al.* estimated the wavelength errors "not to exceed 0.02 Å for lines below 2000 Å and 0.03 Å for the longer wavelengths." These error estimates and the structure of this spectrum would imply uncertainties with respect to the ground level of 1.4 cm^{-1} for the $3s3p\ ^3P^\circ$ term and ~3 cm^{-1} or more for most of the higher levels. By applying a core-polarization formula to the $3snh$ and $3sni$ series, Joelsson *et al.* determined the ionization limit within an estimated uncertainty of ±1.0 cm^{-1} with respect to these high terms. We give their value for the ionization energy here with an estimated uncertainty of ± 3.0 cm^{-1} with respect to the ground level.

The eigenvector percentages are from calculations by Brage and Hibbert, who have included the major configuration interactions for both parities. Second percentages such as "$3snf\ ^1F^\circ$," "$3snd\ ^3D$," etc., include any correlation-orbital contributions and/or additional contributions from the indicated series.

The strong interaction of the $3p^2\ ^1D$ and $3s3d\ ^1D$ terms along the Mg I sequence has been noted in connection with calculations of transition probabilities [see, for example, Godefroid *et al.*, 1985]. Brage and Hibbert's S V calculations also give a strong mixture of the $3p4p\ ^1D$ composition into the $3snd$ series. They obtain a 58% purity for the nominal $3p4p\ ^1D$ level at 460 223 cm^{-1}, with the nominal $3s5d\ ^1D$ level at 470 229 cm^{-1} having a 27% $3p4p\ ^1D$ component.

We have followed Reistad *et al.* [1984] and other authors in designating the level at 366 862 cm^{-1} as $3p3d\ ^1F^\circ$. This changed designation is required for consistency with several calculations and with isoelectronic trends. The level is supported experimentally by at least two strong lines consistent with the $3p3d\ ^1F^\circ$ designation. We also follow Reistad *et al.* in omitting the original $3p3d\ ^1F^\circ$ level (387 273.6 cm^{-1}) as probably not real.

Several of the $3d^2$ and $3p4d$ levels of Joelsson *et al.* are inconsistent with Brage and Hibbert's calculations and with comparisons along the isoelectronic sequence. A possible interchange of the $3d^2\ ^1G$ and ^1D levels was suggested by Baluja and Hibbert [1985]. We have omitted the $3d^2$ and $3p4d$ levels pending further analysis.

References

Aashamar, K., Luke, T. M., and Talman, J. D. [1986], Phys. Scr. **34**, 386–393. AT

Baluja, K. L., and Hibbert, A. [1985], Nucl. Instrum. Methods Phys. Res. B **9**, 477–486. AT

Bowen, I. S. [1932], Phys. Rev. **39**, 8–15. EL CL

Bowen, I. S., and Millikan, R. A. [1925], Phys. Rev. **25**, 591–599. EL CL

Brage, T., and Hibbert, A. [1989], J. Phys. B **22**, 713–726; unpublished material [1985, 1989]. PT AT

Dynefors, B. I., and Martinson, I. [1978], Phys. Scr. **17**, 123–129. EL CL IP SF

Fischer, C. F., and Godefroid, M. [1982], Phys. Scr. **25**, 394–400. AT

Godefroid, M., and Fischer, C. F. [1985], Phys. Scr. **31**, 237–245. AT

Godefroid, M., Magnusson, C. E., Zetterberg, P. O., and Joelsson, I. [1985], Phys. Scr. **32**, 125–128. CL AT

Joelsson, I., Zetterberg, P. O., and Magnusson, C. E. [1981], Phys. Scr. **23**, 1087–1095. EL CL IP SF

Reistad, N., Brage, T., Ekberg, J. O., and Engström, L. [1984], Phys. Scr. **30**, 249– 254. ND

S v

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2$	^{1}S	0	0.0	96	4	$3p^2$ ^{1}S
$3s3p$	^{3}P°	0	*83 024.0*	99		
		1	*83 393.5*	99		
		2	*84 155.2*	99		
$3s3p$	^{1}P°	1	*127 150.7*	96	4	$3p3d$ ^{1}P°
$3p^2$	^{1}D	2	193 739.1	69	30	$3s3d$ ^{1}D
$3p^2$	^{3}P	0	199 967.2	99		
		1	200 370.6	99		
		2	201 146.0	98		
$3s3d$	^{3}D	1	234 941.5	99		
		2	234 947.1	99		
		3	234 956.0	99		
$3p^2$	^{1}S	0	235 350.0	92	4	$3d^2$ ^{1}S
$3s3d$	^{1}D	2	270 700.4	68	28	$3p^2$ ^{1}D
$3s4s$	^{3}S	1	311 595.1	98	1	$3p4p$ ^{3}S
$3s4s$	^{1}S	0	320 108.0	97	2	$3p4p$ ^{1}S
$3p3d$	^{3}F°	2	*323 132.6*	98		
		3	*323 547.3*	98		
		4	*324 080.1*			
$3p3d$	^{1}D°	2	*328 454.3*	99		
$3p3d$	^{3}P°	2	*345 338.2*	95	2	$3p3d$ ^{3}D°
		1	*345 712.8*	95	2	"
		0	*345 953.0*	97	1	$3s4p$ ^{3}P°
$3p3d$	^{3}D°	1	*347 841.1*	97	2	$3p3d$ ^{3}P°
		2	*348 010.2*	96	2	"
		3	*348 131.5*	99		
$3s4p$	^{3}P°	0	*349 122.2*	97	1	$3p3d$ ^{3}P°
		1	*349 161.1*	77	18	$3s4p$ ^{1}P°
		2	*349 478.3*	97	1	$3p3d$ ^{3}P°
$3s4p$	^{1}P°	1	*349 534.4*	73	19	$3s4p$ ^{3}P°
$3p3d$	^{1}F°	3	*366 862.0*	81	18	$3snf$ ^{1}F°
$3s4d$	^{3}D	1	396 025.5	90	7	$3snd$ ^{3}D
		2	396 039.5	90	7	"
		3	396 060.6	90	7	"
$3s4d$	^{1}D	2	397 605.2	87	9	$3snd$ ^{1}D
$3s4f$	^{3}F°	2	*410 909.6*	77	21	$3snf$ ^{3}F°
		3	*410 912.1*	77	21	"
		4	*410 918.1*			
$3s4f$	^{1}F°	3	*417 984.9*	69	16	$3p3d$ ^{1}F°

S v — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3p4s$	$^3P^\circ$	0	*420 742.2*	97		
		1	*421 056.8*	95	2	$3p4s$ $^1P^\circ$
		2	*421 943.4*	97		
$3p4s$	$^1P^\circ$	1	*424 526.0*	81	11	$3s5p$ $^1P^\circ$
$3p5s$	^3S	1	428 439.0	98	1	$3p4p$ ^3S
$3s5s$	^1S	0	430 801.7	95	4	$3p4p$ ^1S
$3s5p$	$^3P^\circ$	0	*445 303.7*	99		
		1	*445 350.5*	99		
		2	*445 498.1*	99		
$3s5p$	$^1P^\circ$	1	*447 925.9*	87	10	$3p4s$ $^1P^\circ$
$3p4p$	^1P	1	450 091.5	94	5	$3p4p$ ^3D
$3p4p$	^3D	1	452 083.8	85	8	$3snd$ ^3D
		2	452 446.8	89	9	″
		3	453 194.7	89	9	″
$3p4p$	^3P	0	457 665.5	97	2	$4p^2$ ^3P
		1	457 913.5	94	2	$3p4p$ ^3S
		2	458 440.9	95	2	$3p4p$ ^1D
$3p4p$	^3S	1	459 893.7	94	2	$3p4p$ ^3P
$3p4p$	^1D	2	460 223.4	58	37	$3s5d$ ^1D
$3s5d$	^3D	1	468 048.2	84	8	$3snd$ ^3D
		2	468 076.9	83	8	″
		3	468 132.1	83	8	″
$3s5d$	^1D	2	470 229.4	52	27	$3p4p$ ^1D
$3p4p$	^1S	0	472 526.1	87	3	$3s5s$ ^1S
$3s5f$	$^3F^\circ$	2	*473 926.0*			
		3	*473 926.5*			
		4	*473 929.5*			
$3s5g$	^1G	4	474 476.8	87	5	$3sng$ ^1G
$3s5g$	^3G	3	474 507.3	93	5	$3sng$ ^3G
		4	474 515.6	91	7	″
		5	474 521.7			
$3s5f$	$^1F^\circ$	3	*475 802.5*			
$3s6s$	^3S	1	483 653.6			
$3s6s$	^1S	0	485 386.8			
$3s6p$	$^3P^\circ$	0	*490 000.8*			
		1	*490 022.6*			
		2	*490 084.8*			
$3s6p$	$^1P^\circ$	1	*492 706.0*			

S v — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s6d$	^{3}D	1	504 296.5	
		2	504 305.7	
		3	504 310.5	
$3s6d$	^{1}D	2	504 761.4	
$3s6g$	^{1}G	4	508 218	
$3s6g$	^{3}G	3,4,5	508 310	
$3s6f$	^{3}F$^{\circ}$	2,3,4	*508 418*	
$3s6h$	^{3}H$^{\circ}$,^{1}H$^{\circ}$	4,5,5,6	*509 105.8*	
$3s6f$	^{1}F$^{\circ}$	3	*510 152*	
$3s7s$	^{3}S	1	513 933.6	
$3s7s$	^{1}S	0	514 595.2	
$3s7p$	^{1}P$^{\circ}$	1	*519 332*	
$3s7p$	^{3}P$^{\circ}$	2	*520 582*	
$3s7d$	^{3}D	1	526 480.3	
		2	*526 494.1*	
		3	*526 501.7*	
$3s7d$	^{1}D	2	526 655.3	
$3s7f$	^{3}F$^{\circ}$	2,3,4	*528 920*	
$3s7h$	^{3}H$^{\circ}$,^{1}H$^{\circ}$	4,5,5,6	*529 375*	
$3s7i$	^{3}I,^{1}I	5,6,6,7	529 479.8	
$3s7f$	^{1}F$^{\circ}$	3	*529 527*	
$3s8s$	^{3}S	1	532 503	
$3s8p$	^{1}P$^{\circ}$	1	*534 691*	
$3s8p$	^{3}P$^{\circ}$	2	*535 965*	
$3s8d$	^{1}D	2	540 451	
$3s8d$	^{3}D	3	540 471	
$3s8f$	^{3}F$^{\circ}$	2,3,4	*542 212*	
$3s8h$	^{3}H$^{\circ}$,^{1}H$^{\circ}$	4,5,5,6	*542 535*	
$3s8i$	^{3}I,^{1}I	5,6,6,7	542 612	
$3s8f$	^{1}F$^{\circ}$	3	*542 615*	
$3s9s$	^{3}S	1	544 683	
$3s9d$	^{3}D	3	550 031	

S V — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s9d$	$^{1}\mathrm{D}$	2	550 334	
$3s9f$	$^{3}\mathrm{F}^{\circ}$	2,3,4	*551 320*	
$3s9f$	$^{1}\mathrm{F}^{\circ}$	3	*551 575*	
$3s9i$	$^{3}\mathrm{I},^{1}\mathrm{I}$	5,6,6,7	551 618	
$3s10f$	$^{3}\mathrm{F}^{\circ}$	2,3,4	*557 842*	
$3s11f$	$^{3}\mathrm{F}^{\circ}$	2,3,4	*562 673*	
S VI ($^{2}\mathrm{S}_{1/2}$)	***Limit***		585 514.1	
S VI ($^{2}\mathrm{P}^{\circ}_{1/2}$)	*Limit*		*691 387.7*	
S VI ($^{2}\mathrm{P}^{\circ}_{3/2}$)	*Limit*		*692 651.8*	

S VI

$Z=16$

Na I isoelectronic sequence

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

Ionization energy 710 194.7 ± 3.0 cm^{-1} (88.0530 ± 0.0004 eV)

The levels below the $2p^6\ ^1S$ limit are from Joelsson *et al.*, who observed some 90 S VI lines between 152 and 5577 Å. In their paper on S V [see S V], these authors estimate that the wavelength errors do not exceed 0.02 Å for lines below 2000 Å and 0.03 Å for lines above 2000 Å. Similar errors for S VI would correspond to an uncertainty of about 2 cm^{-1} for the $3p$ levels with respect to the ground level and uncertainties of several cm^{-1} for some of the higher levels. The separations between some of the levels having $n \geqslant 4$ are determined with uncertainties less than 1 cm^{-1} by longer-wavelength transitions.

Joelsson *et al.* gave a few of the less accurate levels or unresolved doublet terms to the nearest cm^{-1} only. They obtained the $8p$ and $9p$ level positions using series formulae. No $nf\ ^2F^\circ$ fine-structure splittings have as yet been resolved in S VI or P V, but the $4f\ ^2F^\circ$ splittings are known to have hydrogenic values (within the experimental errors) for Si IV and Cl VII; the expected S VI $4f\ ^2F^\circ$ hydrogenic splitting of 9.9 cm^{-1} is thus probably the largest of the unresolved fine structures for the terms given here.

Joelsson *et al.* obtained the quoted ionization energy by fitting a core-polarization formula to the nf, ng, and nh terms. They also fitted Ritz formulae to the ns, np, and nd series and derived an ionization energy in agreement with the polarization-formula value within 1 cm^{-1}. The principal contribution to the uncertainty of the ionization energy thus probably arises from the errors of the higher levels with respect to the ground level; in view of the agreement of ionization-energy values described above, our uncertainty estimate of ±3 cm^{-1} may be conservative. The values of all S VI nl terms can be predicted within errors of this order from formulae given by Joelsson *et al.*

Dynefors and Martinson observed a number of S VI transitions (726–5290 Å) from higher angular-momentum terms, extending up to $10k$. Relatively accurate wavelengths for such lines can be predicted from the polarization-formulae term values.

Jupén *et al.* [1990] have classified 22 lines observed in beam-foil spectra as quartet transitions belonging to the $2p^53s3p-2p^53p^2$ and $2p^53s3p-2p^53s3d$ arrays. The corresponding levels and eigenvector percentages given here are from their work. These excited-core terms have not yet been connected to the one-electron excitation system; the position of the quartet system given here is based on a calculated value for the $2p^53s3p\ ^4S_{3/2}$ level. The correction "x" for this assumed connection is estimated not to exceed a few thousand cm^{-1} (absolute value). The errors of most of the level separations within the quartet system are probably less than 10 cm^{-1}.

References

Berry, H. G. [1971], J. Opt. Soc. Am. **61**, 983. CL

Bowen, I. S., and Millikan, R. A. [1925], Phys. Rev. **25**, 295–305. EL CL IP

Dynefors, B. I., and Martinson, I. [1978], Phys. Scr. **17**, 123-129. CL

Joelsson, I., Zetterberg, P. O., and Magnusson, C. E. [1979], Phys. Scr. **20**, 145-150. EL CL IP SF

Jupén, C., Engström, L., Hutton, R., and Träbert, E. [1988], J. Phys. B **21**, L347–L351. CL

Jupén, C., Engström, L., Hutton, R., Reistad, N., and Westerlind, M. [1990], Phys. Scr. **42**, 44–50. EL PT

Robinson, H. A. [1937], Phys. Rev. **52**, 724–725. EL CL IP

S VI

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s$	^2S	$1/2$	0.0	
$3p$	$^2P^\circ$	$1/2$	*105 873.6*	
		$3/2$	*107 137.7*	
$3d$	^2D	$3/2$	247 422.5	
		$5/2$	247 455.0	

S VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
4*s*	$^{2}\mathrm{S}$	1/2	362 988.8	
4*p*	$^{2}\mathrm{P}^{\circ}$	1/2	*401 169.2*	
		3/2	*401 627.1*	
4*d*	$^{2}\mathrm{D}$	3/2	451 796.8	
		5/2	451 813.8	
4*f*	$^{2}\mathrm{F}^{\circ}$	5/2,7/2	*462 650.1*	
5*s*	$^{2}\mathrm{S}$	1/2	504 102.4	
5*p*	$^{2}\mathrm{P}^{\circ}$	1/2	*522 029.1*	
		3/2	*522 249.5*	
5*d*	$^{2}\mathrm{D}$	3/2	546 047.6	
		5/2	546 058.6	
5*f*	$^{2}\mathrm{F}^{\circ}$	5/2,7/2	*551 759.6*	
5*g*	$^{2}\mathrm{G}$	7/2,9/2	552 115.0	
6*s*	$^{2}\mathrm{S}$	1/2	573 737.7	
6*p*	$^{2}\mathrm{P}^{\circ}$	1/2	*583 551.3*	
		3/2	*583 674.1*	
6*d*	$^{2}\mathrm{D}$	3/2	596 853.0	
		5/2	596 861.3	
6*f*	$^{2}\mathrm{F}^{\circ}$	5/2,7/2	*600 189.4*	
6*g*	$^{2}\mathrm{G}$	7/2,9/2	600 418.8	
6*h*	$^{2}\mathrm{H}^{\circ}$	9/2,11/2	*600 448.9*	
7*s*	$^{2}\mathrm{S}$	1/2	613 198.8	
7*p*	$^{2}\mathrm{P}^{\circ}$	1/2	*619 142.9*	
		3/2	*619 218.4*	
7*d*	$^{2}\mathrm{D}$	3/2,5/2	627 287	
7*f*	$^{2}\mathrm{F}^{\circ}$	5/2,7/2	*629 390.3*	
7*h*	$^{2}\mathrm{H}^{\circ}$	9/2,11/2	*629 563.*8	
7*i*	$^{2}\mathrm{I}$	11/2,13/2	629 569.9	
8*s*	$^{2}\mathrm{S}$	1/2	637 709	
8*p*	$^{2}\mathrm{P}^{\circ}$	1/2	[*641 580*]	
		3/2	[*641 631*]	
8*d*	$^{2}\mathrm{D}$	3/2,5/2	646 931	
8*f*	$^{2}\mathrm{F}^{\circ}$	5/2,7/2	*648 343.2*	
9*p*	$^{2}\mathrm{P}^{\circ}$	1/2	[*656 641*]	
		3/2	[*656 675*]	

S VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$9d$	^{2}D	3/2,5/2	660 341			
$9f$	^{2}F°	5/2,7/2	*661 327*			
$10f$	^{2}F°	5/2,7/2	*670 626*			
S VII $2p^6(^1S_0)$	*Limit*		710 194.7			
$2p^53s(^3P^\circ)3p$	^{4}S	3/2	1 399 400.0+x	96	3	$2p^53s(^3P^\circ)3p$ ^{4}P
$2p^53s(^3P^\circ)3p$	^{4}D	7/2	1 412 130.9+x	100		
		5/2	1 413 580.3+x	88	6	$2p^53s(^3P^\circ)3p$ ^{4}P
		3/2	1 415 620.3+x	83	6	″
		1/2	1 417 934.8+x	86	5	″
$2p^53s(^3P^\circ)3p$	^{4}P	5/2	1 421 695.4+x	83	10	$2p^53s(^1P^\circ)3p$ ^{2}D
		3/2	1 422 885.2+x	56	24	″
		1/2	1 424 715.9+x	88	7	$2p^53s(^3P^\circ)3p$ ^{4}D
$2p^5(^2P^\circ)3p^2(^3P)$	^{4}P°	5/2	*1 529 281.8*+x	94	5	$2p^5(^2P^\circ)3p^2(^3P)$ ^{4}D°
$2p^5(^2P^\circ)3p^2(^3P)$	^{4}D°	7/2	*1 540 112.7*+x	100		
		5/2	*1 541 779.2*+x	77	18	$2p^5(^2P^\circ)3p^2(^3P)$ ^{2}D°
		3/2	*1 542 839.6*+x	48	36	″
		1/2				
$2p^5(^2P^\circ)3s3d(^3D)$	^{4}P°	1/2	*1 569 543.3*+x	100		
		3/2	*1 570 709.1*+x	96	3	$2p^5(^2P^\circ)3s3d(^3D)$ ^{4}D°
		5/2	*1 572 881.8*+x	92	6	″
$2p^5(^2P^\circ)3s3d(^3D)$	^{4}F°	9/2	*1 574 981.4*+x	100		
		7/2	*1 576 792.3*+x	90	5	$2p^5(^2P^\circ)3s3d(^3D)$ ^{4}D°
		5/2	*1 578 784.8*+x	83	6	″
		3/2	*1 581 024.4*+x	83	8	″
S VII $2p^53s(^3P^\circ_2)$	*Limit*		*2 081 979*			

S VII

$Z=16$

Ne I isoelectronic sequence

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

Ionization energy 2 266 000 ± 100 cm^{-1} (280.948±0.012 eV)

Ferner measured and classified most of the $2p^6\ {}^1S_0 - 2p^5ns$ and nd ($J=1$) transitions observed so far for this spectrum (46–73 Å). The position of the $2p^5({}^2P^{\circ}_{3/2})4d\ {}^2[1/2]^{\circ}_1$ level is from Fawcett and Hayes' measurement of the corresponding line. Kononov *et al*. revised and extended the earlier analyses of the $2p^5 3s - 3p$ and $3p - 3d$ lines on the basis of new observations in the 600–1100 Å region and calculations of the energy levels [Garnir *et al*., 1978; Garnir, 1979; Kononov *et al*., 1983]. The $2p^5 3d - 4f$ lines (330–377 Å) were measured and classified by Jupén *et al*.

The $2p^5 3s\ {}^3P^{\circ}_1 - {}^1P^{\circ}_1$ separation determined by Kononov *et al*. is only 18 cm^{-1} larger than the less accurate value given by Ferner's measurements of the corresponding transitions to the $2p^6\ {}^1S_0$ ground level. We adopted the $2p^5 3s\ {}^3P^{\circ}_1 - {}^1P^{\circ}_1$ separation given by Kononov *et al*. and fixed the values of these two levels so that the corresponding calculated wavelengths of both transitions to the ground level still agree with Ferner's measurements to the third decimal place. The resulting position of the $2p^5 3s$, $3p$, $3d$, and $4f$ group of levels is only 13 cm^{-1} lower than the position adopted by Kononov *et al*. and by Jupén *et al*. The error of this connection to the ground level may be of the order of 100 cm^{-1}. The *relative* uncertainties of the $2p^5 3s$ and $3p$ levels are about 3 to 7 cm^{-1}, and the $2p^5 3d$ levels have uncertainties of about 10 to 20 cm^{-1} within the $n=3$ system [Kononov *et al*.]. The combined uncertainties of the $2p^5 3d$ levels and of the measurements of the $2p^5 3d - 4f$ lines [Jupén *et al*.] give estimated errors of about ±25 cm^{-1} for the $2p^5 4f$ levels relative to the $n=3$ system. The $2p^5 4s$, $5s$, and $4d$ to $7d$ levels are all determined only by their transitions to the ground level; the higher levels might have errors of ±200 cm^{-1} or more.

The leading eigenvector percentages for the $2p^5 3s$, $3p$, and $3d$ levels were calculated by Kononov *et al*. We have interchanged the former designations of the $2p^5 3p\ {}^3P_2$ and ${}^1D_2$ levels, this change being supported by the eigenvectors and by the observed relative intensities of the transitions from these two levels to the $2p^5 3s\ {}^3P^{\circ}_2$ level. The $2p^5 ns$ and nd levels having $n \geqslant 4$ are given with $J_1 l$-coupling names, in accordance with calculations for other spectra of this sequence; alternate LS-coupling names are given after the word "or" in the "Leading percentages" column. The $J_1 l$-coupling designations of the $2p^5 4f$ levels by Jupén *et al*. were supported by calculated eigenvector purities of 98% or more in this scheme.

Edlén [1971] and Odabasi [1979] have given formulae for predicting ionization energies for this sequence. When adjusted to experimental values now available for Si V and Cl VIII, both formulae yield the S VII ionization energy given here within about ±25 cm^{-1}. We also used the Si V and Cl VIII data to obtain an interpolated value for the quantum defect of the S VII $2p^5({}^2P^{\circ}_{3/2})4f\ {}^2[9/2]_5$ level; this defect and the experimental level give a value of 2 266 040 cm^{-1} for the limit, with an estimated error of about ±100 cm^{-1}. Ferner derived an ionization energy of 2 266 990 cm^{-1} from the $2p^5 nd$ series, with an estimated error of ±500 cm^{-1}; however, Ferner's measurements of the longest series, $({}^2P^{\circ}_{1/2})nd\ {}^2[3/2]^{\circ}_1$ ($n=3-7$), are quite consistent with the limit adopted here, whereas Ferner's limit would imply relatively large measurement errors for the $6d$ and $7d$ members of this series.

References

Edlén, B. [1971], in *Topics in Modern Physics*, W. E. Brittin and H. Odabasi, Editors, pp. 133–145, Colorado Assoc. Univ. Press, Boulder, CO, USA. IP

Fawcett, B. C. [1984], Phys. Scr. **30**, 326–334. AT

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80–87. CL

Ferner, E. [1948], Ark. Mat., Astron. Fys. **36**, 1–65. EL CL IP

Garnir, H. P. [1979], J. Opt. Soc. Am. **69**, 916–917. CL

Garnir, H. P., Baudinet-Robinet, Y., Dumont, P. D., and Eidelsberg, M. [1978], Phys. Scr. **17**, 463–465. EL CL

Jupén, C., Litzén, U., and Trigueiros, A. [1984], Phys. Scr. **29**, 317–318. EL CL AT PT

Kononov, E. Ya., Kramida, A. E., Podobedova, L. I., Ragozin, E. N., and Chirkov, V. A. [1983], Phys. Scr. **28**, 496–500. EL CL AT PT

Odabasi, H. [1979], Phys. Scr. **19**, 313–317. IP

S VII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2p^6$	^{1}S	0	0			
$2p^53s$	^{3}P°	2	*1 371 784*	100		
		1	*1 376 207*	81	19	$2p^53s$ ^{1}P°
		0	*1 381 805*	100		
$2p^53s$	^{1}P°	1	*1 388 339*	81	19	$2p^53s$ ^{3}P°
$2p^53p$	^{3}S	1	1 466 883	97		
$2p^53p$	^{3}D	3	1 483 165	100		
		2	1 484 428	80	15	$2p^53p$ ^{1}D
		1	1 488 019	74	15	$2p^53p$ ^{1}P
$2p^53p$	^{3}P	2	1 492 496	57	42	$2p^53p$ ^{1}D
		0	1 498 631	99		
		1	1 500 286	66	31	$2p^53p$ ^{1}P
$2p^53p$	^{1}P	1	1 495 849	53	25	$2p^53p$ ^{3}D
$2p^53p$	^{1}D	2	1 499 068	43	38	$2p^53p$ ^{3}P
$2p^53p$	^{1}S	0	1 552 707	99		
$2p^53d$	^{3}P°	0	*1 623 623*	100		
		1	*1 624 773*	98		
		2	*1 627 260*	94	4	$2p^53d$ ^{3}D°
$2p^53d$	^{3}F°	4	*1 630 083*	100		
		3	*1 631 989*	79	19	$2p^53d$ ^{1}F°
		2	*1 635 337*	79	12	$2p^53d$ ^{1}D°
$2p^53d$	^{1}F°	3	*1 637 915*	59	33	$2p^53d$ ^{3}D°
$2p^53d$	^{3}D°	1	*1 644 599*	93	6	$2p^53d$ ^{1}P°
		3	*1 645 921*	64	23	$2p^53d$ ^{1}F°
		2	*1 646 576*	56	37	$2p^53d$ ^{1}D°
$2p^53d$	^{1}D°	2	*1 644 674*	48	31	$2p^53d$ ^{3}D°
$2p^53d$	^{1}P°	1	*1 662 194*	94	5	$2p^53d$ ^{3}D°
$2p^5(^2P^\circ_{3/2})4s$	$^2[^3/_2]^\circ$	2			or	$2p^54s$ ^{3}P°
		1	*1 820 230*		or	″
$2p^5(^2P^\circ_{1/2})4s$	$^2[^1/_2]^\circ$	0			or	$2p^54s$ ^{3}P°
		1	*1 829 760*		or	$2p^54s$ ^{1}P°
$2p^5(^2P^\circ_{3/2})4d$	$^2[^1/_2]^\circ$	0			or	$2p^54d$ ^{3}P°
		1	*1 910 800*		or	″
$2p^5(^2P^\circ_{3/2})4d$	$^2[^3/_2]^\circ$	2				
		1	*1 919 500*		or	$2p^54d$ ^{3}D°
$2p^5(^2P^\circ_{3/2})4f$	$^2[^3/_2]$	1	1 927 524			
		2	1 927 669			
$2p^5(^2P^\circ_{3/2})4f$	$^2[^9/_2]$	5	1 928 490			
		4	1 928 559			

S VII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{3/2})4f$	${}^2[{}^5/_2]$	3	1 928 791	
		2	1 929 004	
$2p^5(^2P^\circ_{3/2})4f$	${}^2[{}^7/_2]$	3	1 929 685	
		4	1 929 732	
$2p^5(^2P^\circ_{1/2})4d$	${}^2[{}^3/_2]^\circ$	2		
		1	*1 930 240*	or $2p^5 4d\ {}^1P^\circ$
$2p^5(^2P^\circ_{1/2})4f$	${}^2[{}^5/_2]$	3	1 938 951	
		2	1 939 088	
$2p^5(^2P^\circ_{1/2})4f$	${}^2[{}^7/_2]$	3	1 939 051?	
		4	1 939 099	
$2p^5(^2P^\circ_{3/2})5s$	${}^2[{}^3/_2]^\circ$	1	*1 998 920*	or $2p^5 5s\ {}^3P^\circ$
$2p^5(^2P^\circ_{3/2})5d$	${}^2[{}^3/_2]^\circ$	1	*2 046 080*	or $2p^5 5d\ {}^3D^\circ$
$2p^5(^2P^\circ_{1/2})5d$	${}^2[{}^3/_2]^\circ$	1	*2 055 630*	or $2p^5 5d\ {}^1P^\circ$
$2p^5(^2P^\circ_{3/2})6d$	${}^2[{}^3/_2]^\circ$	1	*2 113 850*	or $2p^5 6d\ {}^3D^\circ$
$2p^5(^2P^\circ_{1/2})6d$	${}^2[{}^3/_2]^\circ$	1	*2 123 230*	or $2p^5 6d\ {}^1P^\circ$
$2p^5(^2P^\circ_{1/2})7d$	${}^2[{}^3/_2]^\circ$	1	*2 163 940*	or $2p^5 7d\ {}^1P^\circ$
S VIII ($^2P^\circ_{3/2}$)	***Limit***		***2 266 000***	
S VIII ($^2P^\circ_{1/2}$)	*Limit*		*2 276 085*	

S VIII

$Z=16$

F I isoelectronic sequence

Ground state $1s^22s^22p^5\ {}^2P^\circ_{3/2}$

Ionization energy 2 651 500 cm^{-1} (328.75 eV)

Robinson's observation and classification of the $2s^22p^5\ {}^2P^\circ-2s2p^6\ {}^2S$ resonance doublet of this spectrum near 200 Å gave a value 10 080 cm^{-1} for the ${}^2P^\circ_{1/2}-{}^2P^\circ_{3/2}$ fine-structure splitting. The value 10 085 cm^{-1} adopted here is probably somewhat more accurate, being an average of the values 10 084 cm^{-1} [Edlén, 1983] and 10 086 cm^{-1} [Curtis and Ramanujam] obtained from semi-empirical treatments of the isoelectronic data. Kissell and Byard probably observed the forbidden S VIII $2s^22p^5\ {}^2P^\circ_{3/2}-{}^2P^\circ_{1/2}$ line in the solar coronal spectrum, the wavenumber corresponding to their measurement being 10 087 cm^{-1}, but Jefferies listed this observation as needing confirmation.

The $2s2p^6\ {}^2S_{1/2}$ level given here is the sum of the adopted $2s^22p^5\ {}^2P^\circ_{1/2}$ position and Edlén's [1983] value for the $2s^22p^5\ {}^2P^\circ_{1/2}-2s2p^6\ {}^2S_{1/2}$ separation. The result is probably accurate within about 10 cm^{-1} and agrees with the $2s2p^6\ {}^2S_{1/2}$ position obtained directly from Robinson's measurement (503 652 cm^{-1}) within the uncertainties.

Trigueiros and Jupén have observed and classified 40 lines (664−973 Å) as belonging to the $2s^22p^43s-3p$ and $3p-3d$ transition arrays. All the $2p^43s$ and $2p^43p$ levels given here are from their paper, with only $2p^4({}^3P)3p\ {}^2S^\circ_{1/2}$ missing. We have also taken most of the $2p^43d$ levels from Trigueiros and Jupén, including all levels for which transitions in the above region were classified. No doublet-quartet intercombination lines were classified in this region. Most of the level separations determined within either of the $2s^22p^43l$ systems (quartet or doublet) by Trigueiros and Jupén's measurements are probably accurate within ±10 to ±20 cm^{-1}.

Both the quartet and doublet $2s^22p^43l$ systems are connected to the $2s^22p^5$ ground configuration through Ferner's measurements of $2s^22p^5-2s^22p^43s,\ 3d$ transitions in the region below 65 Å; the uncertainty of these connections and of the intersystem connection may be greater than 100 cm^{-1}. The levels of the $2s^22p^4({}^3P)3d\ {}^4P$, ${}^2P$, ${}^2D$, $({}^1D)3d\ {}^2S$, ${}^2P$, ${}^2D$, and $({}^1S)3d\ {}^2D$ terms are based solely on transitions to the $2s^22p^5\ {}^2P^\circ$ levels. We have rounded the values of all these levels to the nearest 10 cm^{-1} because of their relatively large uncertainties even within the $2s^22p^43l$ quartet and doublet systems.

The eigenvector percentages are from calculations of the $2s2p^6+2s^22p^43s+2s^22p^43d$ even levels and $2s^22p^43p$ odd levels by Trigueiros and Jupén. The matrices for the even group included the configuration interactions, and the calculations were carried out with least-squares adjustment of the interaction parameters. No percentages less than 5% were given. The calculations confirmed the extension and revisions of the $2p^43d$ group, including some revisions made earlier on the basis of isoelectronic regularity [references given by Trigueiros and Jupén].

Ferner classified most of the 44 lines he assigned to S VIII (44−65 Å) as $2s^22p^5\ {}^2P^\circ-2s^22p^43s,\ 3d$ transitions. The S VIII line list given by Fawcett and Hayes has Ferner's wavelengths with energy-level classifications including corrections for some $2p^43d$ transitions in accord with the revised analysis of Trigueiros and Jupén.

The positions given for the $2p^4({}^3P)3d\ {}^4P_{5/2}$ and ${}^2P_{3/2}$ levels are based on reclassifications of two lines in Ferner's list [Trigueiros and Jupén]. Ferner derived the $2s2p^5({}^3P^\circ)3s\ {}^2P^\circ$ levels by classifying two lines near 65 Å as the $2s2p^6\ {}^2S_{1/2}-2s2p^5({}^3P^\circ)3s\ {}^2P^\circ$ doublet.

We obtained a value of 2 651 300 cm^{-1} for the ionization energy from an isoelectronic formula of the type used by Edlén [1971], fitted to the data through Al V. Cheng has carried out relativistic Hartree-Fock calculations of the ionization energies for this isoelectronic sequence. A formula for correlation corrections for Cheng's values (with 3 constants we evaluated using data for lower sequence members) gives an ionization energy of 2 651 730 cm^{-1} for S VIII. We have adopted the average of these two predicted values, rounded to the nearest 100 cm^{-1}.

New observations of sulfur spectra including a well developed S VIII spectrum have been made available in connection with this compilation [Cohen]. The relative intensities of several lines in the 44−48 Å region classified by Ferner as $2s^22p^5\ {}^2P^\circ-2s^22p^44s,\ 4d$ transitions are not as expected according to the term designations of the upper levels. Fawcett and Hayes note some of these classifications are inconsistent with their calculations of the spectrum in this region. We have omitted Ferner's $2s^22p^44s,\ 4d$ levels pending further analysis. We give tentative positions for the $2p^4({}^3P)4s\ {}^2P_{3/2}$ and $({}^3P)4d\ {}^2D_{5/2}$ levels; these positions are based on lines having the expected relative intensities and on series regularity (assuming the S IX $2p^4\ {}^3P_1$ and ${}^3P_0$ levels as the respective limits of the S VIII $2p^4({}^3P)ns\ {}^2P_{3/2}$ and $({}^3P)nd\ {}^2D_{5/2}$ series, together with the above principal ionization energy). The experimental uncertainty in this region is several hundred cm^{-1}.

References

Cheng, K. T. [1981], unpublished calculations.

Cohen, L. [1985], unpublished material.

Curtis, L. J., and Ramanujam, P. S. [1982], Phys. Rev. A **26**, 3672–3675. EL

Edlén, B. [1971], in *Topics in Modern Physics*, W. E. Brittin and H. Odabasi, Editors, pp. 133–145, Colorado Assoc. Univ. Press, Boulder, CO.

Edlén, B. [1983], Phys. Scr. **28**, 51–67. EL

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80–87. CL

Ferner, E. [1948], Ark. Mat., Astron. Fys. **36**, 1–65.

Jefferies, J. T. [1969], Mem. Soc. R. Sci. Liege, Collect. 8, **17**, 213–234.

Kissell, K. E., and Byard, P. L. [1965], *Proc. 1965 Solar Eclipse Symposium*, NASA-Ames Research Center, p. 359. CL

Robinson, H. A. [1937], Phys. Rev. **52**, 724–725. EL CL

Trigueiros, A., and Jupén, C. [1985], Phys. Scr. **31**, 359–363. EL CL PT

S VIII

Configuration	Term	*J*	Level (cm^{-1})	Leading percentages		
$2s^22p^5$	$^2P^\circ$	3/2	*0*			
		1/2	*10 085*			
$2s2p^6$	^2S	1/2	503 644	100		
$2s^22p^4(^3P)3s$	^4P	5/2	1 559 341	99		
		3/2	1 565 357	95		
		1/2	1 568 870	99		
$2s^22p^4(^3P)3s$	^2P	3/2	1 579 675	95		
		1/2	1 586 537	99		
$2s^22p^4(^1D)3s$	^2D	5/2	1 623 377	99		
		3/2	1 623 562	99		
$2s^22p^4(^3P)3p$	$^4P^\circ$	5/2	*1 663 529*	96		
		3/2	*1 665 190*	94		
		1/2	*1 668 025*	99		
$2s^22p^4(^3P)3p$	$^4D^\circ$	7/2	*1 677 002*	99		
		5/2	*1 679 963*	80	16	$2s^22p^4(^3P)3p\ ^2D^\circ$
		3/2	*1 683 313*	93		
		1/2	*1 684 694*	97		
$2s^22p^4(^1S)3s$	^2S	1/2	1 688 150	98		
$2s^22p^4(^3P)3p$	$^2D^\circ$	5/2	*1 688 781*	82	16	$2s^22p^4(^3P)3p\ ^4D^\circ$
		3/2	*1 696 125*	60	20	$2s^22p^4(^3P)3p\ ^2P^\circ$
$2s^22p^4(^3P)3p$	$^2P^\circ$	1/2	*1 689 123*	50	30	$2s^22p^4(^1D)3p\ ^2P^\circ$
		3/2	*1 691 951*	40	34	$2s^22p^4(^3P)3p\ ^2D^\circ$
$2s^22p^4(^3P)3p$	$^4S^\circ$	3/2	*1 698 580*	94		
$2s^22p^4(^1D)3p$	$^2F^\circ$	5/2	*1 732 269*	98		
		7/2	*1 733 768*	99		
$2s^22p^4(^1D)3p$	$^2D^\circ$	3/2	*1 746 563*	99		
		5/2	*1 747 665*	98		
$2s^22p^4(^1D)3p$	$^2P^\circ$	3/2	*1 769 011*	64	35	$2s^22p^4(^3P)3p\ ^2P^\circ$
		1/2	*1 773 330*	63	34	"
$2s^22p^4(^1S)3p$	$^2P^\circ$	3/2	*1 806 574*	98		
		1/2	*1 807 269*	93	6	$2s^22p^4(^3P)3p\ ^2P^\circ$

S VIII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^22p^4(^3P)3d$	^{4}D	$^7/_2$	1 812 370	95		
		$^5/_2$	1 813 158	94		
		$^3/_2$	1 814 360	94		
		$^1/_2$	1 815 707	97		
$2s^22p^4(^3P)3d$	^{4}F	$^9/_2$	1 824 865	99		
		$^7/_2$	1 828 045	77	20	$2s^22p^4(^3P)3d$ ^{2}F
		$^5/_2$	1 831 532	88	6	"
		$^3/_2$	1 833 504	94		
$2s^22p^4(^3P)3d$	^{2}F	$^7/_2$	1 834 362	77	19	$2s^22p^4(^3P)3d$ ^{4}F
		$^5/_2$	1 839 250	63	30	$2s^22p^4(^3P)3d$ ^{4}P
$2s^22p^4(^3P)3d$	^{4}P	$^1/_2$		98		
		$^3/_2$	1 834 830	91		
		$^5/_2$	1 837 420?	64	20	$2s^22p^4(^3P)3d$ ^{2}F
$2s^22p^4(^3P)3d$	^{2}D	$^3/_2$	1 842 750	64	11	$2s^22p^4(^1D)3d$ ^{2}D
		$^5/_2$	1 847 810	78	10	$2s^22p^4(^3P)3d$ ^{2}F
$2s^22p^4(^3P)3d$	^{2}P	$^1/_2$		80	18	$2s^22p^4(^1D)3d$ ^{2}P
		$^3/_2$	1 848 830?	67	16	$2s^22p^4(^3P)3d$ ^{2}D
$2s^22p^4(^1D)3d$	^{2}G	$^7/_2$	1 878 029	99		
		$^9/_2$	1 878 138	99		
$2s^22p^4(^1D)3d$	^{2}S	$^1/_2$	1 888 410	95		
$2s^22p^4(^1D)3d$	^{2}F	$^5/_2$	1 891 990	89	10	$2s^22p^4(^1D)3d$ ^{2}D
		$^7/_2$	1 892 962	99		
$2s^22p^4(^1D)3d$	^{2}P	$^3/_2$	1 894 310	84	14	$2s^22p^4(^3P)3d$ ^{2}P
		$^1/_2$	1 897 440	79	18	"
$2s^22p^4(^1D)3d$	^{2}D	$^5/_2$	1 895 520	79	9	$2s^22p^4(^1D)3d$ ^{2}F
		$^3/_2$	1 898 220	85	14	$2s^22p^4(^3P)3d$ ^{2}D
$2s^22p^4(^1S)3d$	^{2}D	$^5/_2$	1 952 100	97		
		$^3/_2$	1 952 960	96		
$2s2p^5(^3P^\circ)3s$	^{2}P°	$^3/_2$	*2 038 590*			
		$^1/_2$	*2 045 090*			
$2s^22p^4(^3P)4s$	^{2}P	$^3/_2$	2 104 420?			
		$^1/_2$				
$2s^22p^4(^3P)4d$	^{2}D	$^3/_2$				
		$^5/_2$	2 207 900?			
S IX ($^3P_2$)	*Limit*		2 651 500			

S IX

$Z=16$

O I isoelectronic sequence

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

Ionization energy 3 061 300 ± 1 500 cm^{-1} (379.55 ± 0.19 eV)

The $2s^22p^4$, $2s2p^5$, and $2p^6$ levels are known from transitions connecting these configurations [Deutschman and House; Kononov; Podobedova *et al.*; Fawcett]. Edlén has evaluated these levels using a method that takes into account the data for the entire isoelectronic sequence. We have adopted his values except for the $2s^22p^4\ ^1D_2$ level. The value given for this level is an average of the $2s^22p^4\ ^3P_2-{}^1D_2$ wavenumbers obtained from measurements of this forbidden line in solar-coronal spectra by Sandlin *et al.* and by Feldman and Doschek; the estimated error is smaller than 1 cm^{-1}. The $2s^22p^4\ ^3P$ intervals are probably accurate within ±10 to ±20 cm^{-1}, and the $2p^5$ levels are probably accurate within about ±30 cm^{-1}. The estimated uncertainty of the $2s^22p^4\ ^1S$ and $2p^6\ ^1S$ levels is about ±50 cm^{-1}.

Ferner's analysis of the $2s^22p^4-2s^22p^33s$ and $3d$ arrays was extended by Fawcett *et al.* [1974] and Fawcett and Hayes [1987], the list of classified lines in the 1987 paper extending from 35 to 56 Å. The $2s^22p^33s$, $3d$, and $4d$ levels given here are from Fawcett and Hayes, who adopted Edlén's values for the $2s^22p^4$ levels in evaluating the upper levels. The estimated wavelength uncertainty of ±0.01 Å corresponds to uncertainties of ±300 to ±700 cm^{-1} for the upper levels.

Most of these upper levels are based on single lines, and Fawcett and Hayes' analysis was partly guided by their calculations of the levels and oscillator strengths. They note that "In general the identifications for $n=2-3$ transitions can be regarded as firmer than those involving levels of higher principal quantum number." We have marked a few of the levels as explicitly tentative and omitted several $2s^22p^34d$ and $5d$ levels pending an extended isoelectronic study of these configurations.

We obtained the ionization energy by fitting an isoelectronic correlation-correction formula to the experimental deviations from theoretical ionization energies calculated by Cheng. The uncertainty is an order-of-magnitude estimate.

References

Cheng, K. T. [1981], unpublished calculations. AT

Deutschman, W. A., and House, L. L. [1966], Astrophys. J. **144**, 435–437. CL

Edlén, B. [1983], Phys. Scr. **28**, 51–67. EL

Fawcett, B. C. [1975], At. Data Nucl. Data Tables **16**, 135–164. CL

Fawcett, B. C., Cowan, R. D., and Hayes, R. W. [1974], Astrophys. J. **187**, 377–383. CL EL AT

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80–87. EL CL AT PT

Feldman, U., and Doschek, G. A. [1977], J. Opt. Soc. Am. **67**, 726–734. CL

Ferner, E. [1948], Ark. Mat., Astron. Fys. **36**, 1–65. CL

Kononov, E. Ya. [1966], Opt. Spectrosc. (USSR) **20**, 303–304. CL

Podobedova, L. I., Kononov, E. Ya., and Koshelev, K. N. [1971], Opt. Spectrosc. (USSR) **30**, 217–220. CL

Sandlin, G. D., Brueckner, G. E., and Tousey, R. [1977], Astrophys. J. **214**, 898–904. CL

S IX

Configuration	Term	*J*	Level (cm^{-1})	Configuration	Term	*J*	Level (cm^{-1})
$2s^22p^4$	^3P	2	0.0	$2s^22p^3(^4S^\circ)3s$	$^3S^\circ$	1	*1 783 150*
		1	7 985				
		0	10 648	$2s^22p^3(^2D^\circ)3s$	$^3D^\circ$	1	*1 844 970*
						2	*1 845 170*
$2s^22p^4$	^1D	2	58 293.9			3	*1 845 870*
$2s^22p^4$	^1S	0	122 700	$2s^22p^3(^2D^\circ)3s$	$^1D^\circ$	2	*1 858 800*
$2s2p^5$	$^3P^\circ$	2	*444 987*	$2s^22p^3(^2P^\circ)3s$	$^3P^\circ$	0	
		1	*451 995*			1	
		0	*455 890*			2	*1 891 830*
$2p^6$	^1S	0	1 039 219				

S IX — Continued

Configuration	Term	*J*	Level (cm^{-1})	Configuration	Term	*J*	Level (cm^{-1})
$2s^22p^3(^2P^\circ)3s$	$^1P^\circ$	1	*1 904 300*	$2s^22p^3(^2P^\circ)3d$	$^3P^\circ$	0	*2 142 780*
						1	*2 144 800*
$2s^22p^3(^4S^\circ)3d$	$^3D^\circ$	2	*2 035 230*			2	*2 146 600*
		1	*2 035 350*				
		3	*2 035 870*	$2s^22p^3(^2P^\circ)3d$	$^3D^\circ$	2	*2 154 580*
						1	*2 156 260*
$2s^22p^3(^2D^\circ)3d$	$^3D^\circ$	1	*2 105 330*			3	*2 156 430*
		2	*2 108 120*				
		3	*2 108 240?*	$2s^22p^3(^2P^\circ)3d$	$^1D^\circ$	2	*2 162 760*
$2s^22p^3(^2D^\circ)3d$	$^1P^\circ$	1	*2 108 900*	$2s^22p^3(^2P^\circ)3d$	$^1F^\circ$	3	*2 166 530*
$2s^22p^3(^2D^\circ)3d$	$^3P^\circ$	2	*2 116 450*	$2s^22p^3(^2P^\circ)3d$	$^1P^\circ$	1	*2 190 220?*
		1	*2 119 330*				
		0		$2s^22p^3(^4S^\circ)4d$	$^3D^\circ$	3	*2 489 360?*
$2s^22p^3(^2D^\circ)3d$	$^1D^\circ$	2	*2 117 430*	$2s^22p^3(^2D^\circ)4d$	$^3D^\circ$	3	*2 566 340?*
$2s^22p^3(^2D^\circ)3d$	$^3S^\circ$	1	*2 125 530*	$2s^22p^3(^2D^\circ)4d$	$^3P^\circ$	2	*2 571 880?*
$2s^22p^3(^2D^\circ)3d$	$^1F^\circ$	3	*2 134 710*	S x ($^4S^\circ_{3/2}$)	***Limit***		***3 061 300***

S X

$Z = 16$

N I isoelectronic sequence

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

Ionization energy 3 609 000 ± 2 500 cm^{-1} (447.5±0.3 eV)

We evaluated the $2s^22p^3\ {}^2D^\circ$ levels using measurements of the $2s^22p^3\ {}^4S^\circ - {}^2D^\circ$ forbidden lines observed in solar-corona spectra [Sandlin, Brueckner, and Tousey; Feldman and Doschek]; the values are probably accurate to about ±1 cm^{-1}. The $2s^22p^3\ {}^2P^\circ$ and $2s2p^4$ levels except $2s^22p^4\ {}^2P_{1/2}$ are from Edlén [1984], who used an isoelectronic smoothing of the experimental deviations from theoretical predictions. Edlén's values are partly based on, and supported within the uncertainties by, observations of the $2s^22p^3 - 2s2p^4$ lines in the 177–265 Å region [Kononov; Deutschman and House; Fawcett *et al.*, 1970; Podobedova *et al.*]. The stated experimental uncertainties and comparisons of wavelengths measured by different observers indicate that most of the $2s^22p^3\ {}^2P^\circ$ and $2s2p^4$ levels should be accurate within errors of ±30 to ±60 cm^{-1}. The $2s2p^4\ {}^2P_{1/2}$ level given here is 24 cm^{-1} below Edlén's value, the lower value being a compromise between Edlén's result and the S X measurements. The $2p^5\ {}^2P^\circ$ levels were established by observation of the $2s2p^4\ {}^2D_{5/2} - 2p^5\ {}^2P^\circ_{3/2}$ and ${}^2D_{3/2} - {}^2P^\circ_{1/2}$ doublet near 210 Å by Fawcett *et al.* [1971]. Edlén's values for the corresponding wavenumbers, adopted here, are respectively 18 cm^{-1} above and 116 cm^{-1} below the values obtained from the measured wavelengths.

The levels of configurations of the types $2s^22p^2nl$ and $2s2p^3nl$ ($n \geqslant 3$) are derived from lines in the region below 51 Å classified as transitions to $2s^22p^3$ or $2s2p^4$ lower levels. "Confirmation of classifications for S X is difficult because of the small line separations and blending" [Fawcett and Hayes, 1987]. Most of the stronger lines were included in the 1973 paper by Fawcett and Hayes, who extended the earlier analyses. In addition to their data, we have also used measurements by Ferner [1948], Kastner *et al.* [1977], Cohen and Crooker [1985], and Fawcett and Hayes [1987] in evaluating the levels given here. Most of these higher levels are given to the nearest 10 cm^{-1}, but the estimated uncertainties are of the order of ±500 cm^{-1} or more.

Fawcett and Hayes based their 1987 extension of the analysis partly on their calculations of energy levels and oscillator strengths for the transitions involved. We have in addition consulted unpublished calculations of the upper even-parity levels and oscillator strengths of transitions to the $2s^22p^3$ levels carried out by Cowan [1985]; his results include comparisons with experiment for Si VIII, P IX, and S X, with all strong configuration interactions included and adjustments of the energy parameters to give good agreement with the more reliably established experimental levels. The analysis problems mentioned by Fawcett and Hayes are especially troublesome for upper ${}^2D$ and ${}^2P$ terms, and we tentatively list different values for the $2p^2({}^3P)3d\ {}^2P_{1/2}$ and ${}^2D$ levels than given by them. Other level values given here agree with those of Fawcett and Hayes within the uncertainties, most of the differences being due to our use of Cohen and Crooker's measurements of some lines. We list several of the more clearly tentative levels with question marks. Pending higher resolution observations and more extensive isoelectronic studies of these difficult spectra, we have omitted a number of higher levels tabulated by Fawcett and Hayes [1987], including most of those based on lines below 41 Å.

Cheng has carried out Dirac-Fock calculations of the ionization energies for this isoelectronic sequence. Evaluating the constants in a correlation-correction formula for Cheng's results by fitting the deviations from experimental ionization energies for lower sequence members, we obtained a corrected value of 3 610 200 cm^{-1} for the ionization energy of S X. An isoelectronic-extrapolation formula derived by Edlén [1971] gives a value of 3 607 880 cm^{-1} for this ionization energy. We have adopted the average of these values (rounded to the nearest 100 cm^{-1}), with an estimated error somewhat greater than their difference.

References

Cheng, K. T. [1981], unpublished material. AT

Cohen, L., and Crooker, A. M. [1985], unpublished observations of vacuum-spark spectra of sulfur.

Cowan, R. D. [1985], unpublished calculations. PT AT

Deutschman, W. A., and House, L. L. [1967], Astrophys. J. **149**, 451–452. CL

Edlén, B. [1971], in *Topics in Modern Physics,* W. E. Brittin and H. Odabasi, Editors, pp. 133–145, Colorado Assoc. Univ. Press, Boulder, CO, USA. IP

Edlén, B. [1984], Phys. Scr. **30**, 135–145. EL

Fawcett, B. C., Cowan, R. D., and Hayes, R. W. [1974], Astrophys. J. **187**, 377–383. EL AT

Fawcett, B. C., Gabriel, A. H., and Paget, T. M. [1971], J. Phys. B **4**, 986–994. CL

Fawcett, B. C., Hardcastle, R. A., and Tondello, G. [1970], J. Phys. B **3**, 564–571. CL

Fawcett, B. C., and Hayes, R. W. [1973], Phys. Scr. **8**, 244–248. CL

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80–87. EL CL PT AT

Feldman, U., and Doschek, G. A. [1977], J. Opt. Soc. Am. **67**, 726–734. CL

Ferner, E. [1948], Ark. Mat., Astron. Fys. **36**, 1–65. CL

Kastner, S. O., Bhatia, A. K., and Cohen, L. [1977], Phys. Scr. **15**, 259–267. CL AT

Kononov, E. Ya. [1966], Opt. Spectrosc. (USSR) **20**, 303–304. CL

Podobedova, L. I., Kononov, E. Ya., and Koshelev, K. N. [1971], Opt. Spectrosc. (USSR) **30**, 217–220. CL

Sandlin, G. D., Brueckner, G. E., and Tousey, R. [1977], Astrophys. J. **214**, 898–904. CL

S x

Configuration	Term	J	Level (cm^{-1})
$2s^22p^3$	$^4S^\circ$	$3/2$	*0*
$2s^22p^3$	$^2D^\circ$	$3/2$	*82 442.3*
		$5/2$	*83 594.9*
$2s^22p^3$	$^2P^\circ$	$1/2$	*126 975*
		$3/2$	*128 804*
$2s2p^4$	^4P	$5/2$	378 458
		$3/2$	385 362
		$1/2$	388 883
$2s2p^4$	^2D	$3/2$	520 723
		$5/2$	520 864
$2s2p^4$	^2S	$1/2$	608 784
$2s2p^4$	^2P	$3/2$	636 898
		$1/2$	645 660
$2p^5$	$^2P^\circ$	$3/2$	*991 249*
		$1/2$	*1 002 372*
$2s^22p^2(^3P)3s$	^4P	$1/2$	2 087 460
		$3/2$	2 092 400
		$5/2$	2 098 440
$2s^22p^2(^3P)3s$	^2P	$1/2$	2 113 100
		$3/2$	2 120 500
$2s^22p^2(^1D)3s$	^2D	$3/2$	2 159 280?
		$5/2$	2 160 140
$2s^22p^2(^3P)3d$	^2P	$3/2$	2 331 160
		$1/2$	2 341 200?
$2s^22p^2(^3P)3d$	^2F	$5/2$	2 342 990
		$7/2$	2 351 480
$2s^22p^2(^3P)3d$	^4P	$5/2$	2 350 560
		$3/2$	2 353 220
		$1/2$	2 353 770
$2s^22p^2(^3P)3d$	^2D	$3/2$	2 378 700?
		$5/2$	2 379 900?
$2s^22p^2(^1D)3d$	^2D?	$3/2$	2 407 650
		$5/2$	2 409 100
$2s^22p^2(^1D)3d$	^2F	$7/2$	2 409 070
		$5/2$	2 412 550
$2s2p^3(^5S^\circ)3p$	^4P	$5/2$	2 417 970?
$2s2p^3(^5S^\circ)3d$	$^4D^\circ$	$1/2$	
		$3/2$	*2 542 660*
		$5/2$	*2 545 280*
		$7/2$	*2 552 510*
$2s2p^3(^3D^\circ)3d$	$^4D^\circ$	$7/2$	*2 689 900?*
$2s2p^3(^3P^\circ)3d$	$^4D^\circ$	$7/2$	*2 759 130?*
$2s^22p^2(^3P)4d$	^4P	$5/2$	2 914 600?
....	....	....	....
S XI ($^3P_0$)	***Limit***		**3 609 000**

S XI

$Z=16$

C I isoelectronic sequence

Ground state $1s^22s^22p^2\ {}^3P_0$

Ionization energy $4\,071\,300 \pm 3\,000\ \mathrm{cm}^{-1}$ $(504.8 \pm 0.4\ \mathrm{eV})$

The main papers for the measurements and analysis of the $2s^22p^2-2s2p^3$ lines (186–292 Å) are by Deutschman and House [1967], and by Podobedova *et al.* [1971]. The line list of Podobedova *et al.* also includes most of the known $2s2p^3-2p^4$ lines (213–362 Å). Fawcett *et al.* [1971] independently classified the $2s^22p^2\ {}^1S_0-2s2p^3\ {}^1P^\circ_1$ line and several $2s2p^3-2p^4$ lines, and Fawcett's 1975 compilation includes the only measurement of the $2s2p^3\ {}^3S^\circ_1-2p^4\ {}^3P_0$ wavelength.

The $2s^22p^2$, $2s2p^3$, and $2p^4$ levels given here are from Edlén [1985] except for the $2s^22p^2\ {}^3P_2$ and ${}^1D_2$ levels. Edlén's isoelectronically smoothed level values agree with values derived from the above-mentioned S XI measurements, within the experimental errors, and are probably somewhat more accurate. The $2p^4\ {}^1S_0$ value is given in brackets because Edlén's results show that no transition from this level (in particular, the $2s2p^3\ {}^1P^\circ_1-2p^4\ {}^1S_0$ line) has as yet been correctly identified. The $2s2p^3\ {}^5S^\circ_2$ levels predicted by Edlén, and also the $2s2p^23d\ {}^5P$ and $2s2p^23s\ {}^5P$ levels, are listed with an unknown correction "$+x$," no line connecting the quintet levels with the lower-multiplicity systems having been classified.

The relative positions of the $2s^22p^2\ {}^3P_1$, ${}^3P_2$, and ${}^1D_2$ levels are based on the wavelengths of the ${}^3P_1-{}^1D_2$ and ${}^3P_2-{}^1D_2$ forbidden lines observed in solar-corona spectra [Sandlin *et al.*; Feldman and Doschek]. The estimated relative uncertainties are about $1\ \mathrm{cm}^{-1}$, and the error of these levels with respect to the ${}^3P_0$ ground level is probably not greater than $15\ \mathrm{cm}^{-1}$. The $2s^22p^2\ {}^1S_0$ level, the connected $2s2p^3$ levels, and the $2p^4$ levels are probably accurate within errors of 25 to $40\ \mathrm{cm}^{-1}$.

Fawcett and Hayes [1987] give a list of lines in the 27–45 Å region classified as transitions from high levels belonging to configurations of the types $2s^22pnl$ and $2s2p^2nl$ $(n \geqslant 3)$. The analysis of the short wavelength spectrum was hampered by lack of sufficient experimental resolution, uncertainties due to overlapping with spectra of other ionization stages, etc. Most of the levels given here from the 1987 paper were first located in Fawcett and Hayes' 1973 analysis. The estimated wavelength uncertainty corresponds to level errors ranging from about 500 to $1000\ \mathrm{cm}^{-1}$. Several upper levels given by Fawcett and Hayes [1987] as classifying lines were not included in their table of levels. We have either omitted such levels or given them as tentative. Pending higher-resolution observations and more detailed isoelectronic studies, we have also omitted most of the $2s^22pnd$ $(n \geqslant 4)$ levels given in the 1987 paper. The line at 43.123 Å classified as $2s^22p^2\ {}^3P_2-2s^22p3s\ {}^3P^\circ_2$ in Fawcett and Hayes' 1973 paper should be added to the 1987 line list.

The leading eigenvector percentages for the $2s^22p3d$ levels are taken from Fawcett [1987], who calculated energies and oscillator strengths for this sequence using a Hartree-Fock program of R. D. Cowan. Some of the energy parameters were adjusted to improve agreement with experiment.

Cheng has calculated the ionization energies for ions of this sequence using Dirac-Fock theory. We evaluated the constants in an isoelectronic correlation-correction formula by fitting the experimental deviations from Cheng's calculated values for lower members of the sequence. The ionization energy given above was obtained by applying the resulting predicted correction for S XI to the theoretical value. The uncertainty is an order-of-magnitude estimate.

References

Cheng, K. T. [1981], unpublished material. AT

Deutschman, W. A., and House, L. L. [1967], Astrophys. J. **149**, 451–452. CL

Edlén, B. [1985], Phys. Scr. **31**, 345–358. EL PT

Fawcett, B. C. [1975], At. Data Nucl. Data Tables **16**, 135–164. EL CL

Fawcett, B. C., [1987], At. Data Nucl. Data Tables **37**, 367–409. AT PT

Fawcett, B. C., Gabriel, A. H., and Paget, T. M. [1971], J. Phys. B **4**, 986–994. CL

Fawcett, B. C., Hardcastle, R. A., and Tondello, G. [1970], J. Phys. B **3**, 564–571. CL

Fawcett, B. C., and Hayes, R. W. [1973], Phys. Scr. **8**, 244–248. CL

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80–87. EL CL AT PT

Feldman, U., and Doschek, G. A. [1977], J. Opt. Soc. Am. **67**, 726–734. CL

Podobedova, L. I., Kononov, E. Ya., and Koshelev, K. N. [1971], Opt. Spectrosc. (USSR), **30**, 217–220. CL

Sandlin, G. D., Brueckner, G. E., and Tousey, R. [1977], Astrophys. J. **214**, 898–904. CL

S XI

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^22p^2$	^{3}P	0	0			
		1	5 208.0			
		2	12 388.1			
$2s^22p^2$	^{1}D	2	67 146.3			
$2s^22p^2$	^{1}S	0	132 929			
$2s2p^3$	^{5}S°	2	*186 251+x*			
$2s2p^3$	^{3}D°	2	*355 076*			
		3	*355 350*			
		1	*355 364*			
$2s2p^3$	^{3}P°	0	*416 947*			
		1	*416 986*			
		2	*417 419*			
$2s2p^3$	^{1}D°	2	*530 177*			
$2s2p^3$	^{3}S°	1	*535 220*			
$2s2p^3$	^{1}P°	1	*592 480*			
$2p^4$	^{3}P	2	811 702			
		1	820 531			
		0	823 645			
$2p^4$	^{1}D	2	868 462			
$2p^4$	^{1}S	0	[986 736]			
$2s^22p3s$	^{3}P°	0				
		1	*2 320 260*			
		2	*2 331 340*			
$2s^22p3s$	^{1}P°	1	*2 345 060*			
$2s2p^2(^4$P$)3s$	^{5}P	1				
		2	2 519 160+*x*			
		3	2 525 380+*x*			
$2s^22p3d$	^{1}D°	2	*2 532 260*	75	14	$2s^22p3d$ ^{3}F°
$2s^22p3d$	^{3}D°	1	*2 548 420*	85		
		2	*2 549 740*	68	21	$2s^22p3d$ ^{3}P°
		3	*2 555 430*	93		
$2s^22p3d$	^{3}P°	2	*2 560 810*	71	24	$2s^22p3d$ ^{3}D°
		1	*2 562 100*	85	10	″
		0		95		
$2s^22p3d$	^{1}F°	3	*2 589 340*	95		
$2s^22p3d$	^{1}P°	1	*2 589 510?*	93		
$2s2p^2(^4$P$)3s$	^{3}P	2	2 590 790?			
$2s2p^2(^4$P$)3p$		1,2	*2 607 500?*			

S XI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s2p^2(^4P)3p$	$^3D^\circ$	3	*2 659 800*	
$2s2p^2(^2D)3s$	^3D	3	2 690 250?	
$2s2p^2(^4P)3d$	^5P	3	2 747 150+x	
		2,1	2 752 600+x?	
$2s2p^2(^4P)3d$	^3F	2	2 762 500	
		3	2 766 200	
		4	2 771 600	
$2s2p^2(^2D)3p$	$^1D^\circ$	2	*2 789 500?*	
$2s2p^2(^2D)3p$	$^1F^\circ$	3	*2 795 000?*	
$2s2p^2(^2P)3d$	^3D	3	2 799 800	
$2s2p^2(^2D)3d$	^3F	4	2 882 400	
$2s2p^2(^2D)3d$	^1F	3	2 891 900	
$2s2p^2(^2D)3d$	^1D	2	2 920 850	
$2s2p^2(^2P)3d$	^3P	2	3 053 050	
$2s^22p4d$	$^3D^\circ$	3	*3 232 600?*	
$2s^22p4d$	$^1F^\circ$	3	*3 243 450?*	
S XII ($^2P^\circ_{1/2}$)	***Limit***		***4 071 300***	

S XII

$Z=16$

B I isoelectronic sequence

Ground state $1s^22s^22p\ ^2P^\circ_{1/2}$

Ionization energy 4 552 500 ± 1 500 cm^{-1} (564.44 ± 0.19 eV)

The measurement and identification of the solar-coronal line at 7611.0 ± 0.4 Å [Jefferies, 1969] gives the value 13 135.3 ± 0.7 cm^{-1} adopted here for the $2s^22p$ $^2P^\circ_{1/2}-{}^2P^\circ_{3/2}$ ground-doublet interval. The $2s2p^2$ doublet levels are based mainly on measurements of transitions to the $^2P^\circ$ ground-term levels by Fawcett [1975] and by Podobedova *et al.* [1971]. We have also used averages of measurements by these authors in determining the $2s2p^2$ $^4P-2p^3$ $^4S^\circ_{3/2}$ separations. The position of the quartet term system with respect to the ground level is based on Edlén's isoelectronically estimated value for the $2s^22p$ $^2P^\circ_{3/2}-2s2p^2$ $^4P_{5/2}$ separation; an unknown correction "$+x$" is given with the quartet levels because their connection to the doublet system has not been determined experimentally. We used Fawcett's [1975] measurements of the $2s2p^2$ $^2D-2p^3$ $^2D^\circ$, $^2P^\circ$ lines and also Edlén's isoelectronically derived separations in evaluating the $2p^3$ doublet levels.

The estimated uncertainties of the various wavelength measurements used to determine the $2s2p^2$ and $2p^3$ levels correspond to wavenumber uncertainties of about ±20 to ±60 cm^{-1}, but larger errors in some cases would not be surprising.

We evaluated the $2s^2nd$ and $2s2pnl$ ($n \geqslant 3$) levels using the wavelengths and classifications of lines in the 23−39 Å region given by Fawcett and Hayes [1987]. Their estimated wavelength uncertainties correspond to wavenumber uncertainties of about ±1000 cm^{-1} for the $2s^23d$ and $2s2p3s$, $3p$, and $3d$ levels. The $2s^2nd$ and $2s2pnl$ levels having $n \geqslant 4$ are expected to have errors of the order of 3500 to 5500 cm^{-1}. These errors should be kept in mind, since in most cases we have rounded the higher levels to the nearest 100 cm^{-1} instead of the nearest 1000 cm^{-1}.

Fawcett and Hayes based their analysis partly on comparisons of observed spectra with the results of their theoretical calculations of levels and oscillator strengths. They note that "In general the identifications for $n=2-3$ transitions can be regarded as firmer than those involving levels of higher principal quantum number." We have marked a few of the higher levels as explicitly questionable, usually because only one line of an expected multiplet was classified.

A single position is given here for both levels of several doublet terms. In each case either the apparent observed doublet interval or the expected line splitting was smaller than the experimental uncertainty; appropriate averaging was used in obtaining the term values. Fawcett and Hayes rounded off the wavelengths below 30 Å to two decimal places in their line list, but apparently used three-place values in determining the corresponding high levels; we have taken a few of the highest levels (rounded off) from their table of levels.

We obtained the ionization energy by fitting an isoelectronic correlation-correction formula to the experimental deviations from theoretical (Dirac-Fock) ionization energies calculated by Cheng. A value for the S XIII $2s^2$ ^1S limit could also be derived by fitting a Ritz formula to the $2s^2nd$ ^2D series, but the present experimental uncertainties of these levels corresponds to an ionization-energy uncertainty much larger than the estimated error of our predicted value.

References

Cheng, K. T. [1981], unpublished material. AT

Edlén, B. [1983], Phys. Scr. **28**, 483−495. EL

Fawcett, B. C. [1970], J. Phys. B **3**, 1152−1163. CL

Fawcett, B. C. [1975], At. Data Nucl. Data Tables **16**, 135−164. EL CL

Fawcett, B. C., and Hayes, R. W. [1973], Phys. Scr. **8**, 244−248. CL

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80−87. EL CL

Jefferies, J. T. [1969], Mem. Soc. R. Sci. Liege, Collect. **8**, **17**, 213−234. CL

Podobedova, L. I., Kononov, E. Ya., and Koshelev, K. N. [1971], Opt. Spectrosc. (USSR) **30**, 217−220. CL

S XII

Configuration	Term	J	Level (cm^{-1})
$2s^22p$	$^2P^\circ$	$1/2$	*0.0*
		$3/2$	*13 135.3*
$2s2p^2$	^4P	$1/2$	193 882+x
		$3/2$	198 675+x
		$5/2$	205 425+x
$2s2p^2$	^2D	$3/2$	346 700
		$5/2$	347 005
$2s2p^2$	^2S	$1/2$	439 580
$2s2p^2$	^2P	$1/2$	464 755
		$3/2$	471 430
$2p^3$	$^4S^\circ$	$3/2$	*610 075+x*
$2p^3$	$^2D^\circ$	$3/2$	*689 910*
		$5/2$	*690 480*
$2p^3$	$^2P^\circ$	$1/2$	*774 020*
		$3/2$	*775 805*
$2s^23d$	^2D	$3/2$	2 747 400
		$5/2$	2 748 100
$2s2p(^3P^\circ)3s$	$^4P^\circ$	$5/2$	*2 774 700+x?*
$2s2p(^3P^\circ)3p$	^2P	$1/2$	2 840 700
		$3/2$	2 848 000
$2s2p(^3P^\circ)3p$	^2D	$3/2$	2 895 800
		$5/2$	2 904 500
$2s2p(^3P^\circ)3p$	^2S	$1/2$	2 929 800?
$2s2p(^3P^\circ)3d$	$^4D^\circ$	$1/2$	
		$5/2$	*2 950 800+x*
		$3/2$	*2 952 300+x*
		$7/2$	*2 957 600+x*
$2s2p(^3P^\circ)3d$	$^2D^\circ$	$5/2$	*2 956 600*
$2s2p(^3P^\circ)3d$	$^4P^\circ$	$5/2$	*2 963 800+x*
		$3/2$	*2 966 900+x*
		$1/2$	
$2s2p(^3P^\circ)3d$	$^2F^\circ$	$5/2$	*2 998 200*
		$7/2$	*3 006 400*
$2s2p(^3P^\circ)3d$	$^2P^\circ$	$3/2$	*3 011 500*
		$1/2$	*3 015 300*
$2s2p(^1P^\circ)3p$	^2D	$3/2, 5/2$	3 061 000
$2s2p(^1P^\circ)3d$	$^2F^\circ$	$5/2, 7/2$	*3 128 200*
$2s2p(^1P^\circ)3d$	$^2D^\circ$	$5/2$	*3 140 700*
$2s^24d$	^2D	$3/2, 5/2$	3 543 300
$2s2p(^3P^\circ)4p$	^2D	$5/2$	3 732 000?
$2s2p(^3P^\circ)4d$	$^4D^\circ$	$7/2$	*3 754 000+x?*
$2s2p(^3P^\circ)4d$	$^2F^\circ$	$5/2$	*3 766 700*
		$7/2$	*3 771 700*
$2s^25d$	^2D	$3/2, 5/2$	3 911 000
$2s2p(^1P^\circ)4d$	$^2F^\circ$	$5/2, 7/2$	*3 933 000?*
$2s^26d$	^2D	$5/2$	4 108 000?
$2s^27d$	^2D	$5/2$	4 228 000?
....	....	....	....
S XIII ($^1S_0$)	*Limit*		4 552 500

S XIII

$Z=16$

Be I isoelectronic sequence

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

Ionization energy 5 260 000 cm^{-1} (652.2 eV)

Fawcett [1970, 1975] and Fawcett and Hayes [1973, 1987] have analyzed this spectrum. We took the $2s^2$, $2s2p$, and $2p^2$ levels from Edlén [1983, 1985], who has smoothed the isoelectronic data by comparisons with theoretical values. The $2s^2\ ^1S_0-2s2p\ ^3P_1^\circ$ intercombination line has been measured in solar-flare spectra [Widing, 1978; Dere, 1978]. The $2s2p\ ^3P_1^\circ$ and $^1P_1^\circ$ levels are probably accurate to $\pm 10\ \mathrm{cm}^{-1}$, the $2s2p\ ^3P_0^\circ$ and $^3P_2^\circ$ levels to $\pm 20\ \mathrm{cm}^{-1}$, and the $2p^2\ ^3P$ and ^1D levels to $\pm 25\ \mathrm{cm}^{-1}$. No transitions from the $2p^2\ ^1S_0$ level to lower levels have been classified, but Edlén's interpolated $2p^2\ ^1S_0$ position (given in brackets) is probably accurate within $\pm 100\ \mathrm{cm}^{-1}$.

Fawcett and Hayes' 1987 line list for the short wavelength region extends from 23 to 37 Å. We evaluated the $2s3l$ and $2p3l$ levels using these wavelengths and Edlén's values for the lower levels. Fawcett and Hayes give the wavelengths below 30 Å to only two decimal places, but apparently used three-place values in determining the corresponding upper levels; we have thus adopted their level values (rounded off) for these higher levels. The estimated wavelength uncertainties correspond to errors of 750 to 1000 cm^{-1} for the $2s3l$, $2p3l$ levels and 4000 to 5500 cm^{-1} for the higher levels. We have rounded off the $2s3l$, $2p3l$ levels to the nearest 100 cm^{-1} and most of the higher levels to the nearest 500 cm^{-1}.

Fawcett and Hayes based their analysis of the short-wavelength spectrum partly on their theoretical calculations of the energy levels and oscillator strengths. The wavenumber separation of two lines measured at 36.559 and 34.872 Å agrees within 50 cm^{-1} with Edlén's value for the $2p^2\ ^1D_2-2p^2\ ^1S_0$ separation. These lines were classified as the $2p^2\ ^1S_0-2p3d\ ^1P_1^\circ$ and $2p^2\ ^1D_2-2p3d\ ^1F_3^\circ$ transitions, respectively, which gives almost coincident values for the $2p3d\ ^1P_1^\circ$ and $^1F_3^\circ$ levels. It seems likely that both lines are transitions from the $2p3d\ ^1P_1^\circ$ level since, in addition to the excellent agreement with the expected $2p^2\ ^1D_2-{}^1S_0$ separation, the observed relative intensity of the 34.872 Å line is much weaker than predicted by the calculations. We have thus omitted the $2p3d\ ^1F_3^\circ$ level as probably not having yet been located.

The difficulty of definitively classifying some of the short-wavelength lines was noted by Fawcett and Hayes. A few of the higher levels based on single weak or blended lines are explicitly indicated here as tentative.

We obtained the ionization energy from semi-empirical formulae for corrections to theoretically calculated values along the Be I sequence. The adopted value, which has been rounded to the nearest 1000 cm^{-1}, is 1100 cm^{-1} lower than the value given by Edlén's [1971] formula for this sequence. More accurate measurements of series in high-ionization spectra in this region of the periodic table will be required to test and improve the available ionization-energy formulae.

References

Dere, K. P. [1978], Astrophys. J. **221**, 1062–1067. CL

Edlén, B. [1971], in *Topics in Modern Physics*, W. E. Brittin and H. Odabasi, Editors, pp. 133–146, Colorado Assoc. Univ. Press, Boulder, CO. IP

Edlén, B. [1983], Phys. Scr. **28**, 51–67. EL CL

Edlén, B. [1985], Phys. Scr. **32**, 86–88. EL CL

Fawcett, B. C. [1970], J. Phys. B **3**, 1152–1163. CL

Fawcett, B. C. [1975], At. Data Nucl. Data Tables **16**, 135–164. EL CL

Fawcett, B. C., and Hayes, R. W. [1973], Phys. Scr. **8**, 244–248. CL

Fawcett, B. C., and Hayes, R. W. [1987], Phys. Scr. **36**, 80–87. EL CL PT

Widing, K. G. [1978], Astrophys. J. **222**, 735–739. CL

S XIII

Configuration	Term	J	Level (cm^{-1})
$2s^2$	^1S	0	0
$2s2p$	$^3P^\circ$	0	*199 181*
		1	*203 474*
		2	*213 182*
$2s2p$	$^1P^\circ$	1	*389 583*
$2p^2$	^3P	0	523 237
		1	528 796
		2	536 856
$2p^2$	^1D	2	589 449
$2p^2$	^1S	0	[721 825]
$2s3s$	^3S	1	3 011 500
$2s3p$	$^1P^\circ$	1	*3 101 500*
$2s3p$	$^3P^\circ$	1	*3 106 500*
$2s3d$	^3D	1	3 157 200
		2	3 157 500
		3	3 158 600
$2s3d$	^1D	2	3 193 300
$2p3p$	^1P	2	3 319 400
$2p3p$	^3D	3	3 343 700
$2p3p$	^3S	1	3 356 100
$2p3p$	^3P	0	
		1	3 365 600?
		2	3 372 500
$2p3p$	^1D	2	3 396 200
$2p3d$	$^3D^\circ$	1	
		2	*3 411 100*
		3	*3 414 700*
$2p3d$	$^3P^\circ$	2	*3 424 400*
$2p3p$	^1S	0	3 438 300
$2p3d$	$^1P^\circ$	1	*3 457 100*
$2s4s$	^3S	1	4 024 900
$2s4p$	$^1P^\circ$	1	*4 066 700*
$2s4d$	^3D	2,3	4 085 500
$2s4d$	^1D	2	4 095 000
$2p4p$	^3D	3	4 308 000?
$2p4d$	$^3D^\circ$	1	
		2	*4 325 000*
		3	*4 331 000*
$2p4d$	$^1F^\circ$	3	*4 333 500?*
$2s5d$	^3D	3	4 516 500?
S XIV ($^2S_{1/2}$)	***Limit***		**5 260 000**

S XIV

$Z=16$

Li I isoelectronic sequence

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

Ionization energy 5 702 400 ± 600 cm^{-1} (707.01 ± 0.08 eV)

The most accurate measurements of the $2s-2p$ resonance doublet lines have been made in solar-flare spectra [Widing and Purcell; Sandlin *et al.*; Dere]. The $2p$ levels here were obtained by adopting the wavelengths 417.66 and 445.70 Å as averages from these references; the errors are probably less than 15 cm^{-1}.

Brown *et al.* [1989] have made new observations of transitions from the higher levels. Their measurements include the $2s-3p$, $2p-3d$, and $2p-3s$ doublets in the 30 Å region and the $3s-4p$, $3p-4d$, and $3d-4f$ doublets in the 90 Å region. In evaluating the levels, we also used measurements of the $2s-3p$ and $2p-3d$ doublets by Fawcett and Hayes and by Goldsmith *et al.* and the measurements of the $3p-4d$ and $3d-4f$ doublets by Fawcett and Ridgeley. We combined the experimental wavenumbers from the 90 Å region with certain other data in evaluating the $4d$ and $4f$ levels. Thus the hydrogenic value for the $4f\ {}^2F^\circ_{5/2}-{}^2F^\circ_{7/2}$ interval, 292 cm^{-1}, as well as the $4d\ {}^2D_{5/2}-4f\ {}^2F^\circ_{5/2}$ separation determined by core-polarization parameters [Edlén, 1979], 546 cm^{-1}, are probably accurate within errors less than 100 cm^{-1}; the respective values for these quantities from the levels here are 300 and 420 cm^{-1}. It seems likely that the errors of the $3s$, $3p$, $3d$, $4d$, and $4f$ levels with respect to the ground level are within about ±600 cm^{-1}.

Edlén's parameterizations of the data for this isoelectronic sequence yielded formulae for the entire $1s^2nl$ energy structure. His values for the levels mentioned above agree with the values here within the uncertainties, the largest discrepancy being a difference of 370 cm^{-1} between the two values for $3p\ {}^2P^\circ_{3/2}$ (Edlén's value is 3 286 180 cm^{-1}). We have given values for the $4s$, $4p$, and $5d$ levels as obtained from Edlén's results. The uncertainty of these levels is comparable to that for the other levels having $n\geqslant 3$ and is significantly less than the uncertainty of the available experimental wavenumbers for corresponding transitions to $n=2$ levels [measurements in the 22–24 Å region by Fawcett *et al.*, 1970]. The measurements of the weak $3s-4p$ doublet near 89 Å by Brown *et al.* agree with Edlén's values within the uncertainties.

Absolute term values (ionization energies) for the $4f$ levels including relativistic and core-polarization corrections [Edlén, 1979] are probably accurate within ±100 cm^{-1}. By adding such term values to the $4f$ levels given here, we obtained a value 5 702 430 cm^{-1} for the principal ionization energy (S XV $1s^2\ {}^1S$), in good agreement with Edlén's value 5 702 380 cm^{-1}. We thus adopt the value 5 702 400 ± 600 cm^{-1}, as given above.

The terms of the lowest configurations having K-shell excitation, $1s2s^2$, $1s2s2p$, and $1s2p^2$, are included in the table. Spectral features due to such configurations have been observed near, or blended with, the S XV $1s^2-1s2p$ resonance lines in the 5 Å region. Transitions from the $1s2s2p$ and $1s2p^2$ doublet terms (to $1s^22s\ {}^2S$ and $1s^22p\ {}^2P^\circ$, respectively) are among the strongest contributors to such features in the spectra of laser-produced plasmas [see, e.g., Aglitskii *et al.*, 1974; Feldman *et al.*, 1974; and Boiko, *et al.*, 1978a]. Since the experimental wavelengths obtained for such features usually refer to unresolved blends of several lines, we derived the K-excitation levels here using calculations by Vainshtein and Safronova [1975; 1978] and a correction for QED and some smaller contributions not included in their calculations. On the basis of comparisons of their values for the S XV $1s^2\ {}^1S-1s2s\ {}^3S,{}^1S$ and $1s^2\ {}^1S-1s2p\ {}^3P^\circ$, ${}^1P^\circ$ energies with more accurate values calculated by Drake [see S XV], we reduced the $1s^22p-1s2s^2$, $1s^22s-1s2s2p$, and $1s^2 2p-1s2p^2$ separations of Vainshtein and Safronova by 3400 cm^{-1} as an average correction. The $1s2s^2$, $1s2s2p$, and $1s2p^2$ levels were then obtained by combining these adjusted separations with the $1s^22s\ {}^2S$ and $1s^22p\ {}^2P^\circ$ levels given here. The errors of the resulting K-excitation levels are expected to be significantly smaller than the experimental uncertainties of the best available measurements (about ±4000 cm^{-1}). Most of the calculated K-excitation fine-structure splittings are probably accurate to a few hundred cm^{-1}

The energies of levels of some higher excited-core configurations, such as those of the type $1s2l3l'$ for example, have also been calculated, and features classified as arising from such levels have been observed as satellites of the S XV $1s^2-1s2p$ and $1s^2-1s3p$ resonance lines [Boiko *et al.*, 1978b, and references therein; a more complete list of calculated wavelengths is given by Vainshtein and Safronova, 1980]

References

Aglitskii, E. V., Boiko, V. A., Zakharov, S. M., Pikuz, S. A., and Faenov, E. Ya. [1974], Sov. J. Quantum Electron. **4,** 500–513. CL

Boiko, V. A., Faenov, A. Ya., and Pikuz, S. A. [1978a], J. Quant. Spectrosc. Radiat. Transfer **19,** 11–50. CL AT. Several theoretical wavelengths for sulfur in Table 3 of this reference are listed opposite the wrong transitions.

Boiko, V. A., Pikuz, S. A., Safronova, U. I., and Faenov, A. Ya. [1978b], Mon. Not. R. Astron. Soc. **185,** 789–805. CL AT

Brown, C. M., Ekberg, J. O., Seely, J. F., and Feldman, U. [1989], J. Opt. Soc. Am. B **6,** 1650–1651.

Dere, K. P. [1978], Astrophys. J. **221,** 1062–1067. W

Edlén, B. [1979], Phys. Scr. **19,** 255–266. EL W IP

Edlén, B. [1983], Phys. Scr. **28,** 51–67. EL W

Fawcett, B. C., Hardcastle, R. A., and Tondello, G. [1970], J. Phys. B **3,** 564–571. CL

Fawcett, B. C., and Hayes, R. W. [1973], Phys. Scr. **8,** 244–248. CL

Fawcett, B. C., and Ridgeley, A. [1981], J. Phys. B **14,** 203–208. EL CL. The original measured wavelengths from Table 1(b) of this reference were used for the compilation here.

Feldman, U., Doschek, G. A., Nagel, D. J., Cowan, R. D., and Whitlock, R. R. [1974], Astrophys. J. **192,** 213–220. CL

Goldsmith, S., Oren, L., and Cohen, L. [1974], Astrophys. J. **188,** 197–200. EL CL

Sandlin, G. D., Brueckner, G. E., Scherrer, V. E., and Tousey, R. [1976], Astrophys. J. **205,** L47–L50. W

Vainshtein, L. A., and Safronova, U. I. [1975], Preprint No. 6, Inst. Spectrosc., Acad. Sci. USSR, Moscow. AT. We used the wavenumbers in Table 2b of this reference except for the $1s2p^2\,{}^4P^\circ_{5/2}$ and $1s2s^2\,{}^2S_{1/2}$ levels. The wavenumber given for the $1s2p^2\,{}^4P^\circ_{5/2}$ transition is clearly a misprint; we have assumed the correct value to be 19 506 925 cm^{-1} (before adjustment as described), in agreement with the calculated wavelengths in the 1978 reference below. We also took the $1s2s^2\,{}^2S_{1/2}$ position (before adjustment) to agree with the wavelengths in the 1978 reference.

Vainshtein, L. A., and Safronova, U. I. [1978], At. Data Nucl. Data Tables **21,** 49–68. AT

Vainshtein, L. A., and Safronova, U. I. [1980], At. Data Nucl. Data Tables **25,** 311–385.

Widing, K. G., and Purcell, J. D. [1976], Astrophys. J. **204,** L151–L15. EL W

S XIV

Configuration	Term	*J*	Level (cm^{-1})	Configuration	Term	*J*	Level (cm^{-1})
$1s^22s$	^2S	1/2	0	S XV ($^1S_0$)	***Limit***		**5 702 400**
$1s^22p$	$^2P^\circ$	1/2	*224 366*	$1s2s^2$	^2S	1/2	[19 422 000]
		3/2	*239 429*				
				$1s(^2S)2s2p(^3P^\circ)$	$^4P^\circ$	1/2	[*19 480 400*]
$1s^23s$	^2S	1/2	3 220 100			3/2	[*19 484 500*]
						5/2	[*19 494 400*]
$1s^23p$	$^2P^\circ$	1/2	*3 282 020*				
		3/2	*3 286 550*	$1s(^2S)2s2p(^3P^\circ)$	$^2P^\circ$	1/2	[*19 656 100*]
						3/2	[*19 663 900*]
$1s^23d$	^2D	3/2	3 309 260				
		5/2	3 310 680	$1s2p^2$	^4P	1/2	[19 721 300]
						3/2	[19 727 900]
$1s^24s$	^2S	1/2	4 319 700			5/2	[19 735 300]
$1s^24p$	$^2P^\circ$	1/2	*4 344 980*	$1s(^2S)2s2p(^1P^\circ)$	$^2P^\circ$	1/2	[*19 736 800*]
		3/2	*4 346 860*			3/2	[*19 740 800*]
$1s^24d$	^2D	3/2	4 356 570	$1s2p^2$	^2D	5/2	[19 838 200]
		5/2	4 357 210			3/2	[19 839 000]
$1s^24f$	$^2F^\circ$	5/2	*4 357 630*	$1s2p^2$	^2P	1/2	[19 864 000]
		7/2	*4 357 930*			3/2	[19 878 500]
$1s^25d$	^2D	3/2,5/2	4 841 300	$1s2p^2$	^2S	1/2	[19 994 200]
....	....	....	....	S XV $1s2s(^3S_1)$	*Limit*		[25 304 400]

S XV

$Z=16$

He I isoelectronic sequence

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

Ionization energy 26 001 513 ± 400 cm^{-1} (3223.78 ± 0.05 eV)

Schleinkofer *et al.* [1982] measured the S XV $1s^2\ ^1S_0-1s2p\ ^1P_1^\circ$ and $^3P_1^\circ$ resonance lines and obtained energies equivalent to 19 846 480±730 and 19 736 630±890 cm^{-1}, respectively. The $1s^2\ ^1S_0-1s2p\ ^1P_1^\circ$ separation as determined by the wavelength measurement of Aglitsky *et al.* [1988] is 19 846 780±1180 cm^{-1}. Aglitskii *et al.* [1974] observed the $1s^2\ ^1S_0-1snp\ ^1P_1^\circ$ series to $n=6$ with uncertainties of ±4000 to ±12 000 cm^{-1}.

The $1s2l$ levels and the ionization energy given here are from Drake's 1988 calculations for this isoelectronic sequence. Measurements of the Ar XVII $1s^2\ ^1S_0-1s2p\ ^1P_1^\circ$ and $^3P_1^\circ$ resonance lines by Deslattes *et al.* agree with Drake's calculations within the estimated experimental uncertainties of 1.2 parts in 10^5. An error of 1.2 parts in 10^5 for the S XV $1s2p$ levels relative to the ground level corresponds to about ±240 cm^{-1}; our assumption of ±400 cm^{-1} as the uncertainty for the $1snl$ levels and ionization energy is based on the agreement with experiment for Ar XVII. The calculations of the S XV $1s^2\ ^1S_0-1s2p\ ^3P_1^\circ$ and $1s^2\ ^1S_0-1s2p\ ^1P_1^\circ$ separations by Indelicato [1988, 1989] and by Aglitsky *et al.* [1988], respectively, agree with Drake's values within this uncertainty. The experimental values for these separations quoted above also agree with Drake's calculated values within the larger uncertainties involved.

The estimated uncertainty of the $1s2s\ ^3S-1s2p\ ^3P^\circ$ level separations here is about ±8 cm^{-1} [Drake, 1988]. The most recent experimental values of the $^3S_1-^3P_2^\circ$ and $^3S_1-^3P_0^\circ$ separations, 148 493 ± 5 and 132 198 ± 10 cm^{-1} [DeSerio *et al.*], are less than the values here by 6 and 42 cm^{-1}, respectively. The deviation of the experimental $^3S_1-^3P_0$ separation from the calculated value appears inconsistent with similar comparisons for $Z=10-15$; pending clarification of this apparent small irregularity along the isoelectronic sequence, we have listed the $1s2s\ ^3S$ and $1s2p\ ^3P^\circ$ levels as calculated by Drake.

The $1s3l$ levels are from Drake's 1985 calculations with small adjustments (3 cm^{-1} or less) based on his 1988 values for the ionization energy and $1s2l$ levels. Ermolaev and Jones [1974] calculated the $1sns$ and $1snp$ levels through $n=5$, and Vainshtein and Safronova [1985] calculated the $1sns$, $1snp$, and $1snd$ levels through $n=5$. If the $1snl$ level systems calculated by these authors are each adjusted to Drake's limit, the agreement with Drake's levels is within ±100 cm^{-1} for all except Vainshtein and Safronova's $1s3p\ ^3P^\circ$ levels. We give the $1sns$ and $1snp$ levels for $n=4$ and 5 as obtained from Ermolaev and Jones' term values (positions with respect to the limit) combined with Drake's value for the limit. The $1sns$ and $1snp$ levels for $n=6-10$ are from series formulae given by Martin (based on lower series members calculated by Ermolaev and Jones) and Drake's limit. We have given the $1snl$ term system complete through $n=6$ by including the terms for $n=4-6$, $l\geqslant 2$ as calculated from series or term-defect formulae [Martin] and Drake's limit. The errors of the $1snf$, $1sng$, and $1snh$ positions with respect to the limit (i.e., their term values or ionization energies) are expected to be well within 100 cm^{-1}, the term-defect uncertainties decreasing for higher n and l values. Comparisons of the $1snd$ series-formulae predictions with the recent calculations by Drake ($1s3d$) and Vainshtein and Safronova ($1s3d-5d$) indicate that the errors of the series-formula $1snd$ levels with respect to the limit are also within ±100 cm^{-1}. (In comparisons of levels given here with values calculated by Vainshtein and Safronova, it is of course necessary to take into account the above-mentioned systematic difference with respect to the ground level.)

Transitions of the type $1snl-2l'nl''$ ($n\geqslant 2$) from doubly-excited configurations in S XV give rise to satellite features near the S XVI $1s\ ^2S-2p\ ^2P^\circ$ resonance doublet at 4.73 Å. Boiko *et al.*, for example, compare experimental and calculated intensities of three features due to transitions from $2s2p$ and $2p^2$ levels observed in spectra of laser-produced plasmas (two of the features being classified as blends of unresolved lines). The positions of the $2s^2$, $2s2p$, and $2p^2$ levels given here are based on calculations by Vainshtein and Safronova [1978], adjusted to include QED contributions omitted by them. Their calculated wavelengths for the satellite transitions were increased by 0.0013 Å on the basis of comparisons of their results for the S XVI $1s-2s$ and $1s-2p$ transitions with those of Mohr (see S XVI). The resulting wavenumbers were combined with the appropriate $1snl$ levels as given here to obtain the doubly-excited levels, averages from several transitions being used in some cases. We list these levels to the nearest 100 cm^{-1}. The still higher configurations of the type $2l'nl''$ ($n\geqslant 3$) can give rise to satellites of both the $1s-2p$ and $1s-np$ resonance lines of S XVI. Vainshtein and Safronova [1980] give calculated wavelengths for such transitions.

References

Aglitskii, E. V., Boiko, V. A., Zakharov, S. M., Pikuz, S. A., and Faenov, A. Ya. [1974], Sov. J. Quantum Electron. **4**, 500–513. CL W

Aglitsky, E. V., Antsiferov, P. S., Mandelstam, S. L., Panin, A. M., Safronova, U. I., Ulitin, S. A., and Vainshtein, L. A. [1988], Phys. Scr. **38**, 136–142. EL W AT

Boiko, V. A., Faenov, A. Ya., Pikuz, S. A., and Safronova, U. I. [1977], Mon. Not. R. Astron. Soc. **181**, 107–120. CL W AT

DeSerio, R., Berry, H. G., Brooks, R. L., Hardis, J., Livingston, A. E., and Hinterlong, S. J. [1981], Phys. Rev. A **24**, 1872–1888. EL AT

Deslattes, R. D., Beyer, H. F., and Folkmann, F. [1984], J. Phys. B **17**, L689–L694. The Ar XVII $1s^2 - 1s2p$ wavelengths quoted from Drake's calculations in this reference are greater than the corresponding values from Drake's more recent results (see below) by about 4 parts per million.

Drake, G. W. F. [1985], unpublished calculations; see Drake [1988]. AT

Drake, G. W. F. [1988], Can. J. Phys. **66**, 586–611. AT

Ermolaev, A. M., and Jones, M. [1974], J. Phys. B **7**, 199–207, and supplement. AT. The $1s2p$, $1s3p$ $^3P^\circ_0$ and $^3P^\circ_2$ term values tabulated in the supplement have been corrected [Martin, 1981].

Goldman, S. P., and Drake, G. W. F. [1984], J. Phys. B **17**, L197–L202. AT

Indelicato, P. [1988], Nucl. Instrum. Meth. Phys. Res. B **31**, 14–20; [1989], unpublished material including calculated values for the $1s2p$ levels. AT

Martin, W. C. [1981], Phys. Scr. **24**, 725–731. W SF

Schleinkofer, L., Bell, F., Betz, H. D., Trollmann, G., and Rothermel, J. [1982], Phys. Scr. **25**, 917–923. EL

Vainshtein, L. A., and Safronova, U. I. [1978], At. Data Nucl. Data Tables **21**, 49–68. AT

Vainshtein, L. A., and Safronova, U. I. [1980], At. Data Nucl. Data Tables **25**, 311–385. AT

Vainshtein, L. A., and Safronova, U. I. [1985], Phys. Scr. **31**, 519–532. AT

S XV

Configuration	Term	J	Level (cm^{-1})
$1s^2$	^{1}S	0	0
$1s2s$	^{3}S	1	[19 602 076]
$1s2p$	^{3}P°	0	*[19 734 314]*
		1	*[19 737 521]*
		2	*[19 750 573]*
$1s2s$	^{1}S	0	[19 745 473]
$1s2p$	^{1}P°	1	*[19 846 285]*
$1s3s$	^{3}S	1	[23 193 163]
$1s3p$	^{3}P°	0	*[23 229 571]*
		1	*[23 230 551]*
		2	*[23 234 429]*
$1s3s$	^{1}S	0	[23 231 087]
$1s3d$	^{3}D	1	[23 254 611]
		2	[23 254 645]
		3	[23 256 165]
$1s3d$	^{1}D	2	[23 257 195]
$1s3p$	^{1}P°	1	*[23 260 416]*
$1s4s$	^{3}S	1	[24 431 101]
$1s4p$	^{3}P°	0	*[24 446 163]*
		1	*[24 446 570]*
		2	*[24 448 199]*
$1s4s$	^{1}S	0	[24 446 439]
$1s4d$	^{3}D	1,2	[24 456 527]
		3	[24 457 176]
$1s4d$	^{1}D	2	[24 457 576]
$1s4f$	^{3}F°,^{1}F°	2,3,3,4	*[24 457 889]*
$1s4p$	^{1}P°	1	*[24 458 842]*
$1s5s$	^{3}S	1	[24 999 972]
$1s5p$	^{3}P°	0	*[25 007 589]*
		1	*[25 007 798]*
		2	*[25 008 632]*
$1s5s$	^{1}S	0	[25 007 605]
$1s5d$	^{3}D	1,2	[25 012 870]
		3	[25 013 202]
$1s5d$	^{1}D	2	[25 013 407]
$1s5f$	^{3}F°,^{1}F°	2,3,3,4	*[25 013 562]*
$1s5g$	^{3}G,^{1}G	3,4,4,5	[25 013 723]
$1s5p$	^{1}P°	1	*[25 014 007]*
$1s6s$	^{3}S	1	[25 307 614]
$1s6s$	^{1}S	0	[25 312 000]
$1s6p$	^{3}P°	0	*[25 312 007]*
		1	*[25 312 128]*
		2	*[25 312 610]*
$1s6d$	^{3}D	1,2	[25 315 047]
		3	[25 315 239]
$1s6d$	^{1}D	2	[25 315 357]

S XV — Continued

Configuration	Term	J	Level (cm^{-1})
$1s6f$	$^3F^\circ,^1F^\circ$	2,3,3,4	[*25 315 445*]
$1s6g$	$^3G,^1G$	3,4,4,5	[25 315 534]
$1s6h$	$^3H^\circ,^1H^\circ$	4,5,5,6	[*25 315 589*]
$1s6p$	$^1P^\circ$	1	[*25 315 693*]
$1s7s$	^3S	1	[25 492 558]
$1s7s$	^1S	0	[25 495 299]
$1s7p$	$^3P^\circ$	0	[*25 495 315*]
		1	[*25 495 392*]
		2	[*25 495 695*]
$1s7p$	$^1P^\circ$	1	[*25 497 627*]
$1s8s$	^3S	1	[25 612 331]
$1s8s$	^1S	0	[25 614 158]
$1s8p$	$^3P^\circ$	0	[*25 614 174*]
		1	[*25 614 225*]
		2	[*25 614 428*]
$1s8p$	$^1P^\circ$	1	[*25 615 718*]
$1s9s$	^3S	1	[25 694 310]
$1s9s$	^1S	0	[25 695 589]
$1s9p$	$^3P^\circ$	0	[*25 695 602*]
		1	[*25 695 638*]
		2	[*25 695 781*]
$1s9p$	$^1P^\circ$	1	[*25 696 685*]
$1s10s$	^3S	1	[25 752 872]
$1s10s$	^1S	0	[25 753 802]
$1s10p$	$^3P^\circ$	0	[*25 753 813*]
		1	[*25 753 839*]
		2	[*25 753 943*]
$1s10p$	$^1P^\circ$	1	[*25 754 601*]
S XVI ($^2S_{1/2}$)	***Limit***		**[26 001 513]**
$2s^2$	^1S	0	[40 511 800]
$2s2p$	$^3P^\circ$	0	[*40 541 800*]
		1	[*40 548 200*]
		2	[*40 564 200*]
$2p^2$	^3P	0	[40 663 600]
		1	[40 671 900]
		2	[40 684 300]
$2p^2$	^1D	2	[40 745 200]
$2s2p$	$^1P^\circ$	1	[*40 748 400*]
$2p^2$	^1S	0	[40 939 100]
S XVI $2p(^2P^\circ_{1/2})$	*Limit*		[*47 130 813*]
S XVI $2s(^2S_{1/2})$	*Limit*		[47 131 660]
S XVI $2p(^2P^\circ_{3/2})$	*Limit*		[*47 155 008*]

S XVI

$Z=16$

H I isoelectronic sequence

Ground state $1s\ ^2\mathrm{S}_{1/2}$

Ionization energy 28 182 526 ± 4 cm^{-1} (3494.1892±0.0010 eV)

The ionization energy and the $2s$ and $2p$ levels are from the calculations by Mohr, which agree to the nearest cm^{-1} with values calculated by Johnson and Soff. Mohr gives an uncertainty of $\pm0.1\ \mathrm{cm}^{-1}$ for the $2p\ ^2\mathrm{P}^\circ_{3/2}-{}^2\mathrm{P}^\circ_{1/2}$ interval and $\pm0.4\ \mathrm{cm}^{-1}$ for the $2s-2p$ separations. The $2s\ ^2\mathrm{S}_{1/2}-2p\ ^2\mathrm{P}^\circ_{3/2}$ separation as measured by Georgiadis *et al.*, $23\,351.7\pm2.1\ \mathrm{cm}^{-1}$, is $3.7\ \mathrm{cm}^{-1}$ greater than Mohr's calculated value, the quoted experimental error representing one standard deviation. Assuming Mohr's calculated value for the $2p\ ^2\mathrm{P}^\circ_{3/2}-{}^2\mathrm{P}^\circ_{1/2}$ interval, Georgiadis *et al.* deduced from their measurement a value of $842.7\pm2.1\ \mathrm{cm}^{-1}$ for the $2s\ ^2\mathrm{S}_{1/2}-2p\ ^2\mathrm{P}^\circ_{1/2}$ Lamb shift. Zacek *et al.* determined a value of $838.6\pm8.0\ \mathrm{cm}^{-1}$ for this shift using a field quench technique. Neither of these experimental results is in strong disagreement with Mohr's value of $846.4\pm0.4\ \mathrm{cm}^{-1}$.

We evaluated the levels for $n=3-5$ by subtracting the binding energies calculated by Erickson from the $1s$ ionization energy quoted here. The resulting $3s$, $4s$, and $5s\ ^2\mathrm{S}_{1/2}$ levels were decreased by 4.2, 1.8, and 0.9 cm^{-1}, respectively, before being rounded to the nearest cm^{-1}; these are estimated corrections to the Lamb shifts. Erickson's table of binding energies has the ns, np, and nl $(l=n-1)$ levels for $n=6-13$. The uncertainty of most of the excited levels with respect to the $1s\ ^2\mathrm{S}_{1/2}$ ground level is about equal to the ionization-energy uncertainty. A nuclear mass appropriate for the $^{16}\mathrm{S}^{32}$ isotope was assumed in all the calculations used here. Use of the natural-abundance average mass for sulfur would reduce all level separations by 5.7 parts in 10^8; this amounts to only $1.6\ \mathrm{cm}^{-1}$ for the ionization energy, which is smaller than the uncertainty.

The experimental uncertainties of measurements of the S XVI $1s-np$ resonance lines made thus far are much larger than the estimated errors of the theoretical wavelengths. The measurements of the $1s\ ^2\mathrm{S}-2p\ ^2\mathrm{P}^\circ$ doublet near 4.73 Å by Schleinkofer *et al.*, for example, are in reasonable agreement with the predicted energies, but the uncertainties are 2200 and 2900 cm^{-1}.

References

Aglitskii, E. V., Boiko, V. A., Zakharov, S. M., Pikuz, S. A., and Faenov, A. Ya. [1974], Sov. J. Quantum Electron. **4**, 500–513. CL

Erickson, G. W. [1977], J. Phys. Chem. Ref. Data **6**, 831–869. TE

Georgiadis, A. P., Müller, D., Sträter, H. D., Gassen, J., von Brentano, P., Sens, J. C., and Pape, A. [1986], Phys. Lett. A **115**, 108–110. EL QF

Johnson, W. R., and Soff, G. [1985], At. Data Nucl. Data Tables **33**, 405–446. TE

Mohr, P. J. [1983], At. Data Nucl. Data Tables **29**, 453–466. TE. Separations involving the $1s$, $2s$, and $2p$ levels are given in Table I of this reference. Results from which the calculated binding energies of the individual levels can be obtained were supplied for this compilation (Mohr, P. J. [1983], unpublished material).

Schleinkofer, L., Bell, F., Betz, H. D., Trollmann, G., Rothermel, J. [1982], Phys. Scr. **25**, 917–923. EL

Sträter, H. D., von Gerdtell, L., Georgiadis, A. P., Müller, D., von Brentano, P., Sens, J. C., and Pape, A. [1984], Phys. Rev. A **29**, 1596–1598. EL QF

Zacek, V., Bohn, H., Brum, H., Faestermann, T., Feilitzsch, F. v., Giorginis, G., Kienle, P., Schuhbeck, S. [1984], Z. Phys. A **318**, 7–11. EL QF

S XVI

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$1s$	$^2\mathrm{S}$	$^1/_2$	0	$3s$	$^2\mathrm{S}$	$^1/_2$	[25 050 703]
$2p$	$^2\mathrm{P}^\circ$	$^1/_2$	[*21 129 300.4*]	$3d$	$^2\mathrm{D}$	$^3/_2$	[25 057 607]
		$^3/_2$	[*21 153 494.8*]			$^5/_2$	[25 059 982]
$2s$	$^2\mathrm{S}$	$^1/_2$	[21 130 146.8]	$4p$	$^2\mathrm{P}^\circ$	$^1/_2$	[*26 421 866*]
						$^3/_2$	[*26 424 890*]
$3p$	$^2\mathrm{P}^\circ$	$^1/_2$	[*25 050 449*]				
		$^3/_2$	[*25 057 620*]	$4s$	$^2\mathrm{S}$	$^1/_2$	[26 421 973]

S XVI — Continued

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
4*d*	$^{2}\mathrm{D}$	$^{3}/_{2}$	[26 424 885]	5*d*	$^{2}\mathrm{D}$	$^{3}/_{2}$	[27 057 760]
		$^{5}/_{2}$	[26 425 887]			$^{5}/_{2}$	[27 058 274]
4*f*	$^{2}\mathrm{F}^{\circ}$	$^{5}/_{2}$	[*26 425 885*]	5*f*	$^{2}\mathrm{F}^{\circ}$	$^{5}/_{2}$	[*27 058 273*]
		$^{7}/_{2}$	[*26 426 385*]			$^{7}/_{2}$	[*27 058 529*]
5*p*	$^{2}\mathrm{P}^{\circ}$	$^{1}/_{2}$	[*27 056 215*]	5*g*	$^{2}\mathrm{G}$	$^{7}/_{2}$	[27 058 528]
		$^{3}/_{2}$	[*27 057 763*]			$^{9}/_{2}$	[27 058 682]
5*s*	$^{2}\mathrm{S}$	$^{1}/_{2}$	[27 056 270]		***Limit***		[28 182 526]