

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

Received December 28, 1989; revised manuscript received February 22, 1990

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 These data have been critically compiled, mainly from published and unpublished material on measurements and analyses of the optical spectra.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	821	S VIII	860
2. Acknowledgments	822	S IX	863
3. Tables of Energy Levels	823	S X	865
S I	823	S XI	867
S II	833	S XII	870
S III	841	S XIII	872
S IV	844	S XIV	874
S V	849	S XV	876
S VI	854	S XVI	879
S VII	857		

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 $8065.5410 \pm 0.0024 \text{ cm}^{-1}$ 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.

^aPresent address: 908 Roswell Drive, Silver Spring, MD 20901.

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.

This work was supported by the NIST Standard Reference Data office, by the National Aeronautics and Space Administration, Astrophysics Division, and by the Department of Energy, Office of Magnetic Fusion Energy.

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 $1s^2 2s^2 2p^6 3s^2 3p^4 \ ^3P_2$ Ionization energy $83\,559.1 \pm 1.0 \text{ cm}^{-1}$ (10.36001 \pm 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 3P_0 as accurate to $\pm 0.005 \text{ cm}^{-1}$, based on his wavelength measurements for three transitions between these levels. Kaufman's determinations gave the $3s^2 3p^4 \ ^3P_0$ level accurate to about $\pm 0.016 \text{ cm}^{-1}$, and the uncertainty of his connection between the most accurate levels of the excited configurations and the ground-configuration levels is about $\pm 0.02 \text{ cm}^{-1}$. 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 cm^{-1} , and the uncertainty of their values as given here with respect to the $3s^2 3p^4$ levels is about $\pm 0.02 \text{ cm}^{-1}$, Jakobsson's values having been increased by 0.950 cm^{-1} [Kaufman].

Most of the two-place and one-place odd levels below the $3p^3(^4S^\circ)$ limit, as well as the $3p^3(^2D^\circ)5s \ ^1D_2^\circ$ and $3p^3(^2P^\circ)5s \ ^1P_1^\circ$ levels, are from Kaufman's list. The uncertainty of these levels is 0.03 to 0.20 cm^{-1} for the two-place values and 0.3 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 $3s^2 3p^3(^4S^\circ)ns \ ^5S^\circ$ ($n \geq 6$), $(^4S^\circ)nd \ ^5D^\circ$ ($n \geq 4$), and $(^4S^\circ)7d \ ^3D^\circ$ and the even levels of $(^4S^\circ)nf$ ($n \geq 5$), $(^4S^\circ)np$ ($n = 7, 8$), and $(^2D^\circ)4p \ ^3F$. Edlén's values for the $(^4S^\circ)7p \ ^3P$ and $(^4S^\circ)8p \ ^3P$ levels have been lowered by 0.30 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 $(^4S^\circ)ns \ ^5S^\circ$ series ($n = 4-10$), the $(^4S^\circ)ns \ ^3S^\circ$ series ($n = 4-11$), the $(^4S^\circ)nd \ ^5D_3^\circ$ series

($n = 4-9$), and the $(^4S^\circ)nf \ ^5F$ 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 ed continuum. The energy parameters were scaled from their Hartree-Fock values to improve agreement with experiment. The assignment of the largest $3s3p^5 \ ^3P^\circ$ eigenvector components to the levels of the $^3P^\circ$ term near $72\,000 \text{ cm}^{-1}$ 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 $3s3p^5 \ ^3P^\circ$ composition is distributed amongst the $3s^2 3p^3(^2D^\circ, ^2P^\circ)nd$, $ed \ ^3P^\circ$ and $3s^2 3p^3(^2P^\circ)ns$, $es \ ^3P^\circ$ series and continua.

Levels Above the Principal Ionization Limit

Five levels above the $3s^2 3p^3 \ ^4S^\circ$ limit have been determined within uncertainties of 0.10 to 0.20 cm^{-1} from relatively sharp emission lines: the $3s^2 3p^3(^2D^\circ)5s \ ^1D_2^\circ$ and $(^2P^\circ)5s \ ^1P_1^\circ$ levels are from Kaufman's list, and the $(^2D^\circ)3d \ ^3P^\circ$ levels were derived by Alder *et al.* from their measurements of the $(^4S^\circ)4p \ ^3P - (^2D^\circ)3d \ ^3P^\circ$ 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 $3s^2 3p^4 \ ^1D$ level as well as from the $3s^2 3p^4 \ ^3P$ 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 $3s^2 3p^3 \ ^4S^\circ$ 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 $(^2D^\circ)nd \ ^3S^\circ$ and $(^2D^\circ)ms \ ^3D^\circ$ series appear to be ambiguous for $n + 2 = m > 5$, and the adopted interpretation of the features on which the apparently overlapping $(^2P^\circ)nd \ ^3P^\circ$, $^3D^\circ$ 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 Zeppen [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 $S \text{ I } 3s^2 3p^4 \ ^1D_2$ level. His method allowed scanning over an upper-level energy range from about $93\,600$ to $98\,900 \text{ cm}^{-1}$, with two-photon transitions being allowed only to upper levels having the same parity as the 1D_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 $S \text{ II } 2s^2 2p^3 (^2D^\circ)$ limits. Most of the stronger lines were assigned to series belonging to $(^2D^\circ)nf$ or $(^2D^\circ)np$ configurations on the basis of quantum-defect behavior. We have tabulated the $(^2D_{3/2}^\circ)nf$ and $(^2D_{5/2}^\circ)nf$ ($n=5-18$) positions as designated by Pratt, and we also list the members of his strongest $(^2D^\circ)np$ series for $n=7-12$. Pratt estimated that his measurements are accurate to $\pm 1 \text{ cm}^{-1}$; his energies have been lowered by 0.4 cm^{-1} for consistency with the $3s^2 3p^4 \ ^1D_2$ 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 $J_1 l$ -coupling designations tentatively suggested by Pratt for the $(^2D^\circ)np$ series. Additional resonances designated as higher members of this series and also the positions for lines assigned to three weaker $(^2D^\circ)np$ 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 Zeppen, 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 percentage
$3s^2 3p^4$	3P	2	0.000	
		1	396.055	
		0	573.640	
$3s^2 3p^4$	1D	2	9 238.609	
$3s^2 3p^4$	1S	0	22 179.954	

S I — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages		
3s ² 3p ³ (⁴ S°)4s	⁵ S°	2	52 623.640	100		
3s ² 3p ³ (⁴ S°)4s	³ S°	1	55 330.811	100		
3s ² 3p ³ (⁴ S°)4p	⁵ P	1	63 446.065			
		2	63 457.142			
		3	63 475.051			
3s ² 3p ³ (⁴ S°)4p	³ P	1	64 888.964			
		0	64 891.386			
		2	64 892.582			
3s ² 3p ³ (² D°)4s	³ D°	1	67 816.351	96	3	3s ² 3p ³ (⁴ S°)3d ³ D°
		2	67 825.188	96	3	"
		3	67 842.867	96	3	"
3s ² 3p ³ (⁴ S°)3d	⁵ D°	4	67 877.635	97	1	3s ² 3p ³ (⁴ S°)4d ⁵ D°
		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 ² 3p ³ (² D°)4s	¹ D°	2	69 237.886	99		
3s ² 3p ³ (⁴ S°)3d	³ D°	1	70 164.658	95	3	3s ² 3p ³ (² D°)4s ³ D°
		2	70 166.195	95	3	"
		3	70 173.968	96	3	"
3s ² 3p ³ (⁴ S°)5s	⁵ S°	2	70 702.790	100		
3s ² 3p ³ (⁴ S°)5s	³ S°	1	71 351.399	99		
3s 3p ⁵	³ P°	2	72 023.495	58	15	3s ² 3p ³ (² D°)3d ³ P°
		1	72 382.328	57	15	"
		0	72 571.630	57	15	"
3s ² 3p ³ (⁴ S°)5p	⁵ P	1	73 911.259			
		2	73 914.928			
		3	73 920.961			
3s ² 3p ³ (⁴ S°)5p	³ P	2	74 268.547			
		1	74 269.600			
		0	74 271.651			
3s ² 3p ³ (⁴ S°)4d	⁵ D°	4	74 973.14	95	2	3s ² 3p ³ (⁴ S°)3d ⁵ D°
		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 ² 3p ³ (⁴ S°)4d	³ D°	1	75 951.95	98		
		2	75 952.35	98		
		3	75 956.53	98		
3s ² 3p ³ (⁴ S°)6s	⁵ S°	2	76 464.06	100		

S I — Continued

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

S I — Continued

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

S I — Continued

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

S I — Continued

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

S I — Continued

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

S I — Continued

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

S I — Continued

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

S II

Z = 16

P I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^3 \ ^4S_{3/2}^{\circ}$ Ionization energy $188\,232.7 \pm 2.0 \text{ cm}^{-1}$ ($23.337\,89 \pm 0.000\,25 \text{ eV}$)

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 $3s^2 3p^2 4s - 7s$, $4p - 5p$, $3d - 7d$, $4f - 7f$, and $5g$ configurations. The levels of the excited configurations are from Pettersson's tables. The $3s^2 3p^3 \ ^2D^{\circ}$ and $^2P^{\circ}$ levels are from measurements of forbidden transitions to the ground level observed in astronomical spectra; the corresponding uncertainties are about $\pm 0.05 \text{ cm}^{-1}$ for the $^2D^{\circ}$ levels [weighted averages of measurements from Bowen, 1955; Trauger *et al.*, 1980; Brown, 1983] and $\pm 0.20 \text{ cm}^{-1}$ for the $^2P^{\circ}$ levels [Bowen]. Pettersson's estimates of the uncertainties of his wavelength determinations indicate that the connection between the $3s^2 3p^3$ levels and the excited-configuration levels should be accurate to about $\pm 0.5 \text{ cm}^{-1}$, and the relative uncertainties within the excited-configuration system should be mainly in the range ± 0.05 to $\pm 0.3 \text{ cm}^{-1}$.

Pettersson derived the ionization energy using the $3s^2 3p^2 (^3P_2)nf \ ^2[5]_{1/2}$ series ($n = 4-7$) and the $(^3P_2) 5g \ ^2[6]_{13/2}$ level. His estimated uncertainty of $\pm 2 \text{ cm}^{-1}$ 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 $3s^2 3p^3$ ground-configuration levels are evident from the leading percentages as tabulated (to the nearest percent) from a calculation of $3s^2 3p^3 + 3p^5$ by Cowan, but we mention here Cowan's more precise percentages for these important levels. The eigenvectors for the $3s^2 3p^3 \ ^2P^{\circ}$ levels each have a 1.48% $3p^5 \ ^2P^{\circ}$ contribution, and there is a 0.45% mutual intermediate-coupling mixture of $3s^2 3p^3 \ ^2P_{3/2}^{\circ}$ and $^2D_{3/2}^{\circ}$. A 0.035% $^4S_{3/2}^{\circ}$, $^2P_{3/2}^{\circ}$ mixing accounts for most of the impurity of the $^4S_{3/2}^{\circ}$ ground-level eigenvector.

Pettersson calculated the levels of the $3s^2 3p^2 4p + 3s^2 3p^2 5p$ and $3s^2 3p^2 4f + 3s^2 3p^2 5f$ 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 $3p^2 4f$ and $3p^2 5f$ levels pertains to the *J₁l*-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 $3s3p^4$, $3s^2 3p^2 3d - 6d$, $3s^2 3p^2 4s - 7s$, and several higher $3s^2 3p^2 nd$ and *ed* 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 $3s^2 3p^2 nd$ character. The term most appropriate for the $3s3p^4 \ ^2P$ designation (near $145\,500 \text{ cm}^{-1}$) is near the "unperturbed" $3s3p^4 \ ^2P$ position obtained from a calculation omitting the configuration interactions, and retains $\sim 35\%$ $3s3p^4 \ ^2P$ character. Interaction with $3s3p^4 \ ^2P$ is mainly responsible for a large downward displacement of the $3s^2 3p^2 (^3P)3d \ ^2P$ term (near $106\,000 \text{ cm}^{-1}$, with 17% $3s3p^4 \ ^2P$ composition), a large upward displacement of the $(^3P)4d \ ^2P$ term (near $159\,000 \text{ cm}^{-1}$, with $\sim 24\%$ $3s3p^4 \ ^2P$ composition), and smaller upward displacements of other higher $3s^2 3p^2 nd$ 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 $3s^2 3p^2 (^3P)4d \ ^2P$ designations. The nominal $3s^2 3p^2 (^3P)3d \ ^2F$ 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 $3s^2 3p^2 (^1D)3d \ ^2S_{1/2}$ level given by Pettersson at $151\,651.72 \text{ cm}^{-1}$ is an exception, the calculated position being 22 cm^{-1} below the $(^3P)5s \ ^4P_{1/2}$ level (experimental value $150\,258.51 \text{ cm}^{-1}$). 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 $119\,783.77 \text{ cm}^{-1}$. 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**, 147–150. 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, 421–414. FI. 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. I. [1980], Astrophys. J. 236,
 1035–1042. W

S II

Configuration	Term	J	Level (cm ⁻¹)	Leading percentages	
$3s^2 3p^3$	$4S^\circ$	$3/2$	0.00	100	
$3s^2 3p^3$	$2D^\circ$	$3/2$	14 852.94	100	
		$5/2$	14 884.73	100	
$3s^2 3p^3$	$2P^\circ$	$1/2$	24 524.83	99	1 $3p^6 2P^\circ$
		$3/2$	24 571.54	98	1 "
$3s 3p^4$	$4P$	$5/2$	79 395.39	85	13 $3s^2 3p^2(3P)3d 4P$
		$3/2$	79 756.83	85	13 "
		$1/2$	79 962.61	85	13 "
$3s 3p^4$	$2D$	$3/2$	97 890.74	67	26 $3s^2 3p^2(1D)3d 2D$
		$5/2$	97 918.86	67	26 "
$3s^2 3p^2(3P)3d$	$2P$	$3/2$	105 599.06	72	17 $3s 3p^4 2P$
		$1/2$	106 044.24	71	17 "
$3s^2 3p^2(3P)4s$	$4P$	$1/2$	109 560.69	99	
		$3/2$	109 831.59	99	
		$5/2$	110 268.60	100	
$3s^2 3p^2(3P)3d$	$4F$	$3/2$	110 177.02	98	1 $3s^2 3p^2(3P)4d 4F$
		$5/2$	110 313.40	98	1 "
		$7/2$	110 508.71	98	1 "
		$9/2$	110 766.56	98	1 "
$3s^2 3p^2(3P)4s$	$2P$	$1/2$	112 937.57	95	2 $3s^2 3p^2(3P)3d 2P$
		$3/2$	113 461.54	96	1 "
$3s^2 3p^2(3P)3d$	$4D$	$1/2$	114 162.30	99	1 $3s^2 3p^2(3P)4d 4D$
		$3/2$	114 200.54	99	1 "
		$5/2$	114 231.04	98	1 "
		$7/2$	114 279.33	97	1 $3s^2 3p^2(1D)3d 2F$
$3s^2 3p^2(3P)3d$	$2F$	$5/2$	114 804.37	49	49 $3s^2 3p^2(1D)3d 2F$
		$7/2$	115 285.61	47	49 "
$3s 3p^4$	$2S$	$1/2$	119 783.77	62	37 $3s^2 3p^2(1D)3d 2S$
$3s^2 3p^2(1D)4s$	$2D$	$3/2$	121 528.72	98	1 $3s^2 3p^2(3P)3d 2D$
		$5/2$	121 530.02	99	
$3s^2 3p^2(3P)4p$	$2S^\circ$	$1/2$	125 485.29	98	2 $3s^2 3p^2(3P)5p 2S^\circ$
$3s^2 3p^2(1D)3d$	$2G$	$7/2$	127 127.10	100	
		$9/2$	127 128.35	100	

S II — Continued

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

S II — Continued

Configuration	Term	<i>J</i>	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	$3s^23p^4 \ ^4P$
		$3/2$	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	$3s^23p^4 \ ^2P$
		$1/2$	159 233.66	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	<i>J</i>	Level (cm ⁻¹)	Leading percentages				
3s ² 3p ² (³ P ₂)4f	2[2] ^o	3/2	161 221.05	85	or	88	3s ² 3p ² (³ P)4f ⁴ F ^o	
		5/2	161 253.47	70	or	74	"	
3s ² 3p ² (³ P ₂)4f	2[4] ^o	7/2	161 329.65	80	or	88	3s ² 3p ² (³ P)4f ⁴ F ^o	
		9/2	161 360.19	94	or	91	"	
3s ² 3p ² (³ P ₂)4f	2[3] ^o	5/2	161 386.45	79	or	76	3s ² 3p ² (³ P)4f ² F ^o	
		7/2	161 454.96	79	or	91	"	
3s ² 3p ² (¹ D)5s	2D	5/2	161 733.10	99		1	3s ² 3p ² (¹ D)4d ² D	
		3/2	161 737.99	99		1	"	
3s ² 3p ² (¹ D)4d	2G	7/2	164 181.17	87		10	3s ² 3p ² (¹ D)4d ² F	
		9/2	164 268.79	100				
3s ² 3p ² (¹ D)4d	2F	5/2	164 232.36	65		25	3s ² 3p ² (³ P)5d ² F	
		7/2	164 337.61	59		19	"	
3s ² 3p ² (³ P)6s	4P	1/2	165 719.23	95		5	3s ² 3p ² (³ P)6s ² P	
		3/2	165 991.35	95		5	"	
		5/2	166 479.82	99		1	3s ² 3p ² (³ P)5d ⁴ P	
3s ² 3p ² (¹ D)4d	2P	1/2	166 151.61	80		17	3s ² 3p ² (³ P)5d ² P	
		3/2	166 185.47	63		18	"	
3s ² 3p ² (³ P)6s	2P	1/2	166 331.19	94		5	3s ² 3p ² (³ P)6s ⁴ P	
		3/2	166 862.71	93		4	"	
3s ² 3p ² (³ P)5d	4F	3/2	166 591.08	79		13	3s ² 3p ² (¹ D)4d ² P	
		5/2	166 709.27	87		11	3s ² 3p ² (³ P)5d ⁴ D	
		7/2	166 918.27	85		13	"	
		9/2	167 269.15	98		1	3s ² 3p ² (³ P)4d ⁴ F	
3s ² 3p ² (³ P)5d	4D	1/2	167 254.84	98		1	3s ² 3p ² (¹ D)4d ² P	
		3/2	167 291.84	91		5	3s ² 3p ² (³ P)5d ⁴ F	
		5/2	167 364.98	83		11	"	
		7/2	167 575.23	86		13	"	
3s ² 3p ² (¹ D)4d	2D	3/2	167 472.42	83		6	3s ² 3p ² (³ P)5d ² D	
		5/2	167 506.39	80		7	"	
3s ² 3p ² (³ P)5d	4P	5/2	168 217.10	89		5	3s ² 3p ² (³ P)5d ⁴ D	
		3/2	168 397.89	94		3	"	
		1/2	168 490.43	96		1	3s ² 3p ² (³ P)6d ⁴ P	
3s ² 3p ² (¹ D)5p	2F ^o	5/2	168 443.14	98		1	3s ² 3p ² (¹ D)5p ² D ^o	
		7/2	168 473.48	100				
3s ² 3p ² (¹ D)4d	2S	1/2	169 109.54	80		6	3s ² 3p ² (¹ D)5d ² S	
3s ² 3p ² (³ P)5d	2F	5/2	169 283.54	62		15	3s ² 3p ² (¹ D)4d ² F	
		7/2	169 702.32	72		14	"	
3s ² 3p ² (³ P)5d	2P	3/2	169 340.39	37		28	3s ² 3p ² (³ P)5d ² D	
		1/2	169 687.52	66		12	3s ² 3p ² (¹ D)4d ² P	
3s ² 3p ² (³ P)5d	2D	3/2	169 922.27	49		24	3s ² 3p ² (³ P)5d ² P	
		5/2	170 015.23	70		6	3s ² 3p ² (³ P)6d ² D	

S II — Continued

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

S II — Continued

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

S II — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages
S III (³ P ₀)	<i>Limit</i>		188 232.7	
S III (³ P ₁)	<i>Limit</i>		188 531.6	
S III (³ P ₂)	<i>Limit</i>		189 066.0	
S III (¹ D ₂)	<i>Limit</i>		199 555	
S III (¹ S ₀)	<i>Limit</i>		215 394	

S III

Z = 16

Si I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^2 \ ^3P_0$ Ionization energy $280\,600\text{ cm}^{-1}$ (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 $3s^2 3p^2 \ ^3P_{2,1} - 3s 3p^3 \ ^5S_2^{\circ}$ 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 $3s^2 3p^2$ 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 $\pm 0.01\text{ cm}^{-1}$, 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 $\pm 0.7\text{ cm}^{-1}$ [Bowen, 1960] and $\pm 0.1\text{ cm}^{-1}$ [Bowen, 1955].

We have reevaluated the levels of the excited configurations using the available data and the $3s^2 3p^2$ level values given here. The estimated wavelength uncertainty of the $3s 3p^3 \ ^5S_2^{\circ}$ 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 $3s^2 3p 4s \ ^1P^{\circ}$ and $3s^2 3p 5s \ ^3P^{\circ}$ 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 $3s 3p^3 \ ^1P_1^{\circ}$ and $3s^2 3p 5s \ ^1P_1^{\circ}$ 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 $3s 3p^3$ and $3s^2 3p 3d$ levels are from Fawcett's calculation, which included the $3s 3p^3$, $3s^2 3p 3d$, $3s^2 3p 4s$, $3s 3p 3d^2$, and $3p^3 3d$ configurations with their interactions. Fawcett's results support the designation $3s^2 3p 3d \ ^1D_2^{\circ}$ for the level at $104\,159\text{ cm}^{-1}$, this change from the former $3s 3p^3 \ ^1D_2^{\circ}$ designation having been proposed by Ho and Henry. Our new tentative value of $151\,978.9\text{ cm}^{-1}$ for the nominal $3s 3p^3 \ ^1D_2^{\circ}$ level is based on the classification of a strong line at 710.951 Å [Kaufman, 1971] as the $3s^2 3p^2 \ ^1D_2 - 3s 3p^3 \ ^1D_2^{\circ}$ transition. Beyer *et al.* [1973] and Dumont *et al.* [1978] assigned this line to S III on experimen-

tal evidence, and the resulting $3s 3p^3 \ ^1D_2^{\circ}$ 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 $3s^2 3p 4s$ 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 $280\,900\text{ cm}^{-1}$ 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 $33.482 \pm 0.002\text{ }\mu\text{m}$ for the S III $^3P_0 - ^3P_1$ ground-term interval assuming $V_{\text{LSR}} = 0$ for the Omega Nebula source. Correction to $V_{\text{LSR}} = 17\text{ km/s}$ for the central region of this nebula [E. C. Reifstein, III *et al.*, 1970, *Astron. Astrophys.* **4**, 357–377] yields a rest wavelength of $33.480 \pm 0.002\text{ }\mu\text{m}$, 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	<i>J</i>	Level (cm ⁻¹)	Leading percentages		
3s ² 3p ²	³ P	0	0.00			
		1	298.69			
		2	833.08			
3s ² 3p ²	¹ D	2	11 322.2			
3s ² 3p 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 ² 3p3d 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 ² 3p3d ³ P°
		1	98 765.2	78	19	"
		0		78	19	"
3s ² 3p3d	¹ D°	2	104 158.7	61	34	3s3p ³ ¹ D°
3s3p ³	¹ P°	1	136 841.0	68	28	3s ² 3p3d ¹ P°
3s3p ³	³ S°	1	138 066.6	92		
3s ² 3p3d	³ P°	0	143 096.91	61	21	3s ² 3p4s ³ P°
		1	143 117.19	63	21	"
		2	143 124.93	66	16	3s3p ³ ³ P°
3s ² 3p4s	³ P°	0	146 697.19			
		1	146 737.54			
		2	147 147.00			
3s ² 3p3d	³ D°	1	147 551.32	69	14	3s ² 3p3d ³ P°
		2	147 691.99	61	21	3s ² 3p4s ³ P°
		3	147 745.54	79	16	3s3p ³ ³ D°
3s ² 3p4s	¹ P°	1	148 398.8			
3s3p ³	¹ D°	2	151 978.9?	59	34	3s ² 3p3d ¹ D°
3s ² 3p4p	³ D	1	169 771.04			
		2	170 068.31			
		3	170 649.94			
3s ² 3p4p	³ P	0	172 632.27			
		1	172 786.77			
		2	173 192.73			
3s ² 3p4p	³ S	1	174 037.19			
3s ² 3p4d	³ F°	2	204 579.89			
		3	205 071.75			
		4	205 561.67			
3s ² 3p4d	³ D°	1	206 539.87			
		2	206 672.61			
		3	206 911.97			

S III — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages
3s ² 3p5s	3p°	0	209 774.4	
		1	209 927.1	
		2	210 698.6	
3s ² 3p5s	1p°	1	211 327.8	
S IV (² P _{1/2})	<i>Limit</i>		280 600	

S IV

Z = 16

Al I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^2 \text{P}_{1/2}^\circ$ Ionization Energy $380\,870 \pm 100 \text{ cm}^{-1}$ ($47.222 \pm 0.012 \text{ eV}$)

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 $3s^2 3p^2 \text{P}^\circ$ ground-term levels are less than $\pm 1 \text{ cm}^{-1}$, and the relative values of many of the levels are accurate within $\pm 0.2 \text{ cm}^{-1}$ or less.

Joelsson *et al.* obtained a value of 951.2 cm^{-1} for the $3s^2 3p^2 \text{P}_{1/2}^\circ - \text{P}_{3/2}^\circ$ 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 $\pm 0.01 \text{ cm}^{-1}$.

Joelsson *et al.* derived the quoted ionization energy by assuming a value for the quantum defect of the $3s^2 5g^2 \text{G}$ 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 $3s^2 nd^2 \text{D}$ components in the eigenvectors of the $3s 3p^2 \text{D}$ and $3s 3p 4p \text{D}$ terms are notable, as are the strong $3s 3p 3d \text{D}^\circ$ and P° contributions to the eigenvectors of the $3p^3 \text{D}^\circ$ and P° terms, respectively. Most of the calculated $3s 3p(1\text{P}^\circ)3d \text{F}^\circ$ composition is distributed as large second percentages in the eigenvectors of the three lowest F° 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 $3s^2(1\text{S})4f \text{F}^\circ$. We have designated these higher two terms only as "b 1F° " and "c 1F° " and thus omitted both $3s 3p(1\text{P}^\circ)3d \text{F}^\circ$ and $3s^2(1\text{S})4f \text{F}^\circ$ 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	
$3s^2(1\text{S})3p$	2P°	$1/2$	0.00	96	2 $3p^3 \text{P}^\circ$
		$3/2$	951.43	96	2 "
$3s 3p^2$	4P	$1/2$	71 184.5	99	
		$3/2$	71 528.2	99	
		$5/2$	72 074.2	99	
$3s 3p^2$	2D	$3/2$	94 103.3	82	16 $3s^2(1\text{S})3d \text{D}$
		$5/2$	94 150.3	82	16 "

S IV — Continued

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

S IV — Continued

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

S IV — Continued

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

S IV — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages	
S v 3s ² (¹ S ₀)	<i>Limit</i>		380 870		
3s3p(¹ P°)4f	² F	⁵ / ₂ ⁷ / ₂	391 426.5 391 442.7	90 90	8 3s(² S)3d ² (³ F) ² F 8 "
S v 3s3p(³ P ₀)	<i>Limit</i>		463 894		
S v 3s3p(³ P ₁)	<i>Limit</i>		464 263		
S v 3s3p(³ P ₂)	<i>Limit</i>		465 025		
S v 3s3p(¹ P ₁)	<i>Limit</i>		508 021		

S V

Z = 16

Mg I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 \ ^1S_0$ Ionization energy $585\,514.1 \pm 3.0 \text{ cm}^{-1}$ ($72.5945 \pm 0.0004 \text{ eV}$)

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 $3s3p \ ^3P^o$ term and $\sim 3 \text{ cm}^{-1}$ 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 $\pm 1.0 \text{ cm}^{-1}$ with respect to these high terms. We give their value for the ionization energy here with an estimated uncertainty of $\pm 3.0 \text{ cm}^{-1}$ 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 “ $3snf \ ^1F^o$,” “ $3snd \ ^3D$,” 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

$460\,223 \text{ cm}^{-1}$, with the nominal $3s5d \ ^1D$ level at $470\,229 \text{ cm}^{-1}$ having a 27% $3p4p \ ^1D$ component.

We have followed Reistad *et al.* [1984] and other authors in designating the level at $366\,862 \text{ cm}^{-1}$ as $3p3d \ ^1F^o$. 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 $3p3d \ ^1F^o$ designation. We also follow Reistad *et al.* in omitting the original $3p3d \ ^1F^o$ level ($387\,273.6 \text{ cm}^{-1}$) 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	<i>J</i>	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	<i>J</i>	Level (cm ⁻¹)	Leading percentages	
3p4s	³ P°	0	420 742.2	97	
		1	421 056.8	95	2 3p4s ¹ P°
		2	421 943.4	97	
3p4s	¹ P°	1	424 526.0	81	11 3s5p ¹ P°
3p5s	³ S	1	428 439.0	98	1 3p4p ³ S
3s5s	¹ S	0	430 801.7	95	4 3p4p ¹ S
3s5p	³ P°	0	445 303.7	99	
		1	445 350.5	99	
		2	445 498.1	99	
3s5p	¹ P°	1	447 925.9	87	10 3p4s ¹ P°
3p4p	¹ P	1	450 091.5	94	5 3p4p ³ D
3p4p	³ D	1	452 083.8	85	8 3snd ³ D
		2	452 446.8	89	9 "
		3	453 194.7	89	9 "
3p4p	³ P	0	457 665.5	97	2 4p ² ³ P
		1	457 913.5	94	2 3p4p ³ S
		2	458 440.9	95	2 3p4p ¹ D
3p4p	³ S	1	459 893.7	94	2 3p4p ³ P
3p4p	¹ D	2	460 223.4	58	37 3s5d ¹ D
3s5d	³ D	1	468 048.2	84	8 3snd ³ D
		2	468 076.9	83	8 "
		3	468 132.1	83	8 "
3s5d	¹ D	2	470 229.4	52	27 3p4p ¹ D
3p4p	¹ S	0	472 526.1	87	3 3s5s ¹ S
3s5f	³ F°	2	473 926.0		
		3	473 926.5		
		4	473 929.5		
3s5g	¹ G	4	474 476.8	87	5 3sng ¹ G
3s5g	³ G	3	474 507.3	98	5 3sng ³ G
		4	474 515.6	91	7 "
		5	474 521.7		
3s5f	¹ F°	3	475 802.5		
3s6s	³ S	1	483 653.6		
3s6s	¹ S	0	485 386.8		
3s6p	³ P°	0	490 000.8		
		1	490 022.6		
		2	490 084.8		
3s6p	¹ P°	1	492 706.0		

S v — Continued

Configuration	Term	<i>J</i>	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°	2,3,4	508 418	
3s6h	³ H°, ¹ H°	4,5,5,6	509 105.8	
3s6f	¹ F°	3	510 152	
3s7s	³ S	1	513 933.6	
3s7s	¹ S	0	514 595.2	
3s7p	¹ P°	1	519 332	
3s7p	³ P°	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°	2,3,4	528 920	
3s7h	³ H°, ¹ H°	4,5,5,6	529 375	
3s7i	³ I, ¹ I	5,6,6,7	529 479.8	
3s7f	¹ F°	3	529 527	
3s8s	³ S	1	532 503	
3s8p	¹ P°	1	534 691	
3s8p	³ P°	2	535 965	
3s8d	¹ D	2	540 451	
3s8d	³ D	3	540 471	
3s8f	³ F°	2,3,4	542 212	
3s8h	³ H°, ¹ H°	4,5,5,6	542 535	
3s8i	³ I, ¹ I	5,6,6,7	542 612	
3s8f	¹ F°	3	542 615	
3s9s	³ S	1	544 683	
3s9d	³ D	3	550 031	

S v — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages
3s9d	¹ D	2	550 334	
3s9f	³ F°	2,3,4	551 320	
3s9f	¹ F°	3	551 575	
3s9i	³ I, ¹ I	5,6,6,7	551 618	
3s10f	³ F°	2,3,4	557 842	
3s11f	³ F°	2,3,4	562 673	
<hr style="border-top: 1px dotted black;"/>				
S VI (² S _{1/2})	<i>Limit</i>		585 514.1	
S VI (² P _{1/2} ⁱ)	<i>Limit</i>		691 387.7	
S VI (² P _{3/2} ⁱ)	<i>Limit</i>		692 651.8	

S VI

Z = 16

Na I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 S_{1/2}$ Ionization energy $710\,194.7 \pm 3.0 \text{ cm}^{-1}$ ($88.0530 \pm 0.0004 \text{ eV}$)

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 $n > 4$ 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° 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 $\pm 3 \text{ cm}^{-1}$ may be conservative. The values of all S VI nl terms can be pre-

dicted 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 $2p^5 3s 3p - 2p^5 3p^2$ and $2p^5 3s 3p - 2p^5 3s 3d$ 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 $2p^5 3s 3p^4 S_{3/2}$ 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
4s	² S	1/2	362 988.8	
4p	² P°	1/2	401 169.2	
		3/2	401 627.1	
4d	² D	3/2	451 796.8	
		5/2	451 813.8	
4f	² F°	5/2, 7/2	462 650.1	
5s	² S	1/2	504 102.4	
5p	² P°	1/2	522 029.1	
		3/2	522 249.5	
5d	² D	3/2	546 047.6	
		5/2	546 058.6	
5f	² F°	5/2, 7/2	551 759.6	
5g	² G	7/2, 9/2	552 115.0	
6s	² S	1/2	573 737.7	
6p	² P°	1/2	583 551.3	
		3/2	583 674.1	
6d	² D	3/2	596 853.0	
		5/2	596 861.3	
6f	² F°	5/2, 7/2	600 189.4	
6g	² G	7/2, 9/2	600 418.8	
6h	² H°	9/2, 11/2	600 448.9	
7s	² S	1/2	613 198.8	
7p	² P°	1/2	619 142.9	
		3/2	619 218.4	
7d	² D	3/2, 5/2	627 287	
7f	² F°	5/2, 7/2	629 390.3	
7h	² H°	9/2, 11/2	629 563.8	
7i	² I	11/2, 13/2	629 569.9	
8s	² S	1/2	637 709	
8p	² P°	1/2	[641 530]	
		3/2	[641 631]	
8d	² D	3/2, 5/2	646 931	
8f	² F°	5/2, 7/2	648 343.2	
9p	² P°	1/2	[656 641]	
		3/2	[656 675]	

S VI — Continued

Configuration	Term	<i>J</i>	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			
<hr/>						
S VII 2p ⁶ (¹ S ₀)	<i>Limit</i>		710 194.7			
2p ⁵ 3s(³ P°)3p	⁴ S	³ / ₂	1 399 400.0+x	96	3	2p ⁵ 3s(³ P°)3p ⁴ P
2p ⁵ 3s(³ P°)3p	⁴ D	⁷ / ₂	1 412 130.9+x	100		
		⁵ / ₂	1 413 580.3+x	88	6	2p ⁵ 3s(³ P°)3p ⁴ P
		³ / ₂	1 415 620.3+x	83	6	"
		¹ / ₂	1 417 934.8+x	86	5	"
2p ⁵ 3s(³ P°)3p	⁴ P	⁵ / ₂	1 421 695.4+x	83	10	2p ⁵ 3s(¹ P°)3p ² D
		³ / ₂	1 422 885.2+x	56	24	"
		¹ / ₂	1 424 715.9+x	88	7	2p ⁵ 3s(³ P°)3p ⁴ D
2p ⁵ (² P°)3p ² (³ P)	⁴ P°	⁵ / ₂	1 529 281.8+x	94	5	2p ⁵ (² P°)3p ² (³ P) ⁴ D°
2p ⁵ (² P°)3p ² (³ P)	⁴ D°	⁷ / ₂	1 540 112.7+x	100		
		⁵ / ₂	1 541 779.2+x	77	18	2p ⁵ (² P°)3p ² (³ P) ² D°
		³ / ₂	1 542 839.6+x	48	36	"
		¹ / ₂				
2p ⁵ (² P°)3s 3d(³ D)	⁴ P°	¹ / ₂	1 569 543.3+x	100		
		³ / ₂	1 570 709.1+x	96	3	2p ⁵ (² P°)3s 3d(³ D) ⁴ D°
		⁵ / ₂	1 572 881.8+x	92	6	"
2p ⁵ (² P°)3s 3d(³ D)	⁴ F°	⁹ / ₂	1 574 981.4+x	100		
		⁷ / ₂	1 576 792.3+x	90	5	2p ⁵ (² P°)3s 3d(³ D) ⁴ D°
		⁵ / ₂	1 578 784.8+x	83	6	"
		³ / ₂	1 581 024.4+x	83	8	"
S VII 2p ⁵ 3s(³ P ₂)	<i>Limit</i>		2 081 979			

S VII

Z = 16

Ne I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 \ ^1S_0$ Ionization energy $2\,266\,000 \pm 100 \text{ cm}^{-1}$ (280.948 \pm 0.012 eV)

Ferner measured and classified most of the $2p^6 \ ^1S_0 - 2p^5 ns$ and nd ($J=1$) transitions observed so far for this spectrum (46–73 Å). The position of the $2p^5 ({}^2P_{3/2}) 4d \ ^2[{}^1/2]_1$ 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 $2p^5 3s \ ^3P_1 - ^1P_1$ 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 $2p^5 3s \ ^3P_1 - ^1P_1$ 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 $\pm 25 \text{ cm}^{-1}$ 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 $\pm 200 \text{ cm}^{-1}$ 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 $2p^5 3s \ ^3P_2$

level. The $2p^5 ns$ and nd levels having $n \geq 4$ 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 $\pm 25 \text{ cm}^{-1}$. We also used the Si V and Cl VIII data to obtain an interpolated value for the quantum defect of the S VII $2p^5 ({}^2P_{3/2}) 4f \ ^2[{}^3/2]_5$ level; this defect and the experimental level give a value of $2\,266\,040 \text{ cm}^{-1}$ for the limit, with an estimated error of about $\pm 100 \text{ cm}^{-1}$. Ferner derived an ionization energy of $2\,266\,990 \text{ cm}^{-1}$ from the $2p^5 nd$ series, with an estimated error of $\pm 500 \text{ cm}^{-1}$; however, Ferner's measurements of the longest series, $({}^2P_{1/2}) nd \ ^2[{}^3/2]_1$ ($n=3-7$), 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 Eidelberg, 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	<i>J</i>	Level (cm ⁻¹)	Leading percentages		
$2p^6$	1S	0	0			
$2p^53s$	$^3P^\circ$	2	1 371 784	100		
		1	1 376 207	81	19	$2p^53s\ ^1P^\circ$
		0	1 381 805	100		
$2p^53s$	$^1P^\circ$	1	1 388 339	81	19	$2p^53s\ ^3P^\circ$
$2p^53p$	3S	1	1 466 883	97		
$2p^53p$	3D	3	1 483 165	100		
		2	1 484 428	80	15	$2p^53p\ ^1D$
		1	1 488 019	74	15	$2p^53p\ ^1P$
$2p^53p$	3P	2	1 492 496	57	42	$2p^53p\ ^1D$
		0	1 498 631	99		
		1	1 500 286	66	31	$2p^53p\ ^1P$
$2p^53p$	1P	1	1 495 849	53	25	$2p^53p\ ^3D$
$2p^53p$	1D	2	1 499 068	43	38	$2p^53p\ ^3P$
$2p^53p$	1S	0	1 552 707	99		
$2p^53d$	$^3P^\circ$	0	1 623 623	100		
		1	1 624 773	98		
		2	1 627 260	94	4	$2p^53d\ ^3D^\circ$
$2p^53d$	$^3F^\circ$	4	1 630 083	100		
		3	1 631 989	79	19	$2p^53d\ ^1F^\circ$
		2	1 635 337	79	12	$2p^53d\ ^1D^\circ$
$2p^53d$	$^1F^\circ$	3	1 637 915	59	33	$2p^53d\ ^3D^\circ$
$2p^53d$	$^3D^\circ$	1	1 644 599	93	6	$2p^53d\ ^1P^\circ$
		3	1 645 921	64	23	$2p^53d\ ^1F^\circ$
		2	1 646 576	56	37	$2p^53d\ ^1D^\circ$
$2p^53d$	$^1D^\circ$	2	1 644 674	48	31	$2p^53d\ ^3D^\circ$
$2p^53d$	$^1P^\circ$	1	1 662 194	94	5	$2p^53d\ ^3D^\circ$
$2p^5(2P_{3/2})4s$	$^2[3/2]^\circ$	2			or	$2p^54s\ ^3P^\circ$
		1	1 820 230		or	"
$2p^5(2P_{1/2})4s$	$^2[1/2]^\circ$	0			or	$2p^54s\ ^3P^\circ$
		1	1 829 760		or	$2p^54s\ ^1P^\circ$
$2p^5(2P_{3/2})4d$	$^2[1/2]^\circ$	0			or	$2p^54d\ ^3P^\circ$
		1	1 910 800		or	"
$2p^5(2P_{3/2})4d$	$^2[3/2]^\circ$	2				
		1	1 919 500		or	$2p^54d\ ^3D^\circ$
$2p^5(2P_{3/2})4f$	$^2[3/2]$	1	1 927 524			
		2	1 927 669			
$2p^5(2P_{3/2})4f$	$^2[9/2]$	5	1 928 490			
		4	1 928 559			

S VII — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages	
$2p^5(^2P_{3/2})4f$	$2^5/2]$	3	1 928 791		
		2	1 929 004		
$2p^5(^2P_{3/2})4f$	$2^7/2]$	3	1 929 685		
		4	1 929 732		
$2p^5(^2P_{1/2})4d$	$2^3/2]^\circ$	2			
		1	1 930 240	or	$2p^54d\ ^1P^\circ$
$2p^5(^2P_{1/2})4f$	$2^5/2]$	3	1 938 951		
		2	1 939 088		
$2p^5(^2P_{1/2})4f$	$2^7/2]$	3	1 939 051?		
		4	1 939 099		
$2p^5(^2P_{3/2})5s$	$2^3/2]^\circ$	1	1 998 920	or	$2p^55s\ ^3P^\circ$
$2p^5(^2P_{3/2})5d$	$2^3/2]^\circ$	1	2 046 080	or	$2p^55d\ ^3D^\circ$
$2p^5(^2P_{1/2})5d$	$2^3/2]^\circ$	1	2 055 630	or	$2p^55d\ ^1P^\circ$
$2p^5(^2P_{3/2})6d$	$2^3/2]^\circ$	1	2 113 850	or	$2p^56d\ ^3D^\circ$
$2p^5(^2P_{1/2})6d$	$2^3/2]^\circ$	1	2 123 230	or	$2p^56d\ ^1P^\circ$
$2p^5(^2P_{1/2})7d$	$2^3/2]^\circ$	1	2 163 940	or	$2p^57d\ ^1P^\circ$
.....					
S VIII ($^2P_{3/2}$)	Limit		2 266 000		
S VIII ($^2P_{1/2}$)	Limit		2 276 085		

S VIII

Z = 16

F I isoelectronic sequence

Ground state $1s^2 2s^2 2p^5 \ ^2P_{3/2}^\circ$ Ionization energy $2\ 651\ 500\ \text{cm}^{-1}$ (328.75 eV)

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

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

Trigueiros and Jupén have observed and classified 40 lines ($664 - 973\ \text{\AA}$) as belonging to the $2s^2 2p^4 3s - 3p$ and $3p - 3d$ transition arrays. All the $2p^4 3s$ and $2p^4 3p$ levels given here are from their paper, with only $2p^4 (^3P) 3p \ ^2S_{1/2}^\circ$ missing. We have also taken most of the $2p^4 3d$ 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 $2s^2 2p^4 3l$ systems (quartet or doublet) by Trigueiros and Jupén's measurements are probably accurate within ± 10 to $\pm 20\ \text{cm}^{-1}$.

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

The eigenvector percentages are from calculations of the $2s^2 2p^6 + 2s^2 2p^4 3s + 2s^2 2p^4 3d$ even levels and $2s^2 2p^4 3p$ 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 $2p^4 3d$ 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 ($44 - 65\ \text{\AA}$) as $2s^2 2p^5 \ ^2P^\circ - 2s^2 2p^4 3s, 3d$ transitions. The S VIII line list given by Fawcett and Hayes has Ferner's wavelengths with energy-level classifications including corrections for some $2p^4 3d$ transitions in accord with the revised analysis of Trigueiros and Jupén.

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

We obtained a value of $2\ 651\ 300\ \text{cm}^{-1}$ 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 $2\ 651\ 730\ \text{cm}^{-1}$ for S VIII. We have adopted the average of these two predicted values, rounded to the nearest $100\ \text{cm}^{-1}$.

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 $44 - 48\ \text{\AA}$ region classified by Ferner as $2s^2 2p^5 \ ^2P^\circ - 2s^2 2p^4 4s, 4d$ 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 $2s^2 2p^4 4s, 4d$ 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	<i>J</i>	Level (cm ⁻¹)	Leading percentages	
2s ² 2p ⁵	2P°	3/2	0		
		1/2	10 085		
2s2p ⁶	2S	1/2	503 644	100	
2s ² 2p ⁴ (3P)3s	4P	5/2	1 559 341	99	
		3/2	1 565 357	95	
		1/2	1 568 870	99	
2s ² 2p ⁴ (3P)3s	2P	3/2	1 579 675	95	
		1/2	1 586 537	99	
2s ² 2p ⁴ (1D)3s	2D	5/2	1 623 377	99	
		3/2	1 623 562	99	
2s ² 2p ⁴ (3P)3p	4P°	5/2	1 663 529	96	
		3/2	1 665 190	94	
		1/2	1 668 025	99	
2s ² 2p ⁴ (3P)3p	4D°	7/2	1 677 002	99	
		5/2	1 679 963	80	16 2s ² 2p ⁴ (3P)3p 2D°
		3/2	1 683 313	93	
		1/2	1 684 694	97	
2s ² 2p ⁴ (1S)3s	2S	1/2	1 688 150	98	
2s ² 2p ⁴ (3P)3p	2D°	5/2	1 688 781	82	16 2s ² 2p ⁴ (3P)3p 4D°
		3/2	1 696 125	60	20 2s ² 2p ⁴ (3P)3p 2P°
2s ² 2p ⁴ (3P)3p	2P°	1/2	1 689 123	50	30 2s ² 2p ⁴ (1D)3p 2P°
		3/2	1 691 951	40	34 2s ² 2p ⁴ (3P)3p 2D°
2s ² 2p ⁴ (3P)3p	4S°	3/2	1 698 580	94	
2s ² 2p ⁴ (1D)3p	2F°	5/2	1 732 269	98	
		7/2	1 733 768	99	
2s ² 2p ⁴ (1D)3p	2D°	3/2	1 746 563	99	
		5/2	1 747 665	98	
2s ² 2p ⁴ (1D)3p	2P°	3/2	1 769 011	64	35 2s ² 2p ⁴ (3P)3p 2P°
		1/2	1 773 330	63	34 "
2s ² 2p ⁴ (1S)3p	2P°	3/2	1 806 574	98	
		1/2	1 807 269	93	6 2s ² 2p ⁴ (3P)3p 2P°

S VIII — Continued

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

S IX

Z = 16

O I isoelectronic sequence

Ground state $1s^2 2s^2 2p^4 \ ^3P_2$ Ionization energy $3\ 061\ 300 \pm 1\ 500\ \text{cm}^{-1}$ ($379.55 \pm 0.19\ \text{eV}$)

The $2s^2 2p^4$, $2s 2p^5$, 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 $2s^2 2p^4 \ ^1D_2$ level. The value given for this level is an average of the $2s^2 2p^4 \ ^3P_2 - ^1D_2$ 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 $1\ \text{cm}^{-1}$. The $2s^2 2p^4 \ ^3P$ intervals are probably accurate within ± 10 to $\pm 20\ \text{cm}^{-1}$, and the $2p^5$ levels are probably accurate within about $\pm 30\ \text{cm}^{-1}$. The estimated uncertainty of the $2s^2 2p^4 \ ^1S$ and $2p^6 \ ^1S$ levels is about $\pm 50\ \text{cm}^{-1}$.

Ferner's analysis of the $2s^2 2p^4 - 2s^2 2p^3 3s$ 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 $2s^2 2p^3 3s$, $3d$, and $4d$ levels given here are from Fawcett and Hayes, who adopted Edlén's values for the $2s^2 2p^4$ levels in evaluating the upper levels. The estimated wavelength uncertainty of $\pm 0.01\ \text{Å}$ corresponds to uncertainties of ± 300 to $\pm 700\ \text{cm}^{-1}$ 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 $2s^2 2p^3 4d$ 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. FI
 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)				
$2s^2 2p^4$	3P	2	0.0	$2s^2 2p^3(^4S^o)3s$	$^3S^o$	1	1 783 150				
		1	7 985			$2s^2 2p^3(^2D^o)3s$	$^3D^o$	1	1 844 970		
		0	10 648					2	1 845 170		
$2s^2 2p^4$	1D	2	58 293.9	3	1 845 870						
		$2s^2 2p^4$	1S	0	122 700	$2s^2 2p^3(^2D^o)3s$	$^1D^o$	2	1 858 800		
				$2s 2p^5$	$^3P^o$			2	444 987	$2s^2 2p^3(^2P^o)3s$	$^3P^o$
1	451 995							1			
0	455 890	2	1 891 830								
$2p^6$	1S	0	1 039 219								

S IX — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Configuration	Term	<i>J</i>	Level (cm ⁻¹)
$2s^2 2p^3(^2P^o)3s$	$^1P^o$	1	1 904 300	$2s^2 2p^3(^2P^o)3d$	$^3P^o$	0	2 142 780
$2s^2 2p^3(^4S^o)3d$	$^3D^o$	2	2 035 230			1	2 144 800
		1	2 035 350			2	2 146 600
		3	2 035 870	$2s^2 2p^3(^2P^o)3d$	$^3D^o$	2	2 154 580
$2s^2 2p^3(^2D^o)3d$	$^3D^o$	1	2 105 330			1	2 156 260
		2	2 108 130			3	2 156 430
		3	2 108 240?	$2s^2 2p^3(^2P^o)3d$	$^1D^o$	2	2 162 760
$2s^2 2p^3(^2D^o)3d$	$^1P^o$	1	2 108 900	$2s^2 2p^3(^2P^o)3d$	$^1F^o$	3	2 166 530
$2s^2 2p^3(^2D^o)3d$	$^3P^o$	2	2 116 450	$2s^2 2p^3(^2P^o)3d$	$^1P^o$	1	2 190 220?
		1	2 119 330	$2s^2 2p^3(^4S^o)4d$	$^3D^o$	3	2 489 360?
		0		$2s^2 2p^3(^2D^o)4d$	$^3D^o$	3	2 566 340?
$2s^2 2p^3(^2D^o)3d$	$^1D^o$	2	2 117 430	$2s^2 2p^3(^2D^o)4d$	$^3P^o$	2	2 571 880?
$2s^2 2p^3(^2D^o)3d$	$^3S^o$	1	2 125 530				
$2s^2 2p^3(^2D^o)3d$	$^1F^o$	3	2 134 710				
				S X ($^4S_{3/2}^o$)	Limit		3 061 300

S x

Z = 16

N I isoelectronic sequence

Ground state $1s^2 2s^2 2p^3 \ ^4S_{3/2}^{\circ}$ Ionization energy $3\ 609\ 000 \pm 2\ 500\ \text{cm}^{-1}$ (447.5 ± 0.3 eV)

We evaluated the $2s^2 2p^3 \ ^2D^{\circ}$ levels using measurements of the $2s^2 2p^3 \ ^4S^{\circ} - ^2D^{\circ}$ forbidden lines observed in solar-corona spectra [Sandlin, Brueckner, and Tousey; Feldman and Doschek]; the values are probably accurate to about $\pm 1\ \text{cm}^{-1}$. The $2s^2 2p^3 \ ^2P^{\circ}$ and $2s 2p^4$ levels except $2s^2 2p^4 \ ^2P_{1/2}$ 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 $2s^2 2p^3 - 2s 2p^4$ 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 $2s^2 2p^3 \ ^2P^{\circ}$ and $2s 2p^4$ levels should be accurate within errors of ± 30 to $\pm 60\ \text{cm}^{-1}$. The $2s 2p^4 \ ^2P_{1/2}$ level given here is $24\ \text{cm}^{-1}$ 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 $2s 2p^4 \ ^2D_{5/2} - 2p^5 \ ^2P_{3/2}^{\circ}$ and $^2D_{3/2} - ^2P_{1/2}^{\circ}$ doublet near 210 Å by Fawcett *et al.* [1971]. Edlén's values for the corresponding wavenumbers, adopted here, are respectively $18\ \text{cm}^{-1}$ above and $116\ \text{cm}^{-1}$ below the values obtained from the measured wavelengths.

The levels of configurations of the types $2s^2 2p^2 nl$ and $2s 2p^3 nl$ ($n \geq 3$) are derived from lines in the region below 51 Å classified as transitions to $2s^2 2p^3$ or $2s 2p^4$ 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 $10\ \text{cm}^{-1}$, but the estimated uncertainties are of the order of $\pm 500\ \text{cm}^{-1}$ 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 $2s^2 2p^3$ 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 parame-

ters 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 $3\ 610\ 200\ \text{cm}^{-1}$ for the ionization energy of S x. An isoelectronic-extrapolation formula derived by Edlén [1971] gives a value of $3\ 607\ 880\ \text{cm}^{-1}$ for this ionization energy. We have adopted the average of these values (rounded to the nearest $100\ \text{cm}^{-1}$), 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. FT 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)	Configuration	Term	J	Level (cm ⁻¹)
$2s^2 2p^3$	$4S^\circ$	$3/2$	0	$2s^2 2p^2(^3P)3d$	$2P$	$3/2$	2 331 160
$2s^2 2p^3$	$2D^\circ$	$3/2$	82 442.3			$1/2$	2 341 200?
		$5/2$	83 594.9	$2s^2 2p^2(^3P)3d$	$2F$	$5/2$	2 342 990
$2s^2 2p^3$	$2P^\circ$	$1/2$	126 975			$7/2$	2 351 480
		$3/2$	128 804	$2s^2 2p^2(^3P)3d$	$4P$	$5/2$	2 350 560
$2s 2p^4$	$4P$	$5/2$	378 458			$3/2$	2 353 220
		$3/2$	385 362			$1/2$	2 353 770
		$1/2$	388 883	$2s^2 2p^2(^3P)3d$	$2D$	$3/2$	2 378 700?
$2s 2p^4$	$2D$	$3/2$	520 723			$5/2$	2 379 900?
		$5/2$	520 864	$2s^2 2p^2(^1D)3d$	$2D?$	$3/2$	2 407 650
$2s 2p^4$	$2S$	$1/2$	608 784			$5/2$	2 409 100
$2s 2p^4$	$2P$	$3/2$	636 898	$2s^2 2p^2(^1D)3d$	$2F$	$7/2$	2 409 070
		$1/2$	645 660			$5/2$	2 412 550
$2p^5$	$2P^\circ$	$3/2$	991 249	$2s 2p^3(^5S^\circ)3p$	$4P$	$5/2$	2 417 970?
		$1/2$	1 002 372	$2s 2p^3(^5S^\circ)3d$	$4D^\circ$	$1/2$	
$2s^2 2p^2(^3P)3s$	$4P$	$1/2$	2 087 460			$3/2$	2 542 660
		$3/2$	2 092 400			$5/2$	2 545 280
		$5/2$	2 098 440	$2s 2p^3(^3D^\circ)3d$	$4D^\circ$	$7/2$	2 552 510
$2s^2 2p^2(^3P)3s$	$2P$	$1/2$	2 113 100				
		$3/2$	2 120 500	$2s 2p^3(^3P^\circ)3d$	$4D^\circ$	$7/2$	2 759 130?
$2s^2 2p^2(^1D)3s$	$2D$	$3/2$	2 159 280?	$2s^2 2p^2(^3P)4d$	$4P$	$5/2$	2 914 600?
		$5/2$	2 160 140				
				S XI (3P_0)	Limit		3 609 000

S XI

Z = 16

C I isoelectronic sequence

Ground state $1s^2 2s^2 2p^2 \ ^3P_0$ Ionization energy $4\ 071\ 300 \pm 3\ 000\ \text{cm}^{-1}$ ($504.8 \pm 0.4\ \text{eV}$)

The main papers for the measurements and analysis of the $2s^2 2p^2 - 2s 2p^3$ 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 $2s 2p^3 - 2p^4$ lines (213–362 Å). Fawcett *et al.* [1971] independently classified the $2s^2 2p^2 \ ^1S_0 - 2s 2p^3 \ ^1P_1^o$ line and several $2s 2p^3 - 2p^4$ lines, and Fawcett's 1975 compilation includes the only measurement of the $2s 2p^3 \ ^3S_1^o - 2p^4 \ ^3P_0$ wavelength.

The $2s^2 2p^2$, $2s 2p^3$, and $2p^4$ levels given here are from Edlén [1985] except for the $2s^2 2p^2 \ ^3P_2$ 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 $2s 2p^3 \ ^1P_1^o - 2p^4 \ ^1S_0$ line) has as yet been correctly identified. The $2s 2p^3 \ ^3S_2^o$ levels predicted by Edlén, and also the $2s 2p^2 3d \ ^5P$ and $2s 2p^2 3s \ ^3P$ 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 $2s^2 2p^2 \ ^3P_1$, 3P_2 , and 1D_2 levels are based on the wavelengths of the $^3P_1 - ^1D_2$ and $^1P_2 - ^1D_2$ forbidden lines observed in solar-corona spectra [Sandlin *et al.*; Feldman and Doschek]. The estimated relative uncertainties are about $1\ \text{cm}^{-1}$, and the error of these levels with respect to the 3P_0 ground level is probably not greater than $15\ \text{cm}^{-1}$. The $2s^2 2p^2 \ ^1S_0$ level, the connected $2s 2p^3$ levels, and the $2p^4$ levels are probably accurate within errors of 25 to $40\ \text{cm}^{-1}$.

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 $2s^2 2pnl$ and $2s 2p^2 nl$ ($n \geq 3$). 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 $1000\ \text{cm}^{-1}$. 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 $2s^2 2pnd$ ($n \geq 4$) levels given in the 1987 paper. The line at 43.123 Å classified as $2s^2 2p^2 \ ^3P_2 - 2s^2 2p 3s \ ^3P_2^o$ in Fawcett and Hayes' 1973 paper should be added to the 1987 line list.

The leading eigenvector percentages for the $2s^2 2p 3d$ 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	<i>J</i>	Level (cm ⁻¹)	Leading percentages		
$2s^2 2p^2$	3P	0	0			
		1	5 208.0			
		2	12 388.1			
$2s^2 2p^2$	1D	2	67 146.3			
$2s^2 2p^2$	1S	0	132 929			
$2s 2p^3$	$^5S^\circ$	2	186 251+x			
$2s 2p^3$	$^3D^\circ$	2	355 076			
		3	355 350			
		1	355 364			
$2s 2p^3$	$^3P^\circ$	0	416 347			
		1	416 986			
		2	417 419			
$2s 2p^3$	$^1D^\circ$	2	530 177			
$2s 2p^3$	$^3S^\circ$	1	535 220			
$2s 2p^3$	$^1P^\circ$	1	592 480			
$2p^4$	3P	2	811 702			
		1	820 531			
		0	823 645			
$2p^4$	1D	2	868 462			
$2p^4$	1S	0	[986 736]			
$2s^2 2p 3s$	$^3P^\circ$	0				
		1	2 320 260			
		2	2 331 340			
$2s^2 2p 3s$	$^1P^\circ$	1	2 345 060			
$2s 2p^2(^4P)3s$	5P	1				
		2	2 519 160+x			
		3	2 525 380+x			
$2s^2 2p 3d$	$^1D^\circ$	2	2 532 260	75	14	$2s^2 2p 3d ^3F^\circ$
$2s^2 2p 3d$	$^3D^\circ$	1	2 548 420	85		
		2	2 549 740	68	21	$2s^2 2p 3d ^3P^\circ$
		3	2 555 430	93		
$2s^2 2p 3d$	$^3P^\circ$	2	2 560 810	71	24	$2s^2 2p 3d ^3D^\circ$
		1	2 562 100	85	10	"
		0		95		
$2s^2 2p 3d$	$^1F^\circ$	3	2 589 340	95		
$2s^2 2p 3d$	$^1P^\circ$	1	2 589 510?	93		
$2s 2p^2(^4P)3s$	3P	2	2 590 790?			
$2s 2p^2(^4P)3p$		1,2	2 607 500?			

S XI — Continued

Configuration	Term	<i>J</i>	Level (cm ⁻¹)	Leading percentages
<i>2s2p²(⁴P)3p</i>	³ D°	3	<i>2 659 800</i>	
<i>2s2p²(²D)3s</i>	³ D	3	<i>2 690 250?</i>	
<i>2s2p²(⁴P)3d</i>	⁵ P	3 2,1	<i>2 747 150+x</i> <i>2 752 600+x?</i>	
<i>2s2p²(⁴P)3d</i>	³ F	2 3 4	<i>2 762 500</i> <i>2 766 200</i> <i>2 771 600</i>	
<i>2s2p²(²D)3p</i>	¹ D°	2	<i>2 789 500?</i>	
<i>2s2p²(²D)3p</i>	¹ F°	3	<i>2 795 000?</i>	
<i>2s2p²(²P)3d</i>	³ D	3	<i>2 799 800</i>	
<i>2s2p²(²D)3d</i>	³ F	4	<i>2 882 400</i>	
<i>2s2p²(²D)3d</i>	¹ F	3	<i>2 891 900</i>	
<i>2s2p²(²D)3d</i>	¹ D	2	<i>2 920 850</i>	
<i>2s2p²(²P)3d</i>	³ P	2	<i>3 053 050</i>	
<i>2s²2p4d</i>	³ D°	3	<i>3 232 600?</i>	
<i>2s²2p4d</i>	¹ F°	3	<i>3 243 450?</i>	
<i>S XII (²P_{1/2})</i>	<i>Limit</i>		<i>4 071 300</i>	

S XII

 $Z=16$

B I isoelectronic sequence

Ground state $1s^2 2s^2 2p^2 P_{1/2}^o$ Ionization energy $4\,552\,500 \pm 1\,500\text{ cm}^{-1}$ ($564.44 \pm 0.19\text{ eV}$)

The measurement and identification of the solar-coronal line at $7611.0 \pm 0.4\text{ \AA}$ [Jefferies, 1969] gives the value $13\,135.3 \pm 0.7\text{ cm}^{-1}$ adopted here for the $2s^2 2p^2 P_{1/2}^o - 2P_{3/2}^o$ ground-doublet interval. The $2s^2 2p^2$ doublet levels are based mainly on measurements of transitions to the $2P^o$ 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 $2s^2 2p^2$ $4P - 2p^3$ $4S_{3/2}$ separations. The position of the quartet term system with respect to the ground level is based on Edlén's isoelectronically estimated value for the $2s^2 2p^2$ $2P_{3/2}^o - 2s^2 2p^2$ $4P_{3/2}$ 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 $2s^2 2p^2$ $2D - 2p^3$ $2D^o$, $2P^o$ 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 $2s^2 2p^2$ and $2p^3$ levels correspond to wavenumber uncertainties of about ± 20 to $\pm 60\text{ cm}^{-1}$, but larger errors in some cases would not be surprising.

We evaluated the $2s^2 nd$ and $2s^2 pnl$ ($n \geq 3$) levels using the wavelengths and classifications of lines in the 23–39 \AA region given by Fawcett and Hayes [1987]. Their estimated wavelength uncertainties correspond to wavenumber uncertainties of about $\pm 1000\text{ cm}^{-1}$ for the $2s^2 3d$ and $2s^2 p3s$, $3p$, and $3d$ levels. The $2s^2 nd$ and $2s^2 pnl$ levels having $n \geq 4$ 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 \AA 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 $2s^2 nd$ $2D$ 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	<i>J</i>	Level (cm ⁻¹)	Configuration	Term	<i>J</i>	Level (cm ⁻¹)
<i>2s</i> ² <i>2p</i>	² P°	1/2	0.0	<i>2s2p</i> (³ P°) <i>3d</i>	² D°	5/2	2 956 600
		3/2	13 135.3			<i>2s2p</i> (³ P°) <i>3d</i>	⁴ P°
<i>2s2p</i> ²	⁴ P	1/2	193 882+x	3/2	2 966 900+x		
		3/2	198 675+x	1/2			
		5/2	205 425+x	<i>2s2p</i> (³ P°) <i>3d</i>	² F°	5/2	2 998 200
<i>2s2p</i> ²	² D	3/2	346 700			7/2	3 006 400
		5/2	347 005	<i>2s2p</i> (³ P°) <i>3d</i>	² P°	3/2	3 011 500
<i>2s2p</i> ²	² S	1/2	439 580			1/2	3 015 300
		<i>2s2p</i> ²	² P	1/2	464 755	<i>2s2p</i> (¹ P°) <i>3p</i>	² D
3/2	471 430			<i>2s2p</i> (¹ P°) <i>3d</i>	² F°		
<i>2p</i> ³	⁴ S°	3/2	610 075+x			<i>2s2p</i> (¹ P°) <i>3d</i>	² D°
<i>2p</i> ³	² D°	3/2	689 910	<i>2s</i> ² <i>4d</i>	² D	3/2, 5/2	3 543 300
		5/2	690 480			<i>2s2p</i> (³ P°) <i>4p</i>	² D
<i>2p</i> ³	² P°	1/2	774 020	<i>2s2p</i> (³ P°) <i>4d</i>	⁴ D°		
		3/2	775 805			<i>2s2p</i> (³ P°) <i>4d</i>	² F°
<i>2s</i> ² <i>3d</i>	² D	3/2	2 747 400	<i>2s</i> ² <i>5d</i>	² D		
		5/2	2 748 100			<i>2s2p</i> (¹ P°) <i>4d</i>	² F°
<i>2s2p</i> (³ P°) <i>3s</i>	⁴ P°	5/2	2 774 700+x?	<i>2s</i> ² <i>6d</i>	² D		
		<i>2s2p</i> (³ P°) <i>3p</i>	² P			1/2	2 840 700
3/2	2 848 000			S XIII (¹ S ₀)	<i>Limit</i>		4 552 500
<i>2s2p</i> (³ P°) <i>3p</i>	² D	3/2	2 895 800				
		5/2	2 904 500				
<i>2s2p</i> (³ P°) <i>3p</i>	² S	1/2	2 929 800?				
<i>2s2p</i> (³ P°) <i>3d</i>	⁴ D°	1/2					
		5/2	2 950 800+x				
		3/2	2 952 300+x				
		7/2	2 957 600+x				

S XIII

 $Z = 16$

Be I isoelectronic sequence

Ground state $1s^2 2s^2 \ ^1S_0$ Ionization energy $5\ 260\ 000\ \text{cm}^{-1}$ (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 $2s^2 \ ^1S_0 - 2s2p \ ^3P_1^o$ intercombination line has been measured in solar-flare spectra [Widing, 1978; Dere, 1978]. The $2s2p \ ^3P_1^o$ and $^1P_1^o$ levels are probably accurate to $\pm 10\ \text{cm}^{-1}$, the $2s2p \ ^3P_0^o$ and $^3P_2^o$ levels to $\pm 20\ \text{cm}^{-1}$, and the $2p^2 \ ^3P$ and 1D levels to $\pm 25\ \text{cm}^{-1}$. 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 $\pm 100\ \text{cm}^{-1}$.

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 $2p^2 \ ^1S_0 - 2p3d \ ^1P_1^o$ and $2p^2 \ ^1D_2 - 2p3d \ ^1F_3^o$ transitions, respectively, which gives almost coincident

values for the $2p3d \ ^1P_1^o$ and $^1F_3^o$ levels. It seems likely that both lines are transitions from the $2p3d \ ^1P_1^o$ 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 $2p3d \ ^1F_3^o$ 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)	Configuration	Term	J	Level (cm ⁻¹)
2s ²	¹ S	0	0	2p3p	¹ D	2	3 396 200
2s2p	³ P°	0	199 181	2p3d	³ D°	1	
		1	203 474			2	3 411 100
		2	213 182			3	3 414 700
2s2p	¹ P°	1	389 533	2p3d	³ P°	2	3 424 400
2p ²	³ P	0	523 237	2p3p	¹ S	0	3 438 300
		1	528 796	2p3d	¹ P°	1	3 457 100
		2	536 856	2s4s	³ S	1	4 024 900
2p ²	¹ D	2	589 449	2s4p	¹ P°	1	4 066 700
2p ²	¹ S	0	[721 825]	2s4d	³ D	2,3	4 085 500
2s3s	³ S	1	3 011 500	2s4d	¹ D	2	4 095 000
2s3p	¹ P°	1	3 101 500	2p4p	³ D	3	4 308 000?
2s3p	³ P°	1	3 106 500	2p4d	³ D°	1	
		2	3 157 200			2	4 325 000
		3	3 158 600			3	4 331 000
2s3d	¹ D	2	3 193 300	2p4d	¹ F°	3	4 333 500?
2p3p	¹ P	2	3 319 400	2s5d	³ D	3	4 516 500?
2p3p	³ D	3	3 343 700				
2p3p	³ S	1	3 356 100	S XIV (² S _{1/2})	<i>Limit</i>		5 260 000
2p3p	³ P	0					
		1	3 365 600?				
		2	3 372 500				

S XIV

 $Z=16$

Li I isoelectronic sequence

Ground state $1s^2 2s^2 2S_{1/2}$ Ionization energy $5\,702\,400 \pm 600 \text{ cm}^{-1}$ ($707.01 \pm 0.08 \text{ eV}$)

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 $4f^2 F_{5/2}^o - 2F_{7/2}^o$ interval, 292 cm^{-1} , as well as the $4d^2 D_{5/2} - 4f^2 F_{5/2}^o$ 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 $\pm 600 \text{ cm}^{-1}$.

Edlén's parameterizations of the data for this isoelectronic sequence yielded formulae for the entire $1s^2 nl$ 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 $3p^2 P_{3/2}^o$ (Edlén's value is $3\,286\,180 \text{ cm}^{-1}$). 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 $n \geq 3$ 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 correc-

tions [Edlén, 1979] are probably accurate within $\pm 100 \text{ cm}^{-1}$. By adding such term values to the $4f$ levels given here, we obtained a value $5\,702\,430 \text{ cm}^{-1}$ for the principal ionization energy (S xv $1s^2 1S$), in good agreement with Edlén's value $5\,702\,380 \text{ cm}^{-1}$. We thus adopt the value $5\,702\,400 \pm 600 \text{ cm}^{-1}$, 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 $1s^2 2s^2 S$ and $1s^2 2p^2 P^o$, 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 $1s^2 1S-1s2s^2 3S, 1S$ and $1s^2 1S-1s2p^2 3P^o, 1P^o$ energies with more accurate values calculated by Drake [see S xv], we reduced the $1s^2 2p-1s2s^2$, $1s^2 2s-1s2s2p$, 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 $1s^2 2s^2 S$ and $1s^2 2p^2 P^o$ 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 $\pm 4000 \text{ cm}^{-1}$). 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 Ridgely, 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 $1s2p^2\ ^4P_{3/2}$ and $1s2s^2\ ^2S_{1/2}$ levels. The wavenumber given for the $1s2p^2\ ^4P_{3/2}$ transition is clearly a misprint; we have assumed the correct value to be $19\ 506\ 925\ \text{cm}^{-1}$ (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	<i>J</i>	Level (cm ⁻¹)	Configuration	Term	<i>J</i>	Level (cm ⁻¹)
1s ² 2s	² S	1/2	0	S XV (¹ S ₀)	<i>Limit</i>		5 702 400
1s ² 2p	² P ^o	1/2 3/2	224 366 239 429	1s2s ²	² S	1/2	[19 422 000]
1s ² 3s	² S	1/2	3 220 100	1s(² S)2s2p(³ P ^o)	⁴ P ^o	1/2 3/2 5/2	[19 480 400] [19 484 500] [19 494 400]
1s ² 3p	² P ^o	1/2 3/2	3 282 020 3 286 550	1s(² S)2s2p(³ P ^o)	² P ^o	1/2 3/2	[19 656 100] [19 663 900]
1s ² 3d	² D	3/2 5/2	3 309 260 3 310 680	1s2p ²	⁴ P	1/2 3/2 5/2	[19 721 300] [19 727 900] [19 735 300]
1s ² 4s	² S	1/2	4 319 700	1s(² S)2s2p(¹ P ^o)	² P ^o	1/2 3/2	[19 736 800] [19 740 800]
1s ² 4p	² P ^o	1/2 3/2	4 344 980 4 346 860	1s2p ²	² D	5/2 3/2	[19 838 200] [19 839 000]
1s ² 4d	² D	3/2 5/2	4 356 570 4 357 210	1s2p ²	² P	1/2 3/2	[19 864 000] [19 878 500]
1s ² 4f	² F ^o	5/2 7/2	4 357 630 4 357 930	1s2p ²	² S	1/2	[19 994 200]
1s ² 5d	² D	3/2, 5/2	4 841 300	S XV 1s2s(³ S ₁)	<i>Limit</i>		[25 304 400]

S XV

Z = 16

He I isoelectronic sequence

Ground state $1s^2 \ ^1S_0$ Ionization energy $26\,001\,513 \pm 400 \text{ cm}^{-1}$ ($3223.78 \pm 0.05 \text{ eV}$)

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

The $1s2l$ levels and the ionization energy given here are from Drake's 1988 calculations for this isoelectronic sequence. Measurements of the Ar xvii $1s^2 \ ^1S_0 - 1s2p \ ^1P_1^o$ and $^3P_1^o$ 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 $\pm 240 \text{ cm}^{-1}$; our assumption of $\pm 400 \text{ cm}^{-1}$ 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 $1s^2 \ ^1S_0 - 1s2p \ ^3P_1^o$ and $1s^2 \ ^1S_0 - 1s2p \ ^1P_1^o$ 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 $1s2s \ ^3S - 1s2p \ ^3P^o$ level separations here is about $\pm 8 \text{ cm}^{-1}$ [Drake, 1988]. The most recent experimental values of the $^3S_1 - ^3P_2^o$ and $^3S_1 - ^3P_0^o$ separations, $148\,493 \pm 5$ and $132\,198 \pm 10 \text{ cm}^{-1}$ [DeSerio *et al.*], are less than the values here by 6 and 42 cm^{-1} , respectively. The deviation of the experimental $^3S_1 - ^3P_0^o$ 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 $1s2p \ ^3P^o$ 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 $\pm 100 \text{ cm}^{-1}$ for all except

Vainshtein and Safronova's $1s3p \ ^3P^o$ 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 $n=4-6$, $l \geq 2$ 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 $\pm 100 \text{ cm}^{-1}$. (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 $1snl - 2l'nl''$ ($n \geq 2$) from doubly-excited configurations in S xv give rise to satellite features near the S xvi $1s \ ^2S - 2p \ ^2P^o$ resonance doublet at 4.73 \AA . 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 \AA 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 $2l'nl''$ ($n \geq 3$) 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 $1s2p$, $1s3p$ $^3P_0^o$ and $^3P_1^o$ 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})	Configuration	Term	J	Level (cm^{-1})
$1s^2$	1S	0	0	$1s4d$	1D	2	[24 457 576]
$1s2s$	3S	1	[19 602 076]	$1s4f$	$^3F^o, ^1F^o$	2,3,3,4	[24 457 889]
$1s2p$	$^3P^o$	0	[19 734 314]	$1s4p$	$^1P^o$	1	[24 458 842]
		1	[19 737 521]	$1s5s$	3S	1	[24 999 972]
		2	[19 750 573]	$1s5p$	$^3P^o$	0	[25 007 589]
$1s2s$	1S	0	[19 745 473]			1	[25 007 798]
$1s2p$	$^1P^o$	1	[19 846 285]			2	[25 008 632]
$1s3s$	3S	1	[23 193 163]	$1s5s$	1S	0	[25 007 605]
$1s3p$	$^3P^o$	0	[23 229 571]	$1s5d$	3D	1,2	[25 012 870]
		1	[23 230 551]			3	[25 013 202]
		2	[23 234 429]	$1s5d$	1D	2	[25 013 407]
$1s3s$	1S	0	[23 231 087]	$1s5f$	$^3F^o, ^1F^o$	2,3,3,4	[25 013 562]
$1s3d$	3D	1	[23 254 611]	$1s5g$	$^3G, ^1G$	3,4,4,5	[25 013 723]
		2	[23 254 645]	$1s5p$	$^1P^o$	1	[25 014 007]
		3	[23 256 165]	$1s6s$	3S	1	[25 307 614]
$1s3d$	1D	2	[23 257 195]	$1s6s$	1S	0	[25 312 000]
$1s3p$	$^1P^o$	1	[23 260 416]	$1s6p$	$^3P^o$	0	[25 312 007]
$1s4s$	3S	1	[24 431 101]			1	[25 312 128]
$1s4p$	$^3P^o$	0	[24 446 163]			2	[25 312 610]
		1	[24 446 570]	$1s6d$	3D	1,2	[25 315 047]
		2	[24 448 199]			3	[25 315 289]
$1s4s$	1S	0	[24 446 439]	$1s6d$	1D	2	[25 315 357]
$1s4d$	3D	1,2	[24 456 527]				
		3	[24 457 176]				

S XV — Continued

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

S XVI

Z=16

H I isoelectronic sequence

Ground state $1s^2S_{1/2}$ Ionization energy $28\,182\,526 \pm 4\text{ cm}^{-1}$ (3494.1892 \pm 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 $\pm 0.1\text{ cm}^{-1}$ for the $2p^2P_{3/2}^{\circ}-2P_{1/2}^{\circ}$ interval and $\pm 0.4\text{ cm}^{-1}$ for the $2s-2p$ separations. The $2s^2S_{1/2}-2p^2P_{3/2}^{\circ}$ separation as measured by Georgiadis *et al.*, $23\,351.7 \pm 2.1\text{ cm}^{-1}$, is 3.7 cm^{-1} greater than Mohr's calculated value, the quoted experimental error representing one standard deviation. Assuming Mohr's calculated value for the $2p^2P_{3/2}^{\circ}-2P_{1/2}^{\circ}$ interval, Georgiadis *et al.* deduced from their measurement a value of $842.7 \pm 2.1\text{ cm}^{-1}$ for the $2s^2S_{1/2}-2p^2P_{1/2}^{\circ}$ Lamb shift. Zacek *et al.* determined a value of $838.6 \pm 8.0\text{ cm}^{-1}$ for this shift using a field quench technique. Neither of these experimental results is in strong disagreement with Mohr's value of $846.4 \pm 0.4\text{ cm}^{-1}$.

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 $5s^2S_{1/2}$ 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 $1s^2S_{1/2}$ ground level is about equal to the ionization-energy uncertainty. A nuclear mass appropriate for the ^{32}S 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 10^6 ; this

amounts to only 1.6 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 $1s^2S-2p^2P^{\circ}$ doublet near 4.73 \AA 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 Gerdtehl, 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})
$1s$	2S	$1/2$	0	$3s$	2S	$1/2$	[25 050 703]
$2p$	$^2P^{\circ}$	$1/2$	[21 129 300.4]	$3d$	2D	$3/2$	[25 057 607]
		$3/2$	[21 153 494.8]			$5/2$	[25 059 982]
$2s$	2S	$1/2$	[21 130 146.8]	$4p$	$^2P^{\circ}$	$1/2$	[26 421 866]
$3p$	$^2P^{\circ}$	$1/2$	[25 050 449]			$3/2$	[26 424 890]
		$3/2$	[25 057 620]	$4s$	2S	$1/2$	[26 421 973]

S XVI — Continued

Configuration	Term	J	Level (cm ⁻¹)	Configuration	Term	J	Level (cm ⁻¹)
4d	² D	³ / ₂	[26 424 885]	5d	² D	³ / ₂	[27 057 760]
		⁵ / ₂	[26 425 887]			⁵ / ₂	[27 058 274]
4f	² F°	⁵ / ₂	[26 425 885]	5f	² F°	⁵ / ₂	[27 058 273]
		⁷ / ₂	[26 426 885]			⁷ / ₂	[27 058 529]
5p	² P°	¹ / ₂	[27 056 215]	5g	² G	⁷ / ₂	[27 058 528]
		³ / ₂	[27 057 763]			⁹ / ₂	[27 058 682]
5s	² S	¹ / ₂	[27 056 270]		<i>Limit</i>		[28 182 526]