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Energy Levels of Phosphorus, P I through P XV

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Energy level data are given for the atom and all positive ions of phosphorus ($Z=15$). These data have been critically compiled, mainly from published and unpublished material on measurements and analyses of the optical spectra.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; phosphorus.

Contents

1. Introduction

This compilation is one of a series being published by the NBS 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, and Si I–XIV [Martin and Zalubas, 1981, 1980, 1979, 1983, respectively]. A series of energy level compilations for the iron-period elements was completed in 1982 with publication of the data for Fe I–XXVI [Corliss and Sugar, 1982, and references therein]; a single-volume collection of updated compilations for these elements (K through Ni) is in press [Sugar and Corliss, 1985].

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 phosphorus spectra have been compiled from data available to us through November, 1984.

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 $8065.479 \pm 0.021\ \text{cm}^{-1}$ being used for the conversion [Cohen and Taylor, 1973].

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, and references for several types of data not included here, are given in several bibliographic publications [Moore, 1968, Hagan and Martin, 1972, Hagan, 1977, Zalubas and Albright, 1980, Musgrove and Zalubas, 1985, Fuhr, Miller, and Martin, 1978, Miller, Fuhr, and Martin, 1980]. 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, and "PT" and "AT" refer to theoretical results.

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

The levels are given in units of cm^{-1} with respect to the ground level at zero. Odd-parity levels are printed in italics. The assignment of a set of levels to a term is indicated by grouping the levels and by listing the configuration and term symbol 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." If two percentages are listed without comment, the second percentage is the largest of the remaining percentages from the same eigenvector as the first percentage. The configuration for the second-percentage term is omitted for a level having both percentages from the same configuration. If the levels of a term group also have second percentages from a common (second) term, this second-percentage term is usually printed only for the first level of the group.

Any variation from the above conventions for the Leading Percentages 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 K. -T. Cheng, R. D. Cowan, G. W. F. Drake, B. Edlén, B. C. Fawcett, C. F. Fischer, H. Li, P. J. Mohr, 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.

We are grateful to Dr. G. A. Martin for a careful reading of the manuscript.

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3. Tables of Energy Levels

P I

$Z=15$

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

Ionization energy 84 580.83 ± 0.12 cm^{-1} (10.486 77 ± 0.000 03 eV)

The levels are from Svendenius, who extended and revised the earlier analyses using much improved observations of this spectrum. He lists some 1800 classified lines over the range 1202–37 345 Å. The uncertainty of the system of higher levels with respect to the $3s^2 3p^3$ levels is about ±0.05 cm^{-1}, which is also the largest estimated error for those levels given to two decimal places. The few levels given to one decimal have uncertainties ±0.2 to ±0.4 cm^{-1}. The three-place levels, based mainly on Fourier-transform spectrometric measurements in the infrared, have estimated relative errors not greater than ±0.005 cm^{-1}.

Svendenius and Vergès give separate wavenumbers for the two resolved hyperfine-structure components obtained for each of 130 transitions in the region 9675–33 976 Å.

Svendenius derived the ionization energy mainly from Ritz-formula fits of two $3p^2(^3P_2)nf$ series having five or six members.

The eigenvector percentages for the even levels are from two calculations made by Cowan for this compilation. Both calculations included the interactions between the $3s3p^4$, $3s^2 3p^2 ns$, and $3s^2 3p^2 md$ configurations, with $n=4-6$, $m=3-6$ and also four additional pseudo configurations to mock up the higher md series members and the ϵd continuum. No systematic level fitting was done, but the interaction parameters were scaled from their Hartree-Fock values to improve agreement with observation. A calculation with parameters scaled to yield relatively large $3s3p^4$ components for the ^2D term near 71 200 cm^{-1} was used for the percentages up through the $3s^2 3p^2(^3P)5s\ ^2P$ term near 73 000 cm^{-1}. A second calculation that gives somewhat better overall agreement with experiment has been used for the higher levels.

Term-dependent Hartree-Fock wavefunctions calculated by Cowan for several of the above configurations gave strongly term-dependent values for some of the important interaction parameters, especially those involving the $3d$ and $4d$ orbitals. Neither Cowan's calculations of the levels, as described above, nor Svendenius's calculations of the smaller group $3s3p^4 + 3s^2 3p^2 md$ ($m=3$, 4, 5) included the effects of these large term dependencies; since their inclusion would certainly affect many of the eigenvectors significantly, especially those having highly mixed compositions, the available eigenvectors should be regarded as indicative rather than definitive. Cowan's results have been chosen for tabulation here because they were derived from a more complete set of the significantly interacting configurations.

Cowan's inclusion of the interaction between the $3s^2 3p^2 4s$ and $3s^2 3p^2 3d$ configurations has forced a reversal of Svendenius's designations of the $3s^2 3p^2(^1S)4s\ ^2S$ and $3s^2 3p^2(^1D)3d\ ^2S$ terms. All other eigenvector assignments have been made in accordance with Svendenius's designations, although the strong mixing in a number of cases indicates that the corresponding names may have little meaning. Although Svendenius's calculation predicted a relatively pure $3s3p^4\ ^2P$ term high above the ionization limit, he was able to deduce a strong interaction between this term and the entire $3s^2 3p^2(^3P)md$ series. Cowan's results have the $3s3p^4\ ^2P$ and ^2S components distributed amongst a number of eigenvectors (mainly $3s^2 3p^2 md$ and ϵd in character) so as to obviate these terms as meaningful names for any particular predicted levels.

No eigenvectors for the odd levels are available, but Svendenius's discussion of the $3s^2 3p^2 np$ configurations was partly based on an unpublished calculation of the $3s^2 3p^3 + 3s^2 3p^2 4p + 3s^2 3p^2 5p$ levels.

The $J_1 l$-coupling names of the $3s^2 3p^2 nf$ and ng levels are supported by Svendenius's calculations, the lowest average purity for any of these configurations in this scheme being 98.4% (for $3s^2 3p^2 4f$).

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P I

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2 3p^3$	$^4\mathrm{S}^\circ$	$\frac{3}{2}$	*0.00*			
$3s^2 3p^3$	$^2\mathrm{D}^\circ$	$\frac{3}{2}$	*11 361.02*			
		$\frac{5}{2}$	*11 376.63*			
$3s^2 3p^3$	$^2\mathrm{P}^\circ$	$\frac{1}{2}$	*18 722.71*			
		$\frac{3}{2}$	*18 748.01*			
$3s^2 3p^2(^3\mathrm{P})4s$	$^4\mathrm{P}$	$\frac{1}{2}$	55 939.421	98	1	$3s3p^4\ ^4\mathrm{P}$
		$\frac{3}{2}$	56 090.626	98	1	
		$\frac{5}{2}$	56 339.656	98	1	
$3s^2 3p^2(^3\mathrm{P})4s$	$^2\mathrm{P}$	$\frac{1}{2}$	57 876.574	98	1	$(^3\mathrm{P})3d\ ^2\mathrm{P}$
		$\frac{3}{2}$	58 174.366	98	1	
$3s3p^4$	$^4\mathrm{P}$	$\frac{5}{2}$	59 534.549	70	14	$3s^2 3p^2(^3\mathrm{P})3d\ ^4\mathrm{P}$
		$\frac{3}{2}$	59 715.921	70	14	
		$\frac{1}{2}$	59 820.371	70	14	
$3s^2 3p^2(^3\mathrm{P})4p$	$^2\mathrm{S}^\circ$	$\frac{1}{2}$	*64 239.591*			
$3s^2 3p^2(^1\mathrm{D})4s$	$^2\mathrm{D}$	$\frac{3}{2}$	65 156.242	98	1	$(^1\mathrm{D})3d\ ^2\mathrm{D}$
		$\frac{5}{2}$	65 157.126	98	1	
$3s^2 3p^2(^3\mathrm{P})4p$	$^4\mathrm{D}^\circ$	$\frac{1}{2}$	*65 373.556*			
		$\frac{3}{2}$	*65 450.125*			
		$\frac{5}{2}$	*65 585.130*			
		$\frac{7}{2}$	*65 788.455*			
$3s^2 3p^2(^3\mathrm{P})4p$	$^4\mathrm{P}^\circ$	$\frac{1}{2}$	*66 343.438*			
		$\frac{3}{2}$	*66 360.282*			
		$\frac{5}{2}$	*66 544.243*			
$3s^2 3p^2(^3\mathrm{P})4p$	$^2\mathrm{D}^\circ$	$\frac{3}{2}$	*66 813.271*			
		$\frac{5}{2}$	*67 113.870*			
$3s^2 3p^2(^3\mathrm{P})4p$	$^4\mathrm{S}^\circ$	$\frac{3}{2}$	*66 834.648*			
$3s^2 3p^2(^3\mathrm{P})3d$	$^2\mathrm{P}$	$\frac{3}{2}$	67 909.136	85	4	$3s3p^4\ ^2\mathrm{P}$
		$\frac{1}{2}$	68 126.607	86	4	
$3s^2 3p^2(^3\mathrm{P})4p$	$^2\mathrm{P}^\circ$	$\frac{1}{2}$	*67 971.072*			
		$\frac{3}{2}$	*68 088.076*			
$3s^2 3p^2(^3\mathrm{P})3d$	$^4\mathrm{F}$	$\frac{3}{2}$	68 183.186	96	2	$(^3\mathrm{P})4d\ ^4\mathrm{F}$
		$\frac{5}{2}$	68 262.151	95	2	
		$\frac{7}{2}$	68 377.472	95	2	
		$\frac{9}{2}$	68 532.653	96	2	
$3s^2 3p^2(^3\mathrm{P})3d$	$^4\mathrm{D}$	$\frac{1}{2}$	69 878.033	99		
		$\frac{3}{2}$	69 894.307	98		
		$\frac{5}{2}$	69 924.453	94	2	$(^3\mathrm{P})3d\ ^2\mathrm{F}$
		$\frac{7}{2}$	69 980.077	95	3	$(^3\mathrm{P})3d\ ^2\mathrm{F}$
$3s^2 3p^2(^3\mathrm{P})3d$	$^2\mathrm{F}$	$\frac{5}{2}$	70 391.801	94	2	$(^3\mathrm{P})3d\ ^4\mathrm{D}$
		$\frac{7}{2}$	70 689.504	94	3	
$3s3p^4$	$^2\mathrm{D}$	$\frac{5}{2}$	71 168.229	34	29	$3s^2 3p^2(^3\mathrm{P})3d\ ^2\mathrm{D}$
		$\frac{3}{2}$	71 202.979	34	30	

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2\,3p^2(^3P)5s$	^4P	1/2	72 378.000	98	2	$(^3P)5s\ ^2P$
		3/2	72 572.400	97	2	
		5/2	72 807.203	100		
$3s^2\,3p^2(^3P)3d$	^4P	5/2	72 386.347	51	26	$(^3P)3d\ ^2D$
		3/2	72 493.806	81	8	$3s3p^4\ ^4P$
		1/2	72 617.789	82	8	$3s3p^4\ ^4P$
$3s^2\,3p^2(^3P)3d$	^2D	3/2	72 741.808	64	14	$3s3p^4\ ^2D$
		5/2	72 884.865	40	31	$(^3P)3d\ ^4P$
$3s^2\,3p^2(^3P)5s$	^2P	1/2	72 943.803	95	2	$(^3P)3d\ ^2P$
		3/2	73 249.806	94	3	$(^3P)5s\ ^4P$
$3s^2\,3p^2(^1D)4p$	$^2D^\circ$	3/2	*74 271.699*			
		5/2	*74 301.473*			
$3s^2\,3p^2(^1D)4p$	$^2F^\circ$	5/2	*74 717.628*			
		7/2	*74 739.786*			
$3s^2\,3p^2(^3P)5p$	$^2S^\circ$	1/2	*75 104.423*			
$3s^2\,3p^2(^3P)5p$	$^4D^\circ$	1/2	*75 291.257*			
		3/2	*75 351.512*			
		5/2	*75 484.459*			
		7/2	*75 705.601*			
$3s^2\,3p^2(^1D)4p$	$^2P^\circ$	1/2	*75 455.774*			
		3/2	*75 488.904*			
$3s^2\,3p^2(^3P)4d$	^2P	3/2	75 676.09	80	4	$(^3P)3d\ ^2P$
		1/2	75 813.72	79	4	
$3s^2\,3p^2(^3P)5p$	$^4P^\circ$	3/2	*75 689.282*			
		1/2	*75 699.831*			
		5/2	*75 905.112*			
$3s^2\,3p^2(^3P)4d$	^2F	5/2	75 833.18	65	23	$(^1D)3d\ ^2F$
		7/2	75 956.87	58	27	
$3s^2\,3p^2(^3P)4d$	^4F	3/2	75 949.47	91	2	$(^3P)3d\ ^4F$
		5/2	76 045.99	82	6	$(^3P)4d\ ^2F$
		7/2	76 173.35	81	6	$(^3P)4d\ ^4D$
		9/2	76 318.01	94	2	$(^3P)3d\ ^4F$
$3s^2\,3p^2(^3P)5p$	$^4S^\circ$	3/2	*76 021.601*			
$3s^2\,3p^2(^3P)5p$	$^2D^\circ$	3/2	*76 192.199*			
		5/2	*76 425.224*			
$3s^2\,3p^2(^3P)4d$	^4D	1/2	76 566.49	96	2	$(^3P)4d\ ^2P$
		3/2	76 585.71	94	2	$(^3P)4d\ ^4F$
		5/2	76 627.90	91	4	$(^3P)4d\ ^4F$
		7/2	76 709.42	90	4	$(^3P)4d\ ^4F$
$3s^2\,3p^2(^3P)5p$	$^2P^\circ$	1/2	*76 762.279*			
		3/2	*76 875.250*			

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2 3p^2(^1S)4s$	^2S	1/2	76 912.25	71	26	$(^1D)3d\ ^2S$
$3s^2 3p^2(^3P_0)4f$	$^2[3]^\circ$	5/2	*77 654.560*			
		7/2	*77 655.315*			
$3s^2 3p^2(^3P)4d$	^4P	5/2	77 733.68	64	24	$(^3P)4d\ ^2D$
		3/2	77 888.81	86	4	$(^3P)5d\ ^4P$
		1/2	77 965.5	81	7	$(^3P)6s\ ^4P$
$3s^2 3p^2(^3P)6s$	^4P	1/2	77 769.50	85	7	$(^3P)4d\ ^4P$
		3/2	77 942.55	93	6	$(^3P)6s\ ^2P$
		5/2	78 211.34	100		
$3s^2 3p^2(^3P_1)4f$	$^2[3]^\circ$	5/2	*77 783.840*			
		7/2	*77 784.743*			
$3s^2 3p^2(^3P_1)4f$	$^2[4]^\circ$	9/2	*77 830.305*			
		7/2	*77 831.093*			
$3s^2 3p^2(^3P)4d$	^2D	3/2	77 833.75	90	3	$(^3P)5d\ ^2D$
		5/2	77 946.70	66	23	$(^3P)4d\ ^4P$
$3s^2 3p^2(^3P_1)4f$	$^2[2]^\circ$	3/2	*77 843.316*			
		5/2	*77 843.981*			
$3s^2 3p^2(^3P)6s$	^2P	1/2	78 049.07	90	7	$(^3P)6s\ ^4P$
		3/2	78 358.80	90	7	
$3s^2 3p^2(^3P_2)4f$	$^2[1]^\circ$	3/2	*78 069.110*			
		1/2	*78 069.275*			
$3s^2 3p^2(^3P_2)4f$	$^2[5]^\circ$	11/2	*78 100.894*			
		9/2	*78 102.997*			
$3s^2 3p^2(^3P_2)4f$	$^2[2]^\circ$	3/2	*78 132.673*			
		5/2	*78 133.478*			
$3s^2 3p^2(^3P_2)4f$	$^2[3]^\circ$	7/2	*78 169.970*			
		5/2	*78 170.285*			
$3s^2 3p^2(^3P_2)4f$	$^2[4]^\circ$	9/2	*78 178.054*			
		7/2	*78 179.687*			
$3s^2 3p^2(^1D)3d$	^2F	5/2	78 339.84	56	2	$(^3P)4d\ ^2F$
		7/2	78 429.31	54	3	
$3s^2 3p^2(^1D)3d$	^2G	9/2	78 565.10	100		
		7/2	78 579.96	100		
$3s^2 3p^2(^3P)6p$	$^2S^\circ$	1/2	*79 044.08*			
$3s^2 3p^2(^3P)6p$	$^4D^\circ$	3/2	*79 100.12*			
		1/2	*79 129.64*			
		5/2	*79 229.97*			
		7/2	*79 484.84*			
$3s^2 3p^2(^3P)5d$	^2P	3/2	79 122.19	47	31	$(^1D)3d\ ^2P$
		1/2	79 219.56	40	38	

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2\,3p^2(^3P)6p$	$^4P^\circ$	3/2	*79 297.23*			
		5/2	*79 561.99*			
$3s^2\,3p^2(^3P)5d$	^4F	3/2	79 339.38	87	5	$(^3P)5d\ ^4D$
		5/2	79 402.10	80	13	$(^3P)5d\ ^4D$
		7/2	79 515.35	77	16	$(^3P)5d\ ^4D$
		9/2	79 720.70	93	3	$(^3P)4d\ ^4F$
$3s^2\,3p^2(^3P)6p$	$^2D^\circ$	3/2	*79 415.38*			
		5/2	*79 711.41*			
$3s^2\,3p^2(^3P)6p$	$^4S^\circ$	3/2	*79 621.43*			
$3s^2\,3p^2(^3P)6p$	$^2P^\circ$	1/2	*79 690.04*			
		3/2	*79 830.28*			
$3s^2\,3p^2(^3P)5d$	^4D	1/2	79 696.59	92	5	$(^1D)3d\ ^2P$
		3/2	79 718.49	85	5	$(^3P)5d\ ^4F$
		5/2	79 761.77	71	12	$(^3P)5d\ ^4F$
		7/2	79 863.71	80	16	$(^3P)5d\ ^4F$
$3s^2\,3p^2(^3P_0)5f$	$^2[3]^\circ$	5/2	*80 154.30*			
		7/2	*80 154.88*			
$3s^2\,3p^2(^3P)5d$	^2F	5/2	80 183.29	69	15	$(^3P)5d\ ^2D$
		7/2	80 461.17	88	6	$(^1D)3d\ ^2F$
$3s^2\,3p^2(^3P)7s$	^4P	1/2	80 220.46			
		3/2	80 380.49			
		5/2	80 679.30			
$3s^2\,3p^2(^3P)5d$	^2D	3/2	80 299.41	69	10	$(^3P)5d\ ^2P$
		5/2	80 517.06	45	37	$(^3P)5d\ ^4P$
$3s^2\,3p^2(^3P_1)5f$	$^2[3]^\circ$	5/2	*80 299.78*			
		7/2	*80 300.45*			
$3s^2\,3p^2(^3P)5d$	^4P	5/2	80 308.41	44	29	$(^3P)5d\ ^2D$
		3/2	80 426.27	84	4	$(^3P)6d\ ^4P$
		1/2	80 508.15	89	4	$(^3P)6d\ ^4P$
$3s^2\,3p^2(^3P_1)5f$	$^2[4]^\circ$	9/2	*80 324.67*			
		7/2	*80 325.43*			
$3s^2\,3p^2(^3P_1)5f$	$^2[2]^\circ$	3/2	*80 334.16*			
		5/2	*80 334.85*			
$3s^2\,3p^2(^3P)7s$	^2P	1/2	80 372.65			
		3/2	80 810.13			
$3s^2\,3p^2(^1D)3d$	^2P	3/2	80 548.77	44	29	$(^3P)5d\ ^2P$
		1/2	80 672.81	44	48	$(^3P)5d\ ^2P$
$3s^2\,3p^2(^3P_2)5f$	$^2[1]^\circ$	3/2	*80 594.18*			
		1/2	*80 594.20*			
$3s^2\,3p^2(^3P_2)5f$	$^2[5]^\circ$	11/2	*80 609.46*			
		9/2	*80 611.16*			

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2\,3p^2(^3P_2)5f$	$^2[2]^\circ$	$3/2$	*80 621.93*			
		$5/2$	*80 622.44*			
$3s^2\,3p^2(^3P_2)5f$	$^2[3]^\circ$	$7/2$	*80 642.92*			
		$5/2$	*80 643.16*			
$3s^2\,3p^2(^3P_2)5f$	$^2[4]^\circ$	$9/2$	*80 647.14*			
		$7/2$	*80 648.40*			
$3s^2\,3p^2(^1D)3d$	^2S	$1/2$	80 655.21	69	26	$(^1S)4s\ ^2S$
$3s^2\,3p^2(^3P)6d$	^4F	$3/2$	81 069.94	64	12	$(^3P)6d\ ^2P$
		$5/2$	81 123.64	66	21	$(^3P)6d\ ^4D$
		$7/2$	81 233.76	65	25	$(^3P)6d\ ^4D$
		$9/2$	81 467.72	95	3	$(^3P)5d\ ^4F$
$3s^2\,3p^2(^3P)6d$	^2P	$3/2$	81 277.27	60	23	$(^3P)6d\ ^4F$
		$1/2$	81 516.73	52	40	$(^3P)6d\ ^4D$
$3s^2\,3p^2(^3P)6d$	^4D	$1/2$	81 283.84	57	36	$(^3P)6d\ ^2P$
		$5/2$	81 402.56	22	20	$(^3P)6d\ ^4F$
		$3/2$	81 415.75	66	7	$(^3P)6d\ ^2D$
		$7/2$	81 534.32	68	28	$(^3P)6d\ ^4F$
$3s^2\,3p^2(^1D)5s$	^2D	$5/2$	81 296.70	84	8	$(^3P)6d\ ^2D$
		$3/2$	81 302.81	87	6	$(^3P)6d\ ^4D$
$3s^2\,3p^2(^3P_0)6f$	$^2[3]^\circ$	$5/2$	*81 510.56*			
		$7/2$	*81 510.84*			
$3s^2\,3p^2(^3P)6d$	^2F	$5/2$	81 522.20	53	31	$(^3P)6d\ ^4D$
		$7/2$	81 795.11	89	6	
$3s^2\,3p^2(^3P_0)6g$	$^2[4]$	$7/2$	81 527.562			
		$9/2$	81 527.596			
$3s^2\,3p^2(^3P)8s$	^4P	$1/2$	81 578.64			
		$3/2$	81 719.54			
		$5/2$	82 014.99			
$3s^2\,3p^2(^3P_1)6f$	$^2[3]^\circ$	$5/2$	*81 663.75*			
		$7/2$	*81 664.23*			
$3s^2\,3p^2(^3P_1)6f$	$^2[4]^\circ$	$9/2$	*81 678.44*			
		$7/2$	*81 679.01*			
$3s^2\,3p^2(^3P_1)6f$	$^2[2]^\circ$	$3/2$	*81 684.53*			
		$5/2$	*81 685.07*			
$3s^2\,3p^2(^3P_1)6g$	$^2[4]$	$7/2$	81 687.072			
		$9/2$	81 867.087			
$3s^2\,3p^2(^3P_1)6g$	$^2[5]$	$11/2$	81 694.357			
		$9/2$	81 694.358			
$3s^2\,3p^2(^3P)6d$	^4P	$5/2$	81 719.97	48	16	$(^1D)3d\ ^2D$
		$3/2$	81 840.73	70	10	$(^1D)3d\ ^2D$
		$1/2$	81 896.33	90	2	$(^3P)5d\ ^4P$

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2\,3p^2(^3P)6d$	^2D	$3/2$	81 764.68	64	9	$(^3P)6d\ ^2P$
		$5/2$	81 890.08	36	16	$(^3P)6d\ ^4P$
$3s^2\,3p^2(^3P)8s$	^2P	$1/2$	81 771.3			
		$3/2$	82 064.43			
$3s^2\,3p^2(^3P_2)6f$	$^2[1]^\circ$	$1/2, 3/2$	*81 961.17*			
$3s^2\,3p^2(^3P_2)6f$	$^2[5]^\circ$	$11/2$	*81 970.73*			
		$9/2$	*81 971.91*			
$3s^2\,3p^2(^3P_2)6f$	$^2[2]^\circ$	$3/2$	*81 976.76*			
		$5/2$	*81 977.19*			
$3s^2\,3p^2(^3P_2)6f$	$^2[3]^\circ$	$7/2$	*81 989.31*			
		$5/2$	*81 989.49*			
$3s^2\,3p^2(^3P_2)6f$	$^2[4]^\circ$	$9/2$	*81 991.94*			
		$7/2$	*81 992.78*			
$3s^2\,3p^2(^3P_2)6g$	$^2[6]$	$13/2$	81 992.727			
		$11/2$	81 992.728			
$3s^2\,3p^2(^3P_2)6g$	$^2[4]$	$7/2$	81 997.273			
		$9/2$	81 997.386			
$3s^2\,3p^2(^3P_2)6g$	$^2[5]$	$11/2$	82 001.922			
		$9/2$	82 001.933			
$3s^2\,3p^2(^3P)7d$	^4F	$3/2$	82 075.89			
		$5/2$	82 112.37			
		$7/2$	82 224.15			
		$9/2$	82 479.06			
$3s^2\,3p^2(^1D)3d$	^2D	$3/2$	82 195.77	39	14	$(^3P)6d\ ^4P$
		$5/2$	82 233.05	30	24	$(^3P)6d\ ^2D$
$3s^2\,3p^2(^3P)7d$	^2P	$3/2$	82 251.36			
$3s^2\,3p^2(^3P_0)7f$	$^2[3]^\circ$	$5/2$	*82 327.19*			
		$7/2$	*82 327.40*			
$3s^2\,3p^2(^3P)7d$	^4D	$5/2$	82 346.23			
		$7/2$	82 514.88			
$3s^2\,3p^2(^3P)7d$	^2F	$5/2$	82 374.80			
		$7/2$	82 640.41			
$3s^2\,3p^2(^3P_1)7f$	$^2[3]^\circ$	$7/2$	*82 484.95*			
		$5/2$	*82 484.97*			
$3s^2\,3p^2(^3P_1)7f$	$^2[4]^\circ$	$9/2$	*82 493.91*			
		$7/2$	*82 494.33*			
$3s^2\,3p^2(^3P_1)7f$	$^2[2]^\circ$	$5/2$	*82 498.41*			
		$3/2$	*82 498.46*			
$3s^2\,3p^2(^3P)9s$	^4P	$3/2$	82 521.95			
		$5/2$	82 820.60			

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^2\,3p^2(^3\mathrm{P})7d$	^{4}P	5/2	82 590.22	
		3/2	82 665.31	
		1/2	82 738.86	
$3s^2\,3p^2(^3\mathrm{P})8d$	^{4}F	3/2	82 689.80	
		5/2	82 734.40	
		7/2	82 846.91	
		9/2	83 115.90	
$3s^2\,3p^2(^3\mathrm{P})7d$	^{2}D	5/2	82 753.31	
$3s^2\,3p^2(^3\mathrm{P}_2)7f$	$^2[1]^\circ$	1/2,3/2	*82 783.04*	
$3s^2\,3p^2(^3\mathrm{P}_2)7f$	$^2[5]^\circ$	11/2	*82 790.39*	
		9/2	*82 791.20*	
$3s^2\,3p^2(^3\mathrm{P}_2)7f$	$^2[2]^\circ$	3/2	*82 795.47*	
		5/2	*82 795.85*	
$3s^2\,3p^2(^3\mathrm{P}_2)7f$	$^2[3]^\circ$	7/2	*82 800.76*	
		5/2	*82 800.84*	
$3s^2\,3p^2(^3\mathrm{P}_2)7f$	$^2[4]^\circ$	9/2	*82 803.43*	
		7/2	*82 803.91*	
$3s^2\,3p^2(^3\mathrm{P})9s$	^{2}P	3/2	82 843.16	
$3s^2\,3p^2(^3\mathrm{P})8d$	^{2}P	3/2	82 861.8	
$3s^2\,3p^2(^3\mathrm{P})8d$	^{4}D	5/2	82 943.04	
		7/2	83 136.73	
$3s^2\,3p^2(^3\mathrm{P})8d$	^{2}F	5/2	82 949.43	
		7/2	83 197.76	
$3s^2\,3p^2(^3\mathrm{P}_1)8f$	$^2[3]^\circ$	5/2	*83 016.31*	
		7/2	*83 016.35*	
$3s^2\,3p^2(^3\mathrm{P}_1)8f$	$^2[4]^\circ$	9/2	*83 022.82*	
		7/2	*83 023.11*	
$3s^2\,3p^2(^3\mathrm{P})8d$	^{4}P	5/2	83 167.15	
$3s^2\,3p^2(^3\mathrm{P})9d$	^{4}F	7/2	83 265.41	
		9/2	83 542.59	
$3s^2\,3p^2(^3\mathrm{P}_2)8f$	$^2[5]^\circ$	11/2	*83 321.63*	
		9/2	*83 322.22*	
$3s^2\,3p^2(^3\mathrm{P}_2)8f$	$^2[4]^\circ$	9/2	*83 332.04*	
$3s^2\,3p^2(^3\mathrm{P})9d$	^{4}D	7/2	83 555.24	
$3s^2\,3p^2(^3\mathrm{P})9d$	^{2}F	7/2	83 594.91	
$3s^2\,3p^2(^3\mathrm{P}_2)9f$	$^2[5]^\circ$	11/2	*83 685.48*	
$3s^2\,3p^2(^3\mathrm{P}_2)9f$	$^2[4]^\circ$	9/2	*83 691.91*	

P I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
P II ($^3P_0$)	*Limit*		84 580.83	
P II ($^3P_1$)	*Limit*		84 745.73	
P II ($^3P_2$)	*Limit*		85 049.94	
P II ($^1D_2$)	*Limit*		93 463.15	
P II ($^1S_0$)	*Limit*		106 156.45	

P II

$Z = 15$

Si I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^2\ {}^3\mathrm{P}_0$

Ionization energy 159 451.5 ± 1.0 cm^{-1} (19.769 63 ± 0.000 13 eV)

New observations of this spectrum by Svendenius, Magnusson, and Zetterberg [1983] gave more than 900 classified lines over the range 700–12 000 Å. The level values here are from their paper, with a few exceptions noted below. No uncertainties for the wavelengths or energy levels were given. Wavelength uncertainties comparable to those estimated by Svendenius for P I [see P I] would correspond to an uncertainty of about ±0.5 cm^{-1} for most of the better determined excited-configuration levels of P II with respect to the ground level. The ${}^3\mathrm{P}^\circ$ ground term intervals are probably in error by less than 0.2 cm^{-1}, and the better determined term and fine-structure separations of the excited configurations are probably accurate to within a few hundredths of a cm^{-1}.

The $3s3p^3\ {}^5\mathrm{S}_2^\circ$ position given by Svendenius *et al.* was based mainly on a measured wavelength of 2195.549 Å for the $3s^23p^2\ {}^3\mathrm{P}_1 - 3s3p^3\ {}^5\mathrm{S}_2^\circ$ transition. Since the line measured was later found to belong mainly to P IV [Smith *et al.*, 1984], we have reevaluated the $3s3p^3\ {}^5\mathrm{S}_2^\circ$ level using an average of the original measurements of the $3s3p^3\ {}^5\mathrm{S}_2^\circ$ transitions to the $3s^23p^2\ {}^3\mathrm{P}_2$ and ${}^3\mathrm{P}_1$ levels [Martin, 1959] and the measurement of the first (and stronger) of these lines by Svendenius *et al.* The resulting lowering of the ${}^5\mathrm{S}_2^\circ$ level by 0.36 cm^{-1} has also been applied to the three $3s3p^23d\ {}^5\mathrm{P}$ levels, first derived by Robinson [1937] from three lines classified as the $3s3p^3\ {}^5\mathrm{S}^\circ - 3s3p^23d\ {}^5\mathrm{P}$ multiplet.

We evaluated the $3s^23p5p\ {}^1\mathrm{S}_0$ level using the transitions to the $3s3p^3\ {}^1\mathrm{P}_1^\circ$ and $3s^23p3d\ {}^1\mathrm{P}_1^\circ$ levels observed and classified by Li [1972]. The experimental $3p5p\ {}^1\mathrm{S}_0$ position at 132 901.0 cm^{-1} is only 1 cm^{-1} above the value predicted theoretically by Li (see below). Several of the fainter lines observed by Li are not given in the line list of Svendenius *et al.*, including the $3p5p\ {}^1\mathrm{S}_0$ combinations and the two lines on which Li based his discovery of the $3p5p\ {}^3\mathrm{P}_0$ level.

The *g* values are also from Li's paper. The stated uncertainty of most of these values is 0.01 or less, although the uncertainty of most of the *g* values for the $3p5d$ levels is 0.02.

Li's calculations of P II energy structures included the levels of the group $(3s3p^3 + 3s^23p3d + 3s^23p4d + 3s^23p5d)$ with the configuration interactions taken into account. The leading eigenvector percentages from this calculation are given here. The interactions of the terms common to the $3s3p^3$ and $3s^23p3d$ configurations and also the strong mixtures of $3s^23p3d\ {}^3\mathrm{P}^\circ$ and ${}^3\mathrm{D}^\circ$ components in the pertinent eigenvectors for these two terms could be deduced even without the detailed calculation of these effects [Martin, 1959]. Good agreement between the calculated and experimental *g* values allowed Li to make unambiguous eigenvector assignments despite the strong configuration interactions and intermediate-coupling effects. The table here incorporates his interchanges of Martin's designations of five pairs of levels of the above group, the new names being optimal even though the leading percentages of the relevant eigenvectors are in the range 49% to 64%. The new names were used in the line list of Svendenius *et al.*, but by oversight the less appropriate earlier designations of the ten levels involved were retained in their energy-level table.

The eigenvector percentages for the levels of the three other odd-parity configurations, $3s^23p4s$, $3s^23p5s$, and $3s^23p6s$, and for the levels of the even configurations $3s^23p4p$, $3s^23p5p$, and $3s^23p4f$, are also from Li's calculations. Li assumed the single-configuration approximation in each case, the results indicating that no strong configuration interactions were involved. The first percentages given for the $3s^23p4f$ levels are for the LS_1 coupling scheme used to designate these levels [Cowan and Andrew, 1965]; the leading percentage in the LS scheme is also listed for each $3p4f$ level, following the word "or."

Svendenius *et al.* designated the $3s^23pnf$ and $3png$ pair terms in the LS_1 coupling scheme. We have added the alternate J_1l-coupling names for the $3p5f$ and $3p6f$ pairs (last column, following the word "or"). Since the structure of the $3png$ configurations is dominated by the $3p\ {}^2\mathrm{P}_{3/2}^\circ - {}^2\mathrm{P}_{1/2}^\circ$ splitting, we give the J_1l-coupling names for these pairs in the first column and the LS_1-coupling names as alternates.

Svendenius *et al.* determined the ionization energy by fitting a Ritz formula to the $3p({}^2\mathrm{P}_{3/2}^\circ)ng\ {}^2[\frac{11}{2}]^\circ$ series ($n = 5-9$). Their adopted value also agrees to within the quoted uncertainty with a value they obtained from the $3p({}^2\mathrm{P}_{1/2}^\circ)ng\ {}^2[\frac{9}{2}]^\circ$ series ($n = 5-7$).

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P II

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$3s^2 3p^2$	$^{3}\mathrm{P}$	0	0.00				
		1	164.90				
		2	469.12				
$3s^2 3p^2$	$^{1}\mathrm{D}$	2	8 882.31				
$3s^2 3p^2$	$^{1}\mathrm{S}$	0	21 575.63				
$3s3p^3$	$^{5}\mathrm{S}^{\circ}$	2	*45 697.02*		100		
$3s3p^3$	$^{3}\mathrm{D}^{\circ}$	1	*65 251.45*	0.504	81	17	$3p3d$ $^{3}\mathrm{D}^{\circ}$
		2	*65 272.35*	1.160	81	17	
		3	*65 307.17*	1.329	81	17	
$3s3p^3$	$^{3}\mathrm{P}$	2	*76 764.06*	1.486	71	25	$3p3d$ $^{3}\mathrm{P}^{\circ}$
		1	*76 812.33*	1.50	74	25	
		0	*76 823.11*		74	25	
$3s^2 3p3d$	$^{1}\mathrm{D}$	2	*77 710.19*	1.014	63	32	$3s3p^3$ $^{1}\mathrm{D}^{\circ}$
$3s^2 3p4s$	$^{3}\mathrm{P}$	0	*86 597.55*		100		
		1	*86 743.96*	1.495	99	1	$^{1}\mathrm{P}^{\circ}$
		2	*87 124.60*	1.499	100		
$3s^2 3p3d$	$^{3}\mathrm{F}^{\circ}$	2	*87 804.10*	0.666	100		
		3	*87 966.81*	1.083	100		
		4	*88 192.13*	1.25	100		
$3s^2 3p4s$	$^{1}\mathrm{P}^{\circ}$	1	*88 893.22*	1.006	99	1	$^{3}\mathrm{P}^{\circ}$
$3s^2 3p4p$	$^{1}\mathrm{P}$	1	101 635.69	0.998	98	2	$^{3}\mathrm{D}$
$3s^2 3p3d$	$^{1}\mathrm{P}^{\circ}$	1	*102 798.26*	1.00	64	33	$3s3p^3$ $^{1}\mathrm{P}^{\circ}$
$3s^2 3p4p$	$^{3}\mathrm{D}$	1	103 165.61	0.511	98	2	$^{1}\mathrm{P}$
		2	103 339.14	1.166	99		
		3	103 667.86	1.334	100		
$3s^2 3p3d$	$^{3}\mathrm{P}^{\circ}$	2	*103 629.70*	1.408	55	21	$3p3d$ $^{3}\mathrm{D}^{\circ}$
		1	*103 755.91*	1.05	41	36	$3p3d$ $^{3}\mathrm{D}^{\circ}$
		0	*103 940.38*		75	24	$3s3p^3$ $^{3}\mathrm{P}^{\circ}$
$3s^2 3p3d$	$^{3}\mathrm{D}^{\circ}$	3	*104 050.27*	1.326	82	15	$3s3p^3$ $^{3}\mathrm{D}^{\circ}$
		1	*104 053.81*	0.94	46	33	$3p3d$ $^{3}\mathrm{P}^{\circ}$
		2	*104 101.75*	1.26	61	19	$3p3d$ $^{3}\mathrm{P}^{\circ}$
$3s^2 3p4p$	$^{3}\mathrm{P}$	0	105 224.06		100		
		1	105 302.37	1.525	94	6	$^{3}\mathrm{S}$
		2	105 549.67	1.499	99		
$3s^2 3p4p$	$^{3}\mathrm{S}$	1	106 001.25	1.968	94	6	$^{3}\mathrm{P}$
$3s^2 3p3d$	$^{1}\mathrm{F}^{\circ}$	3	*107 360.25*	1.004	100		
$3s^2 3p4p$	$^{1}\mathrm{D}$	2	107 922.93	1.002	99		
$3s3p^3$	$^{3}\mathrm{S}^{\circ}$	1	*110 254.77*		100		

P II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$3s^2\,3p4p$	$^{1}\mathrm{S}$	0	111 507.66		100			
$3s3p^3$	$^{1}\mathrm{D}^{\circ}$	2	*112 606.86*	0.998	50		31	$3p3d\ ^{1}\mathrm{D}^{\circ}$
$3s3p^3$	$^{1}\mathrm{P}^{\circ}$	1	*118 341.71*	0.99	58		34	$3p3d\ ^{1}\mathrm{P}^{\circ}$
$3s^2\,3p5s$	$^{3}\mathrm{P}^{\circ}$	0	*123 344.19*		100			
		1	*123 455.46*	1.465	93		7	$^{1}\mathrm{P}^{\circ}$
		2	*123 890.81*	1.497	100			
$3s^2\,3p5s$	$^{1}\mathrm{P}^{\circ}$	1	*124 432.26*	1.036	93		7	$^{3}\mathrm{P}^{\circ}$
$3s^2\,3p4d$	$^{3}\mathrm{F}^{\circ}$	2	*124 946.73*	0.664	99			
		3	*125 128.87*	1.081	99			
		4	*125 391.13*	1.25	100			
$3s^2\,3p4d$	$^{3}\mathrm{P}^{\circ}$	2	*127 367.23*	1.278	49		24	$3p4d\ ^{1}\mathrm{D}^{\circ}$
		0	*127 899.54*		98		2	$3s3p^3\ ^{3}\mathrm{P}^{\circ}$
		1	*127 934.09*	1.129	62		35	$3p4d\ ^{3}\mathrm{D}^{\circ}$
$3s^2 3p4d$	$^{3}\mathrm{D}^{\circ}$	1	*127 599.16*	0.870	61		35	$3p4d\ ^{3}\mathrm{P}^{\circ}$
		3	*127 888.42*	1.33	96		3	$3s3p^3\ ^{3}\mathrm{D}^{\circ}$
		2	*127 949.70*	1.284	58		37	$3p4d\ ^{3}\mathrm{P}^{\circ}$
$3s^2\,3p4d$	$^{1}\mathrm{D}^{\circ}$	2	*127 755.50*	1.098	55		19	$3p4d\ ^{3}\mathrm{D}^{\circ}$
$3s^2\,3p5p$	$^{1}\mathrm{P}$	1	129 109.68	0.94	85		13	$^{3}\mathrm{D}$
$3s^2\,3p5p$	$^{3}\mathrm{D}$	1	129 569.36	0.62	82		11	$^{1}\mathrm{P}$
		2	129 665.20	1.187	93		5	$^{3}\mathrm{P}$
		3	130 019.50	1.34	100			
$3s^2\,3p5p$	$^{3}\mathrm{P}$	0	130 058.11		99		1	$^{1}\mathrm{S}$
		1	130 173.43	1.473	84		7	$^{3}\mathrm{S}$
		2	130 399.78	1.47	93		6	$^{3}\mathrm{D}$
$3s^2\,3p4d$	$^{1}\mathrm{F}^{\circ}$	3	*130 142.72*	1.00	100			
$3s^2\,3p5p$	$^{3}\mathrm{S}$	1	130 800.74	1.96	91		8	$^{3}\mathrm{P}$
$3s^2\,3p(^{2}\mathrm{P}^{\circ})4f\,\mathrm{F}$	$^{2}[5/2]$	3	130 912.84	1.02	76	or	81	$^{1}\mathrm{F}$
		2	130 949.29	0.674	96	or	96	$^{3}\mathrm{F}$
$3s^2\,3p(^{2}\mathrm{P}^{\circ})4f\,\mathrm{F}$	$^{2}[7/2]$	3	130 993.03	1.03	70	or	78	$^{3}\mathrm{F}$
		4	131 024.90	1.22	90	or	90	$^{3}\mathrm{F}$
$3s^2\,3p5p$	$^{1}\mathrm{D}$	2	131 352.39	1.005	97		1	$^{3}\mathrm{D}$
$3s^2\,3p(^{2}\mathrm{P}^{\circ})4f\,\mathrm{G}$	$^{2}[7/2]$	3	131 631.16	0.79	89	or	89	$^{3}\mathrm{G}$
		4	131 688.74	1.06	81	or	77	$^{3}\mathrm{G}$
$3s^2\,3p4d$	$^{1}\mathrm{P}^{\circ}$	1	*131 762.84*	0.999	92		7	$3s3p^3\ ^{1}\mathrm{P}^{\circ}$
$3s^2\,3p(^{2}\mathrm{P}^{\circ})4f\,\mathrm{G}$	$^{2}[9/2]$	5	131 940.29	1.20	100	or	100	$^{3}\mathrm{G}$
		4	132 077.74	1.01	90	or	83	$^{1}\mathrm{G}$
$3s^2\,3p(^{2}\mathrm{P}^{\circ})4f\,\mathrm{D}$	$^{2}[5/2]$	3	132 132.46	1.320	96	or	96	$^{3}\mathrm{D}$
		2	132 163.47	1.063	96	or	54	$^{1}\mathrm{D}$

P II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$3s^2\,3p(^2P^\circ)4f$ D	$^2[3/2]$	1	132 371.74	0.50	100	or	100	^{3}D
		2	132 396.92	1.083	100	or	56	^{3}D
$3s^2\,3p5p$	^{1}S	0	132 901.01		99		1	^{3}P
$3s^2\,3p6s$	$^3P^\circ$	0	*137 757.09*		100			
		1	*137 826.52*	1.42	83		17	$^1P^\circ$
		2	*138 309.09*	1.50	100			
$3s^2\,3p6s$	$^1P^\circ$	1	*138 521.70*	1.08	83		17	$^3P^\circ$
$3s^2\,3p5d$	$^3F^\circ$	2	*138 552.47*	0.69	95		4	$^1D^\circ$
		3	*138 743.41*	1.08	96		3	$^3D^\circ$
		4	*139 039.70*	1.25	100			
$3s^2\,3p5d$	$^1D^\circ$	2	*139 212.72*	1.12	60		21	$^3P^\circ$
$3s^2\,3p5d$	$^3D^\circ$	1	*139 526.35*	0.69	79		19	$^3P^\circ$
		2	*139 622.67*	1.18	40		31	$^1D^\circ$
		3	*139 804.25*	1.33	95		4	$^3F^\circ$
$3s^2\,3p5d$	$^3P^\circ$	2	*139 923.54*	1.34	54		44	$^3D^\circ$
		1	*139 957.96*	1.30	80		19	$^3D^\circ$
		0	*139 971.33*		99			
$3s^2\,3p5d$	$^1F^\circ$	3	*140 950.27*	1.01	98		1	$^3D^\circ$
$3s^2\,3p(^2P^\circ)5f$ F	$^2[5/2]$	3	141 324.52			or		$(^2P^\circ_{1/2})\ ^2[5/2]$
		2	141 335.48					
$3s^2\,3p(^2P^\circ)5f$ F	$^2[7/2]$	3	141 354.16			or		$(^2P^\circ_{1/2})\ ^2[7/2]$
		4	141 370.03					
$3s^2\,3p5d$	$^1P^\circ$	1	*141 487.87*					
$3s^2\,3p(^2P^\circ_{1/2})5g$	$^2[7/2]^\circ$	4	*141 787.55*			or		$(^2P^\circ)\ G^\circ\ ^2[7/2]^\circ$
		3	*141 787.64*					
$3s^2\,3p(^2P^\circ_{1/2})5g$	$^2[9/2]^\circ$	4	*141 795.84*			or		$(^2P^\circ)\ G^\circ\ ^2[9/2]^\circ$
		5	*141 796.18*					
$3s^2\,3p(^2P^\circ)5f$ G	$^2[7/2]$	3	141 813.00			or		$(^2P^\circ_{3/2})\ ^2[7/2]$
		4	141 847.91					
$3s^2\,3p(^2P^\circ)5f$ G	$^2[9/2]$	5	142 007.39			or		$(^2P^\circ_{3/2})\ ^2[9/2]$
		4	142 118.72					
$3s^2\,3p(^2P^\circ)5f$ D	$^2[5/2]$	3	142 090.95			or		$(^2P^\circ_{3/2})\ ^2[5/2]$
		2	142 104.04					
$3s^2\,3p(^2P^\circ)5f$ D	$^2[3/2]$	1	142 276.25			or		$(^2P^\circ_{3/2})\ ^2[3/2]$
		2	142 280.69					
$3s^2\,3p(^2P^\circ_{3/2})5g$	$^2[9/2]^\circ$	4	*142 295.25*			or		$(^2P^\circ)\ H^\circ\ ^2[9/2]^\circ$
		5	*142 295.53*					
$3s^2\,3p(^2P^\circ_{3/2})5g$	$^2[7/2]^\circ$	4	*142 357.60*			or		$(^2P^\circ)\ F^\circ\ ^2[7/2]^\circ$
		3	*142 357.76*					

P II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3s^2\,3p(^2P^\circ_{3/2})5g$	$^2[11/2]^\circ$	6	*142 418.45*		or $(^2P^\circ)\ H^\circ\ ^2[11/2]^\circ$
		5	*142 418.95*		
$3s^2\,3p(^2P^\circ_{3/2})5g$	$^2[5/2]^\circ$	2	*142 472.31*		or $(^2P^\circ)\ F^\circ\ ^2[5/2]^\circ$
		3	*142 472.59*		
$3s^2\,3p(^2P^\circ)6f\ F$	$^2[5/2]$	2	146 881.33		or $(^2P^\circ_{1/2})\ ^2[5/2]$
		3	146 894.38		
$3s^2\,3p(^2P^\circ)6f\ F$	$^2[7/2]$	3	146 911.32		or $(^2P^\circ_{1/2})\ ^2[7/2]$
		4	146 921.76		
$3s^2\,3p(^2P^\circ_{1/2})6g$	$^2[7/2]^\circ$	4	*147 198.21*		or $(^2P^\circ)\ G^\circ\ ^2[7/2]^\circ$
		3	*147 198.33*		
$3s^2\,3p(^2P^\circ_{1/2})6g$	$^2[9/2]^\circ$	4	*147 199.88*		or $(^2P^\circ)\ G^\circ\ ^2[9/2]^\circ$
		5	*147 200.24*		
$3s^2\,3p(^2P^\circ)6f\ G$	$^2[7/2]$	3	147 382.89		or $(^2P^\circ_{3/2})\ ^2[7/2]$
		4	147 388.09		
$3s^2\,3p(^2P^\circ)6f\ G$	$^2[9/2]$	5	147 509.39		or $(^2P^\circ_{3/2})\ ^2[9/2]$
		4	147 589.10		
$3s^2\,3p(^2P^\circ_{3/2})6g$	$^2[9/2]^\circ$	4	*147 717.03*		or $(^2P^\circ)\ H^\circ\ ^2[9/2]^\circ$
		5	*147 717.25*		
$3s^2\,3p(^2P^\circ_{3/2})6g$	$^2[7/2]^\circ$	4	*147 750.51*		or $(^2P^\circ)\ F^\circ\ ^2[7/2]^\circ$
		3	*147 750.66*		
$3s^2\,3p(^2P^\circ_{3/2})6g$	$^2[11/2]^\circ$	6	*147 791.75*		or $(^2P^\circ)\ H^\circ\ ^2[11/2]^\circ$
		5	*147 792.23*		
$3s^2\,3p(^2P^\circ_{3/2})6g$	$^2[5/2]^\circ$	2	*147 823.28*		or $(^2P^\circ)\ F^\circ\ ^2[5/2]^\circ$
		3	*147 823.53*		
$3s^2\,3p(^2P^\circ_{1/2})7g$	$^2[9/2]^\circ$	4	*150 455.45*		or $(^2P^\circ)\ G^\circ\ ^2[9/2]^\circ$
		5	*150 455.71*		
$3s^2\,3p(^2P^\circ_{1/2})7g$	$^2[7/2]^\circ$	4	*150 455.68*		or $(^2P^\circ)\ G^\circ\ ^2[7/2]^\circ$
		3	*150 455.71*		
$3s^2\,3p(^2P^\circ_{3/2})7g$	$^2[9/2]^\circ$	4	*150 985.84*		or $(^2P^\circ)\ H^\circ\ ^2[9/2]^\circ$
		5	*150 985.97*		
$3s^2\,3p(^2P^\circ_{3/2})7g$	$^2[7/2]^\circ$	4	*151 005.90*		or $(^2P^\circ)\ F^\circ\ ^2[7/2]^\circ$
		3	*151 006.00*		
$3s^2\,3p(^2P^\circ_{3/2})7g$	$^2[11/2]^\circ$	6	*151 033.88*		or $(^2P^\circ)\ H^\circ\ ^2[11/2]^\circ$
		5	*151 034.32*		
$3s^2\,3p(^2P^\circ_{3/2})7g$	$^2[5/2]^\circ$	2	*151 053.80*		or $(^2P^\circ)\ F^\circ\ ^2[5/2]^\circ$
		3	*151 054.14*		
$3s^2\,3p(^2P^\circ_{3/2})8g$	$^2[9/2]^\circ$	4	*153 106.05*		or $(^2P^\circ)\ H^\circ\ ^2[9/2]^\circ$
		5	*153 106.15*		
$3s^2\,3p(^2P^\circ_{3/2})8g$	$^2[11/2]^\circ$	6	*153 138.61*		or $(^2P^\circ)\ H^\circ\ ^2[11/2]^\circ$
		5	*153 138.88*		

P II—Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3s3p^2(^4P)3d$	^5P	3	153 266.66		
		2	153 392.85		
		1	153 477.03		
$3s^2 3p(^2P^\circ_{3/2})9g$	$^2[11/2]^\circ$	6	*154 581.71*		or $(^2P^\circ)$ H° $^2[11/2]^\circ$
		5	*154 581.90*		
P III ($^2P^\circ_{1/2}$)	*Limit*		***159 451.5***		
P III ($^2P^\circ_{3/2}$)	*Limit*		*160 010.6*		

P III

$Z = 15$

Al I isoelectronic sequence

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

Ionization energy 243 600.7 ± 0.7 cm^{-1} (30.202 88 ± 0.000 12 eV)

The levels are from Magnusson and Zetterberg, who observed this spectrum from 395 Å to 8315 Å using a sliding-spark source. Their results represent a large extension of the earlier analysis, which was mainly due to Bowen with additions by Robinson. About 640 lines are now classified by the levels of 58 complete terms.

Magnusson and Zetterberg state that "the wavelength errors of undisturbed lines are believed not to exceed 0.01 Å for $\lambda < 4900$ Å and 0.02 Å for $\lambda > 4900$ Å" and estimate that wavelengths recalculated from their levels should be accurate to a few mÅ. The corresponding relative uncertainty of the levels varies from about ±0.03 to ±0.2 cm^{-1} or so for levels connected by lines in the region above 2000 Å; most of the other levels are probably accurate to within errors of less than 1 cm^{-1}, although the $3s^2 7s$, $8s$, and $9s$ levels based solely on lines near the short-wavelength limit could have errors of several cm^{-1}.

Magnusson and Zetterberg derived the ionization energy by fitting a core-polarization formula to the $3s^2nh$ $^2H^\circ$ series. The quoted uncertainty of ±0.7 cm^{-1} probably represents mainly the uncertainty of these terms with respect to the ground term; the uncertainty in eV units arises almost equally from the uncertainty in cm^{-1} and the uncertainty in the conversion factor.

Magnusson and Zetterberg found most of the observed series to be perturbed, the plots of several $3s^2nl$ doublet series indicating interactions with corresponding $3s3pml'$ doublet terms. The largest interactions among the lower configurations are between the $3s3p^2$ and $3s^2 3d$ ^2D terms and between the $3p^3$ and $3s3p(^3P^\circ)3d$ $^2P^\circ$ terms. Except for the $3p^3$ $^2P^\circ$ term, the leading percentages given here are from multiconfiguration Hartree-Fock results obtained by Fischer in calculations of lifetimes in this isoelectronic sequence. The designation of the $^2P^\circ$ term near 170 100 cm^{-1} as belonging mainly to $3p^3$, and also the percentages for this term, are from Aashamar *et al.*; the second percentage, which is the total $3s3p3d$ $^2P^\circ$ percentage, presumably belongs mainly to $3s3p(^3P^\circ)3d$. We give both the term designated $3s3p(^3P^\circ)3d$ $^2P^\circ$ by Aashamar *et al.* and the nominal $3s^2 6p$ $^2P^\circ$ term with questionable configuration assignments because these terms "lie very close, give similar combinations and have practically the same splittings. Thus their configuration assignments are quite arbitrary" [Magnusson and Zetterberg]. The paper by Aashamar *et al.* includes eigenvectors for the nominal $3s3p(^3P^\circ)3d$ $^2P^\circ$ term (strongly configuration-mixed) and for the relatively pure $3s^2 4s$ ^2S and $3s3p^2$ ^2S terms. Additional multiconfigurational calculations of the structures of both parities are needed for a better understanding of this spectrum.

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P III

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2(^1S)3p$	$^2P^\circ$	1/2	*0.00*	94	3	$3p^3$ $^2P^\circ$
		3/2	*559.14*	94	3	
$3s3p^2$	^4P	1/2	56 921.67			
		3/2	57 125.98			
		5/2	57 454.00			
$3s3p^2$	^2D	3/2	74 916.85	75	21	$3s^2(^1S)3d$ ^2D
		5/2	74 945.86	75	21	
$3s3p^2$	^2S	1/2	100 200.44			

P III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s3p^2$	^2P	1/2	109 037.25			
		3/2	109 412.98			
$3s^2(^1S)3d$	^2D	3/2	116 874.56	74	19	$3s3p^2\ ^2D$
		5/2	116 885.87	74	19	
$3s^2(^1S)4s$	^2S	1/2	117 835.95			
$3s^2(^1S)4p$	$^2P^\circ$	1/2	*141 376.91*	94	4	$3p^2(^1S)4p\ ^2P^\circ$
		3/2	*141 513.63*	94	4	
$3s3p(^3P^\circ)3d$	$^2D^\circ$	3/2	*147 323.19*			
		5/2	*147 385.26*			
$3s3p(^3P^\circ)3d$	$^4F^\circ$	3/2	*159 124.77*			
		5/2	*159 238.72*			
		7/2	*159 401.12*			
		9/2	*159 613.67*			
$3p^3$	$^4S^\circ$	3/2	*159 715.35*			
$3p^3$	$^2P^\circ$	3/2	*170 110.47*	59	29	$3s3p3d\ ^2P^\circ$
		1/2	*170 170.65*	59	29	
$3s^2(^1S)4d$	^2D	5/2	172 429.81	94	4	$3p^2(^1S)4d\ ^2D$
		3/2	172 430.49	94	4	
$3s3p(^3P^\circ)3d$	$^4P^\circ$	5/2	*173 813.17*			
		3/2	*173 985.69*			
		1/2	*174 106.20*			
$3s3p(^3P^\circ)3d$	$^4D^\circ$	1/2	*175 259.73*			
		3/2	*175 314.07*			
		5/2	*175 376.40*			
		7/2	*175 425.36*			
$3s^2(^1S)5s$	^2S	1/2	176 042.87			
$3s^2(^1S)4f$	$^2F^\circ$	5/2	*178 655.23*	93	4	$3p^2(^1S)4f\ ^2F^\circ$
		7/2	*178 655.78*	93	4	
$3s3p(^3P^\circ)4s$	$^4P^\circ$	1/2	*184 453.79*			
		3/2	*184 639.75*			
		5/2	*185 045.62*			
$3s^2(^1S)5p$	$^2P^\circ$	1/2	*184 740.77*			
		3/2	*184 858.12*			
$3p^3$	$^2D^\circ$	5/2	*185 074.34*			
		3/2	*185 098.48*			
$3s3p(^3P^\circ)3d$	$^2F^\circ$	5/2	*188 215.25*	97	1	$3p^2(^1S)4f\ ^2F^\circ$
		7/2	*188 677.37*	97	1	
$3s3p(^3P^\circ)4s$	$^2P^\circ$	1/2	*191 281.97*			
		3/2	*191 641.09*			

P III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^2(^1S)5d$	^2D	5/2	199 154.83	
		3/2	199 154.89	
$3s^2(^1S)5f$	$^2F^\circ$	7/2	*200 538.96*	
		5/2	*200 571.27*	
$3s^2(^1S)6s$	^2S	1/2	201 291.73	
$3s^2(^1S)5g$	^2G	7/2	203 784.58	
		9/2	203 784.78	
$3s^2(^1S)6p$?	$^2P^\circ$	3/2	*206 003.36*	
		1/2	*206 020.84*	
$3s3p(^3P^\circ)4p$	^4D	1/2	206 553.77	
		3/2	206 742.62	
		5/2	207 036.54	
		7/2	207 361.92	
$3s3p(^3P^\circ)3d$?	$^2P^\circ$	3/2	*206 613.72*	
		1/2	*206 631.65*	
$3s3p(^3P^\circ)4p$	^2P	1/2	206 950.34	
		3/2	207 053.78	
$3s3p(^3P^\circ)4p$	^4P	1/2	209 939.20	
		3/2	210 055.97	
		5/2	210 306.05	
$3s3p(^1P^\circ)3d$	$^2F^\circ$	7/2	*210 048.82*	
		5/2	*210 111.79*	
$3s3p(^3P^\circ)4p$	^4S	3/2	211 339.88	
$3s^2(^1S)6d$	^2D	3/2	212 662.19	
		5/2	212 802.45	
$3s3p(^3P^\circ)4p$	^2D	3/2	213 996.52	
		5/2	214 217.41	
$3s^2(^1S)6f$	$^2F^\circ$	5/2,7/2	*214 433.5?*	
$3s^2(^1S)7s$	^2S	1/2	214 577.3	
$3s^2(^1S)6g$	^2G	7/2	215 956.10	
		9/2	215 956.23	
$3s^2(^1S)6h$	$^2H^\circ$	9/2,11/2	*216 106.40*	
$3s3p(^3P^\circ)4p$	^2S	1/2	218 892.10	
$3s3p(^1P^\circ)3d$	$^2D^\circ$	3/2	*219 708.71*	
		5/2	*219 847.31*	
$3s3p(^1P^\circ)3d$	$^2P^\circ$	1/2	*220 152.51*	
		3/2	*220 176.76*	
$3s^2(^1S)8s$	^2S	1/2	222 488.0	

P III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s3p(^1\mathrm{P}^\circ)4s$	$^2\mathrm{P}^\circ$	1/2	*222 787.62*	
		3/2	*222 816.15*	
$3s^2(^1\mathrm{S})7g$	$^2\mathrm{G}$	7/2	223 298.65	
		9/2	223 298.75	
$3s^2(^1\mathrm{S})7h$	$^2\mathrm{H}^\circ$	9/2,11/2	*223 402.82*	
$3s^2(^1\mathrm{S})9s$	$^2\mathrm{S}$	1/2	227 527.3	
$3s^2(^1\mathrm{S})8g$	$^2\mathrm{G}$	7/2	228 064.12	
		9/2	228 064.29	
$3s^2(^1\mathrm{S})8h$	$^2\mathrm{H}^\circ$	9/2,11/2	*228 138.98*	
$3s^2(^1\mathrm{S})9h$	$^2\mathrm{H}^\circ$	9/2,11/2	*231 385.67*	
$3s3p(^3\mathrm{P}^\circ)4d$	$^4\mathrm{F}^\circ$	3/2	*238 167.36*	
		5/2	*238 261.53*	
		7/2	*238 426.49*	
		9/2	*238 738.35*	
$3s3p(^3\mathrm{P}^\circ)4d$	$^4\mathrm{D}^\circ$	1/2	*238 688.57*	
		3/2	*238 742.18*	
		5/2	*238 831.48*	
		7/2	*238 960.87*	
$3s3p(^3\mathrm{P}^\circ)4d$	$^4\mathrm{P}^\circ$	5/2	*240 783.37*	
		3/2	*240 980.75*	
		1/2	*241 089.25*	
$3s3p(^3\mathrm{P}^\circ)4d$	$^2\mathrm{D}^\circ$	3/2	*241 282.23*	
		5/2	*241 403.67*	
…………	…………	…………	…………	
P IV ($^1\mathrm{S}_0$)	***Limit***		**243 600.7**	
$3s3p(^3\mathrm{P}^\circ)5s$	$^4\mathrm{P}^\circ$	1/2	*243 634.22*	
		3/2	*243 851.68*	
		5/2	*244 247.44*	
$3s3p(^3\mathrm{P}^\circ)5s$	$^2\mathrm{P}^\circ$	1/2	*248 765.31*	
		3/2	*248 899.98*	
$3s3p(^3\mathrm{P}^\circ)5p$	$^2\mathrm{P}$	1/2	252 487.01	
		3/2	252 700.59	
$3s3p(^3\mathrm{P}^\circ)4f$	$^4\mathrm{F}$	3/2	254 722.26	
		5/2	254 810.62	
		7/2	254 935.83	
		9/2	255 099.21	
P IV $3s3p(^3\mathrm{P}^\circ_0)$	*Limit*		*311 518.7*	
P IV $3s3p(^3\mathrm{P}^\circ_1)$	*Limit*		*311 747.2*	
P IV $3s3p(^3\mathrm{P}^\circ_2)$	*Limit*		*312 215.8*	
P IV $3s3p(^1\mathrm{P}^\circ_1)$	*Limit*		*348 791.1*	

P IV

$Z=15$

Mg I isoelectronic sequence

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

Ionization energy 414 922.8 ± 1.0 cm^{-1} (51.4443 ± 0.0002 eV)

Zetterberg and Magnusson list some 590 classified lines for this spectrum as observed over the range 256–9603 Å using a sliding spark. The levels here are from their large extension of the previous analyses. They state that "the wavelength error of lines not affected by special difficulties is believed not to exceed 0.01 Å for lines below 4500 Å and 0.02 Å for the longer wavelengths." These wavelength errors would correspond to uncertainties of ±1 cm^{-1} or more for all excited terms, except $3s3p\ ^3P^\circ$, with respect to the ground level. Zetterberg and Magnusson obtained the quoted ionization energy by application of a core-polarization formula to the $3snh$, $3sni$, and $3snk$ terms. Since the quoted ionization-energy uncertainty of 1.0 cm^{-1} requires an uncertainty <1.0 cm^{-1} for even these high terms, the actual estimated wavelength errors apparently were considerably less than 0.01 Å over much of the region below 2000 Å. Some of the better determined separations of excited levels should have uncertainties less than 0.1 cm^{-1}.

Zetterberg and Magnusson note several perturbations of particular levels, strong configuration interactions being a feature of this isoelectronic sequence. The leading eigenvector percentages given here for the $3s^2\ ^1S$, $3p^2\ ^1S$, $3s3p\ ^1P^\circ$, and $3p3d\ ^1P^\circ$ levels are from Zare's 1967 paper, and those for the $3p^2\ ^1D$, $3s3d\ ^1D$ and ^3D, and $3s4d\ ^1D$ and ^3D levels are from his 1966 paper. Fischer and Godefroid have made extensive MCHF calculations of transition probabilities for lines involving singlets from configurations of the $3l3l'$ type. The percentages for the $3p3d\ ^1F^\circ$ and $3s4f\ ^1F^\circ$ levels and for the $3d^2\ ^1D$ and $3s7g\ ^1G$ levels are from their 1982a paper, the eigenvector assignments being confirmed by the agreement of calculated and observed oscillator strengths. For convenience we have retained the names of these levels assigned by Zetterberg and Magnusson; the eigenvectors indicate an interchange of the $3s4f$ and $3p3d\ ^1F^\circ$ names as being optimal [Fischer and Godefroid, 1982a, 1982b]. Fischer and Godefroid also suggest the designation $3d^2\ ^1G_4$ for the level at 378 508 cm^{-1}, but the calculated distribution of the $3d^2\ ^1G$ composition is such that this name is not really appropriate for any level. The $3s7g\ ^1G$ name seems at least as appropriate for the level at 378 508 cm^{-1}, the eigenvector having 50% total $3sng$ character. The eigenvectors from complete calculations for this spectrum would no doubt yield strongly mixed compositions for many other levels in the table.

References

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P IV

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2$	^1S	0	0.0	95	4	$3p^2\ ^1S$
$3s3p$	$^3P^\circ$	0	*67 918.03*			
		1	*68 146.48*			
		2	*68 615.17*			
$3s3p$	$^1P^\circ$	1	*105 190.42*	95	4	$3p3d\ ^1P^\circ$
$3p^2$	^1D	2	158 141.82	71	27	$3s3d\ ^1D$
$3p^2$	^3P	0	164 941.44			
		1	165 185.39			
		2	165 654.04			

P IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s3d$	^{3}D	1,2,3	189 398.13	99			
$3p^2$	^{1}S	0	194 591.75	91		4	$3d^2\ ^1$S
$3s3d$	^{1}D	2	219 153.88	69		24	$3p^2\ ^1$D
$3s4s$	^{3}S	1	226 898.14				
$3s4s$	^{1}S	0	233 997.96				
$3s4p$	$^3\mathrm{P}^\circ$	0	*256 553.36*				
		1	*256 611.97*				
		2	*256 760.46*				
$3s4p$	$^1\mathrm{P}^\circ$	1	*257 522.66*				
$3p3d$	$^3\mathrm{F}^\circ$	2	*262 005.27*				
		3	*262 248.46*				
		4	*262 567.20*				
$3p3d$	$^1\mathrm{D}^\circ$	2	*267 015.23*				
$3p3d$	$^3\mathrm{P}^\circ$	2	*281 020.00*				
		1	*281 257.85*				
		0	*281 399.92*				
$3p3d$	$^3\mathrm{D}^\circ$	1	*283 150.04*				
		2	*283 246.87*				
		3	*283 329.08*				
$3s4f$	$^1\mathrm{F}^\circ$	3	*290 327.71*	50	$3snf\ ^1\mathrm{F}^\circ$	50	$3pnd\ ^1\mathrm{F}^\circ$
$3s4d$	^{3}D	1	293 242.94	98		2	$3p4p\ ^3$D
		2	293 247.69	98		2	
		3	293 255.27	98		2	
$3s4d$	^{1}D	2	295 328.63	93		4	$3p4p\ ^1$D
$3s4f$	$^3\mathrm{F}^\circ$	2	*303 660.64*				
		3	*303 665.80*				
		4	*303 672.49*				
$3p3d$	$^1\mathrm{P}^\circ$	1	*307 083.34*	81		9	$3s5p\ ^1\mathrm{P}^\circ$
$3s5s$	^{3}S	1	309 111.44				
$3s5s$	^{1}S	0	311 183.04				
$3p3d$	$^1\mathrm{F}^\circ$	3	*314 423.69*	44	$3pnd\ ^1\mathrm{F}^\circ$	55	$3snf\ ^1\mathrm{F}^\circ$
$3s5p$	$^1\mathrm{P}^\circ$	1	*316 888.09*				
$3p4s$	$^3\mathrm{P}^\circ$	0	*317 675.35*				
		1	*317 957.41*				
		2	*318 362.54*				

P IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
3s5p	$^3P^\circ$	0	*322 387.52*	
		1	*322 438.99*	
		2	*322 541.98*	
3p4s	$^1P^\circ$	1	*327 873.54*	
3s5d	^3D	1	337 245.64	
		2	337 324.91	
		3	337 432.26	
3s5d	^1D	2	338 035.09	
3p4p	^1P	1	340 908.55	
3s5f	$^3F^\circ$	2	*343 603.59*	
		3	*343 603.90*	
		4	*343 604.88*	
3s5g	^3G	3	344 006.44	
		4	344 007.66	
		5	344 011.21	
3s5g	^1G	4	344 011.61	
3p4p	^3D	1	344 540.00	
		2	344 758.07	
		3	345 140.16	
3s5f	$^1F^\circ$	3	*345 655.20*	
3s6s	^3S	1	346 472.11	
3p4p	^3P	0	347 182.92	
		1	347 373.99	
		2	347 704.36	
3s6s	^1S	0	347 602.39	
3p4p	^3S	1	349 196.23	
3p4p	^1D	2	352 389.40	
3s6p	$^3P^\circ$	0	*353 659.02*	
		1	*353 673.27*	
		2	*353 707.50*	
3s6p	$^1P^\circ$	1	*354 234.79*	
3p4p	^1S	0	359 708.14	
3s6d	^3D	1	363 041.47	
		2	363 043.30	
		3	363 050.67	
3s6d	^1D	2	363 751.86	
3s6f	$^3F^\circ$	2	*365 445.49*	
		3	*365 446.09*	
		4	*365 446.95*	

P IV—Continued

Configuration	Term	*J*	Level (cm^{-1})	Leading percentages
3s6g	^{1}G	4	365 569.46	
3s6g	^{3}G	3	365 578.07	
		4	365 582.98	
		5	365 586.13	
3s6h	^{3}H°,^{1}H°	4,5,5,6	*366 026.17*	
3s6f	^{1}F°	3	*366 146.37*	
3s7s	^{3}S	1	367 535.64	
3s7s	^{1}S	0	368 240.73	
3s7p	^{3}P°	0	*371 469.13*	
		1	*371 471.60*	
		2	*371 482.50*	
3s7p	^{1}P°	1	*371 585.76*	
3s7d	^{3}D	1	377 035.1	
		2	377 037.03	
		3	377 049.14	
3s7d	^{1}D	2	377 179.98	
3s7f	^{3}F°	2,3,4	*378 493.37*	
3s7g	^{1}G	4	378 508.15	50 *3sng* ^{1}G 32 *3d*^{2} ^{1}G
3s7g	^{3}G	3	378 523.25	
		4	378 531.99	
		5	378 542.15	
3s7f	^{1}F°	3	*378 548.10*	
3s7h	^{3}H°,^{1}H°	4,5,5,6	*379 000.09*	
3s7i	^{3}I,^{1}I	5,6,6,7	379 060.00	
3s8s	^{3}S	1	379 968.82	
3p4d	^{1}D°	2	*380 145.04*	
3s8s	^{1}S	0	380 315.6	
3d^{2}	^{3}F	2	380 647.21	
		3	380 673.19	
		4	380 712.65	
3p4d	^{3}F°	2	*381 247.18*	
		3	*381 428.02*	
		4	*381 729.38*	
3p4d	^{3}D°	1	*381 614.80*	
		2	*381 809.62*	
		3	*382 012.68*	

P IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s8p$	$^3\mathrm{P}^\circ$	0,1,2	*381 715.1*	
$3s8p$	$^1\mathrm{P}^\circ$	1	*382 450.8*	
$3p4d$	$^3\mathrm{P}^\circ$	2	*385 205.91*	
		1	*385 424.96*	
		0	*385 546.60*	
$3s8d$	$^1\mathrm{D}$	2	385 802.4	
$3p4d$	$^1\mathrm{F}^\circ$	3	*385 980.04*	
$3s8d$	$^3\mathrm{D}$	1,2,3	386 083.5	
$3s8f$	$^3\mathrm{F}^\circ$	2,3,4	*387 268.1*	
$3s8h$	$^3\mathrm{H}^\circ,^1\mathrm{H}^\circ$	4,5,5,6	*387 423.4*	
$3s8i$	$^3\mathrm{I},^1\mathrm{I}$	5,6,6,7	387 465.5	
$3s9s$	$^3\mathrm{S}$	1	388 078.6	
$3s8f$	$^1\mathrm{F}^\circ$	3	*388 124.17*	
$3s9s$	$^1\mathrm{S}$	0	388 287.3	
$3p4d$	$^1\mathrm{P}^\circ$	1	*388 642.07*	
$3d^2$	$^1\mathrm{D}$	2	389 296.50	41 35 $3pnf$ $^1\mathrm{D}$
$3s9p$	$^3\mathrm{P}^\circ$	0,1,2	*389 810.6*	
$3s9p$	$^1\mathrm{P}^\circ$	1	*389 935.0*	
$3s9d$	$^3\mathrm{D}$	1,2,3	392 174.5	
$3s9f$	$^3\mathrm{F}^\circ$	2,3,4	*393 060.8*	
$3s9i$	$^3\mathrm{I},^1\mathrm{I}$	5,6,6,7	393 229.2	
$3s9k$	$^3\mathrm{K}^\circ,^1\mathrm{K}^\circ$	6,7,7,8	*393 239.1*	
$3s9f$	$^1\mathrm{F}^\circ$	3	*393 444.3*	
$3s10s$	$^3\mathrm{S}$	1	393 662.8	
$3s10s$	$^1\mathrm{S}$	0	393 799.0	
$3p(^2\mathrm{P}^\circ_{1/2})4f$	$^2[5/2]$	3,2	395 199.84	
$3p(^2\mathrm{P}^\circ_{1/2})4f$	$^2[7/2]$	4,3	395 253.91	
$3d^2$	$^3\mathrm{P}$	0	396 179.6	
		1	396 180.67	
		2	396 182.92	
$3s10d$	$^3\mathrm{D}$	1,2,3	396 699.6	
$3s10f$	$^3\mathrm{F}^\circ$	2,3,4	*397 221.9*	

P IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s10f$	$^1F^\circ$	3	*397 473.6*	
$3s11d$	^3D	1,2,3	399 871.3	
$3s11f$	$^3F^\circ$	2,3,4	*400 298.2*	
$3s12d$	^3D	1,2,3	402 309.8	
$3s12f$	$^3F^\circ$	2,3,4	*402 639.1*	
P V ($^2S_{1/2}$)	***Limit***		**414 922.8**	
$3p5p$	^1P	1	415 223.56	
P V ($^2P^\circ_{1/2}$)	*Limit*		*503 574.7*	
P V ($^2P^\circ_{3/2}$)	*Limit*		*504 370.0*	

P v

$Z=15$

Na I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s\ ^2\mathrm{S}_{1/2}$

Ionization energy 524 462.9 ± 1.0 cm^{-1} (65.025 64 ± 0.000 21 eV)

Bowen and Millikan [1925] classified the stronger lines of this spectrum to obtain the *ns* ($n=3-5$), *np* ($n=3$, 4), *nf* ($n=4$, 5), *ng* ($n=5$, 6), and 6*h* terms. Robinson [1937] extended the observations to the region below 500 Å and added to the *ns* through *nf* series. The levels here are from Magnusson and Zetterberg [1974], whose measurements gave a total of 126 classified lines over the region 200–7000 Å. They redetermined all previously known levels and added new terms. Magnusson and Zetterberg estimate an error of the order of 0.5 cm^{-1} for most of the excited levels with respect to the ground level. The separations between some of the excited levels based on measurements at longer wavelengths have significantly better accuracy. The three levels in brackets were determined from series formulae.

Magnusson and Zetterberg derived the ionization energy by fitting a core-polarization formula to the *nf*, *ng*, and *nh* terms.

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Robinson, H. A. [1937], Phys. Rev. **51**, 726–735. EL CL IP

P v

Configuration	Term	*J*	Level (cm^{-1})
3*s*	$^2\mathrm{S}$	1/2	0.0
3*p*	$^2\mathrm{P}^\circ$	1/2	*88 651.87*
		3/2	*89 447.25*
3*d*	$^2\mathrm{D}$	3/2	204 198.99
		5/2	204 206.04
4*s*	$^2\mathrm{S}$	1/2	272 959.27
4*p*	$^2\mathrm{P}^\circ$	1/2	*304 160.87*
		3/2	*304 445.28*
4*d*	$^2\mathrm{D}$	3/2	345 395.62
		5/2	345 400.75
4*f*	$^2\mathrm{F}^\circ$	5/2,7/2	*352 594.24*
5*s*	$^2\mathrm{S}$	1/2	376 645.25
5*p*	$^2\mathrm{P}^\circ$	1/2	*391 118.07*
		3/2	*391 251.91*
5*d*	$^2\mathrm{D}$	3/2	410 635.53
		5/2	410 638.67
5*f*	$^2\mathrm{F}^\circ$	5/2,7/2	*414 467.73*
5*g*	$^2\mathrm{G}$	7/2,9/2	414 686.79
6*s*	$^2\mathrm{S}$	1/2	427 185.41
6*p*	$^2\mathrm{P}^\circ$	1/2	*435 048.96*
		3/2	*435 122.44*
6*d*	$^2\mathrm{D}$	3/2,5/2	445 838.8
6*f*	$^2\mathrm{F}^\circ$	5/2,7/2	*448 090.23*
6*g*	$^2\mathrm{G}$	7/2,9/2	448 230.28
6*h*	$^2\mathrm{H}^\circ$	9/2,11/2	*448 250.34*
7*s*	$^2\mathrm{S}$	1/2	455 602.53
7*p*	$^2\mathrm{P}^\circ$	1/2	*460 341.6*
		3/2	*460 386.3*
7*d*	$^2\mathrm{D}$	3/2,5/2	466 936.1
7*f*	$^2\mathrm{F}^\circ$	5/2,7/2	*468 363.51*
7*g*	$^2\mathrm{G}$	7/2,9/2	468 456.20
7*h*	$^2\mathrm{H}^\circ$	9/2,11/2	*468 469.52*
7*i*	$^2\mathrm{I}$	11/2,13/2	468 474.79
8*s*	$^2\mathrm{S}$	1/2	473 161.3
8*p*	$^2\mathrm{P}^\circ$	1/2	*476 234.4*
		3/2	*476 263.9*
8*d*	$^2\mathrm{D}$	3/2,5/2	480 560.1
8*f*	$^2\mathrm{F}^\circ$	5/2,7/2	*481 519.4*
8*g*	$^2\mathrm{G}$	7/2,9/2	481 584.2

P v—Continued

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$9s$	^2S	$\frac{1}{2}$	484 768.2	$11f$	$^2F^\circ$	$\frac{5}{2},\frac{7}{2}$	*501 758.5*
$9p$	$^2P^\circ$	$\frac{1}{2}$ $\frac{3}{2}$	[*486 872.1*] [*486 892.2*]	$12f$	$^2F^\circ$	$\frac{5}{2},\frac{7}{2}$	[*505 386.9*]
$9f$	$^2F^\circ$	$\frac{5}{2},\frac{7}{2}$	*490 537.6*	P VI ($2p^6\ ^1S_0$)	***Limit***		**524 462.9**
$9g$	^2G	$\frac{7}{2},\frac{9}{2}$	490 584.7				
$10f$	$^2F^\circ$	$\frac{5}{2},\frac{7}{2}$	*496 987.0*				

P VI

$Z=15$

Ne I isoelectronic sequence

Ground state $1s^22s^22p^6\ {}^1S_0$

Ionization energy 1 777 820 ± 100 cm^{-1} (220.423 ± 0.012 eV)

Robinson observed and classified the resonance lines of this spectrum in the region 58–92 Å, thus locating $2p^5ns$ and $2p^5nd$ levels having $J=1$. His analysis was extended by Eidelsberg and Artru, who measured and classified 76 lines at longer wavelengths (436–1345 Å) as belonging to the arrays $2p^53s-2p^53p$, $2p^53p-2p^53d$, and $2p^53d-2p^54f$. The relative values of the $2p^53s$, $3p$, $3d$, and $4f$ levels are from Eidelsberg and Artru. We adjusted the position of these levels with respect to the ground level by combining Robinson's values for the $2p^53s$ and $2p^53d$ levels ($J=1$) with the accurate separations of these upper levels from Eidelsberg and Artru. The uncertainty of this connection to the ground level is probably of the order of 100 cm^{-1}, and some of Robinson's higher $2p^5ns$ and $2p^5nd$ levels ($n \geqslant 4$) may have errors of several hundred cm^{-1}. Eidelsberg and Artru state that the $2p^53s$, $3p$, and $3d$ levels (given to the nearest 0.1 cm^{-1}) "have an internal consistency better than 1 cm^{-1}," and they estimate the corresponding uncertainty of the $2p^54f$ levels to be about ±3 cm^{-1}.

The leading percentages are from Eidelsberg and Artru. We have listed J_1l-coupling designations for the $2p^5ns$ and nd levels ($n \geqslant 4$), in accordance with neighboring spectra of this isoelectronic sequence; the LS names are also given (last column, after the word "or") so that these higher members of the five $2p^5ns$ and nd series ($J=1$) can be correlated with the $n=3$ members. The reversal of Robinson's $2p^53d\ {}^1P_1^\circ$ and ${}^3D_1^\circ$ identifications by Eidelsberg and Artru has been extended to the higher members of these two $2p^5nd$ series, in accordance with the isoelectronic data and theoretical expectations. Several lines observed by Fawcett *et al.* in the region below 100 Å were classified as P VI resonance transitions predicted by Robinson's levels; two of the three $2p^6\ {}^1S_0-2p^54d$ ($J=1$) lines are apparently blends, the relative intensities deviating markedly from theoretical and isoelectronic predictions.

Odabasi derived the quoted ionization energy from a semi-empirical isoelectronic extrapolation formula. Our estimate of ±100 cm^{-1} for the uncertainty is based on the accuracy of the formula in reproducing the isoelectronic data through Si V and on the agreement (within about 30 cm^{-1}) of Odabasi's value with the value from a similar formula of Edlén after the latter is adjusted to the currently available ionization energies for Al IV and Si V.

The ionization energy derived by Robinson from $2p^5ns$ and nd series ($J=1$) is 430 cm^{-1} above Odabasi's value. Robinson's higher levels are consistent with the new limit, to within their uncertainties, except for the $({}^2P^\circ_{3/2})5d\ {}^2[\frac{1}{2}]^\circ_1$ and $({}^2P^\circ_{3/2})9d\ {}^2[\frac{3}{2}]^\circ_1$ levels, the latter having been given as questionable by Robinson. We have omitted these two levels here and have also not included the $({}^2P^\circ_{3/2})7d\ {}^2[\frac{3}{2}]^\circ_1$ level, for which Robinson gave a calculated value. The behavior of the two $2p^5ns$ ($J=1$) series is more regular with the new limit than with the original higher value.

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P VI

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^6$	^{1}S	0	0	
$2p^5 3s$	^{3}P°	2	*1 089 844.6*	
		1	*1 093 290.0*	
		0	*1 097 062.1*	
$2p^5 3s$	^{1}P°	1	*1 103 116.1*	
$2p^5 3p$	^{3}S	1	1 171 426.2	
$2p^5 3p$	^{3}D	3	1 185 452.0	
		2	1 186 645.4	
		1	1 189 314.2	
$2p^5 3p$	^{1}D	2	1 193 303.4	
$2p^5 3p$	^{1}P	1	1 195 616.4	
$2p^5 3p$	^{3}P	2	1 197 853.4	
		0	1 197 983.4	
		1	1 198 998.6	
$2p^5 3p$	^{1}S	0	1 242 588.5	
$2p^5 3d$	^{3}P°	0	*1 305 796.3*	
		1	*1 306 655.8*	
		2	*1 308 493.3*	
$2p^5 3d$	^{3}F°	4	*1 310 890.6*	
		3	*1 312 297.8*	
		2	*1 314 860*	
$2p^5 3d$	^{1}F°	3	*1 316 804.4*	
$2p^5 3d$	^{1}D°	2	*1 321 901.4*	
$2p^5 3d$	^{3}D°	1	*1 322 016.9*	
		3	*1 322 750.5*	
		2	*1 323 378.4*	
$2p^5 3d$	^{1}P°	1	*1 334 166.4*	
$2p^5(^2\mathrm{P}^\circ_{3/2})4s$	$^2[3/2]^\circ$	2		or ^{3}P°
		1	*1 439 840*	or ^{3}P°
$2p^5(^2\mathrm{P}^\circ_{1/2})4s$	$^2[1/2]^\circ$	0		or ^{3}P°
		1	*1 446 740*	or ^{1}P°
$2p^5(^2\mathrm{P}^\circ_{3/2})4d$	$^2[1/2]^\circ$	0		or ^{3}P°
		1	*1 516 530*	or ^{3}P°
$2p^5(^2\mathrm{P}^\circ_{3/2})4d$	$^2[3/2]^\circ$	2		
		1	*1 523 460*	or ^{3}D°
$2p^5(^2\mathrm{P}^\circ_{3/2})4f$	$^2[3/2]$	1	1 529 334	
		2	1 529 450	
$2p^5(^2\mathrm{P}^\circ_{3/2})4f$	$^2[9/2]$	5	1 529 982	
		4	1 529 999	

P vi—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{3/2})4f$	$^2[5/2]$	3	1 530 271	
		2	1 530 389	
$2p^5(^2P^\circ_{3/2})4f$	$^2[7/2]$	3	1 530 877	
		4	1 530 893	
$2p^5(^2P^\circ_{1/2})4d$	$^2[3/2]^\circ$	2		
		1	*1 531 210*	or ^{1}P°
$2p^5(^2P^\circ_{1/2})4f$	$^2[5/2]$	3	1 537 573	
		2	1 537 657	
$2p^5(^2P^\circ_{1/2})4f$	$^2[7/2]$	3	1 537 607	
		4	1 537 631	
$2p^5(^2P^\circ_{3/2})5s$	$^2[3/2]^\circ$	1	*1 576 040*	or ^{3}P°
$2p^5(^2P^\circ_{1/2})5s$	$^2[1/2]^\circ$	1	*1 582 860*	or ^{1}P°
$2p^5(^2P^\circ_{3/2})5d$	$^2[3/2]^\circ$	1	*1 616 320*	or ^{3}D°
$2p^5(^2P^\circ_{1/2})5d$	$^2[3/2]^\circ$	1	*1 622 800*	or ^{1}P°
$2p^5(^2P^\circ_{1/2})6s$	$^2[1/2]^\circ$	1	*1 650 930*	or ^{1}P°
$2p^5(^2P^\circ_{3/2})6d$	$^2[3/2]^\circ$	1	*1 666 220*	or ^{3}D°
$2p^5(^2P^\circ_{1/2})6d$	$^2[3/2]^\circ$	1	*1 672 940*	or ^{1}P°
$2p^5(^2P^\circ_{1/2})7d$	$^2[3/2]^\circ$	1	*1 702 790*	or ^{1}P°
$2p^5(^2P^\circ_{3/2})8d$	$^2[3/2]^\circ$	1	*1 715 440*	or ^{3}D°
P vii ($^2P^\circ_{3/2}$)	***Limit***		*1 777 820*	
P vii ($^2P^\circ_{1/2}$)	***Limit***		*1 785 090*	

P VII

$Z=15$

F I isoelectronic sequence

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

Ionization energy 2 125 800 ± 500 cm^{-1} (263.57 ± 0.06 eV)

Robinson's analysis of this spectrum gave classified lines in the 49–81 Å region and also included the $2s^22p^5\ {}^2\mathrm{P}^\circ-2s2p^6\ {}^2\mathrm{S}$ resonance doublet near 220 Å. We have taken the $2s2p^6\ {}^2\mathrm{S}_{1/2}$ level from more recent measurements of this doublet by Eidelsberg and Artru. Edlén's [1983] treatment of the isoelectronic data indicates that both this level and the $2s^22p^5\ {}^2\mathrm{P}^\circ$ ground-term interval adopted here are accurate to within a few cm^{-1}; for comparison, available values for the ${}^2\mathrm{P}^\circ$ interval are 7268 cm^{-1} [Robinson], 7275 ± 2 cm^{-1} [Eidelsberg and Artru], 7273 cm^{-1} [Curtis and Ramanujam], 7272 cm^{-1} [Edlén, 1983], and 7269 ± 5 cm^{-1} [Kim and Huang].

The eigenvector percentages are from Fawcett's calculations for this isoelectronic sequence. The interactions between the $2s^22p^5$, $2s^22p^43p$, $2s2p^53s$, and $2s2p^53d$ configurations were included in the matrices for the odd-parity configurations, and the interactions between $2s2p^6$, $2s^22p^43s$, $2s^22p^43d$, $2s2p^53p$, and $2s^22p^44s$ were included in the calculations for the even-parity configurations.

Robinson derived the $2s^22p^4ns$ and nd levels by classifying their transitions to the $2s^22p^5\ {}^2\mathrm{P}^\circ$ levels. Some of the higher levels may have errors of several hundred cm^{-1}. Robinson's tentative $2p^4({}^3\mathrm{P})3s\ {}^4\mathrm{P}_{1/2}$ level has been omitted as being inconsistent with the isoelectronic data. The positions of the $2p^43d$ levels are in satisfactory agreement with the isoelectronic data and calculations, but more recent work along the sequence has given changed term designations for six of these levels [Feldman *et al.*; Artru and Kaufman; Artru and Brillet, 1974, 1977; Fawcett, 1984]. The $2p^4({}^1\mathrm{D})3d\ {}^2\mathrm{F}_{5/2}$ and ${}^2\mathrm{D}_{5/2}$ levels are given as tentative, each being based on a single line also classified by another transition.

Robinson gave the $2p^4({}^1\mathrm{D})3s\ {}^2\mathrm{D}$ term with $J=\frac{5}{2}$ (only), but Fawcett *et al.* observed the $2p^5\ {}^2\mathrm{P}^\circ_{1/2}-2p^4({}^1\mathrm{D})3s\ {}^2\mathrm{D}_{3/2}$ line predicted by almost coincident positions for the $({}^1\mathrm{D})\ {}^2\mathrm{D}_{5/2}$ and ${}^2\mathrm{D}_{3/2}$ levels.

We derived the ionization energy from an isoelectronic formula of the type used by Edlén [1971], fitted to the data through Al V. A simpler semi-empirical formula for corrections to theoretically calculated ionization energies gives a value for P VII 200 cm^{-1} greater than the above adopted value. Robinson's value for the ionization energy is 1500 cm^{-1} below our value, but the P VIII $2p^4({}^1\mathrm{D})$ and $({}^1\mathrm{S})$ limits determined from our $2p^4({}^3\mathrm{P}_2)$ limit are consistent with the observed $2p^4({}^1\mathrm{D})ns\ {}^2\mathrm{D}$ and $2p^4({}^1\mathrm{S})nd\ {}^2\mathrm{D}$ series ($n=3, 4, 5$). The highest term of the only other series having three observed members, $2p^4({}^3\mathrm{P})5s\ {}^2\mathrm{P}_{3/2}$, appears doubtful.

The changes of the original $2p^43d$ term designations and the mixed character of some of these levels indicate that Robinson's $2p^4({}^3\mathrm{P})4d$ and $({}^1\mathrm{D})4d$ term designations are dubious or, in some cases, almost certainly incorrect. We have listed most of these levels without term names and as having either of the possible J values $\frac{3}{2}$ or $\frac{1}{2}$. New names are suggested tentatively for two $2p^4({}^1\mathrm{D})4d$ levels on the basis of their (ground-term) combinations and series regularities. We have omitted the levels previously given as $2p^4({}^3\mathrm{P})4d\ {}^2\mathrm{D}_{5/2}$ and $({}^1\mathrm{D})4d\ {}^2\mathrm{P}_{1/2}$, each having been based on a single line classification now unsupported by the series data.

Robinson located the $2s2p^5({}^3\mathrm{P}^\circ)3s\ {}^2\mathrm{P}^\circ$ levels by classifying their transitions to the $2s2p^6\ {}^2\mathrm{S}_{1/2}$ level. Five possible $2s2p^5({}^3\mathrm{P}^\circ)3d$ levels derived from similar but tentative classifications of transitions to the $2s2p^6\ {}^2\mathrm{S}_{1/2}$ level have been omitted.

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P VII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^5$	$^2P^\circ$	3/2	*0*	100		
		1/2	*7 273*	100		
$2s2p^6$	^2S	1/2	454 725	99		
$2s^2 2p^4(^3P)3s$	^4P	5/2	1 259 730	99		
		3/2	1 264 170	97	2	$(^3P)\ ^2P$
		1/2		99		
$2s^2 2p^4(^3P)3s$	^2P	3/2	1 277 380	97	2	$(^3P)\ ^4P$
		1/2	1 282 550	99		
$2s^2 2p^4(^1D)3s$	^2D	5/2 }	1 317 110	99		
		3/2 }		99	1	$(^3P)\ ^2P$
$2s^2 2p^4(^1S)3s$	^2S	1/2	1 375 810	98	1	$2s^2 2p^4(^1D)3d\ ^2S$
$2s^2 2p^4(^3P)3d$	^4F	9/2		99	1	$(^1D)\ ^2G$
		7/2		82	16	$(^3P)\ ^2F$
		5/2	1 496 890	91	5	$(^3P)\ ^2F$
		3/2	1 498 400	96	2	$(^3P)\ ^4P$
$2s^2 2p^4(^3P)3d$	^4P	1/2		98	1	$(^3P)\ ^4D$
		3/2	1 500 040	95	2	$(^3P)\ ^4D$
		5/2	1 502 040	77	12	$(^3P)\ ^2F$
$2s^2 2p^4(^3P)3d$	^2P	1/2	1 505 300	83	15	$(^1D)\ ^2P$
		3/2	1 511 310	63	23	$(^3P)\ ^2D$
$2s^2 2p^4(^3P)3d$	^2D	3/2	1 506 730	62	24	$(^3P)\ ^2P$
		5/2	1 510 050	82	7	$(^3P)\ ^2F$
$2s^2 2p^4(^1D)3d$	^2S	1/2	1 548 480	96	2	$(^1D)\ ^2P$
$2s^2 2p^4(^1D)3d$	^2F	5/2	1 552 120?	90	9	$(^1D)\ ^2D$
		7/2		99	1	$(^3P)\ ^2F$
$2s^2 2p^4(^1D)3d$	^2P	3/2	1 552 170	87	12	$(^3P)\ ^2P$
		1/2	1 554 420	82	15	
$2s^2 2p^4(^1D)3d$	^2D	5/2	1 553 740?	82	9	$(^1D)\ ^2F$
		3/2	1 555 560	88	11	$(^3P)\ ^2D$
$2s^2 2p^4(^1S)3d$	^2D	5/2	1 606 550	98	1	$(^1D)\ ^2D$
		3/2	1 606 880	97	1	
$2s2p^5(^3P^\circ)3s$	$^2P^\circ$	3/2	*1 692 150*	98	1	$(^3P^\circ)\ ^4P^\circ$
		1/2	*1 696 850*	99	1	$2s^2 2p^4(^1D)3p\ ^2P^\circ$
$2s^2 2p^4(^3P)4s$	^2P	3/2	1 695 720	69	30	$(^3P)\ ^4P$
		1/2	1 701 380	95	4	
$2s^2 2p^4(^1D)4s$	^2D	5/2 }	1 741 710	99	1	$(^3P)\ ^4P$
		3/2 }		99	1	$(^3P)\ ^2P$
$2s^2 2p^4(^3P)4d$		1/2,3/2	1 778 690			
$2s^2 2p^4(^3P)4d$		1/2,3/2	1 780 190			

P VII—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^4(^3P)4d$		1/2,3/2	1 782 260	
$2s^2 2p^4(^3P)4d$		1/2,3/2	1 784 030	
$2s^2 2p^4(^1S)4s$	^2S	1/2	1 801 570	
$2s^2 2p^4(^1D)4d$	^2S?	1/2?	1 827 890	
$2s^2 2p^4(^1D)4d$	^2P?	3/2?	1 828 630	
$2s^2 2p^4(^1D)4d$		1/2,3/2	1 830 190	
$2s^2 2p^4(^3P)5s$	^2P	3/2	1 865 680?	
$2s^2 2p^4(^1S)4d$	^2D	5/2,3/2	1 885 000	
$2s^2 2p^4(^1D)5s$	^2D	5/2,3/2	1 913 620	
$2s^2 2p^4(^1S)5d$	^2D	5/2,3/2	2 013 690	
…………	…………	…………	…………	
P VIII ($^3P_2$)	*Limit*		2 125 800	
P VIII ($^3P_1$)	*Limit*		2 131 600	
P VIII ($^3P_0$)	*Limit*		2 133 600	
P VIII ($^1D_2$)	*Limit*		2 178 100	
P VIII ($^1S_0$)	*Limit*		2 236 600	

P VIII

$Z=15$

O I isoelectronic sequence

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

Ionization energy $2\,497\,100 \pm 800\ \mathrm{cm^{-1}}$ $(309.60 \pm 0.10\ \mathrm{eV})$

In his 1937 paper, Robinson described briefly the observations from which his analyses of the higher spectra of phosphorus were derived. The energy levels for most of these spectra were, however, published only in Moore's *Atomic Energy Levels* [1949] from material supplied by Robinson. We took Robinson's P VIII levels from Moore's compilation as the starting point for the present compilation. The wavelength range implied by the levels extends from 45 to 251 Å, with an additional line at 261 Å having been classified as the $2s2p^5\ {}^1P^\circ_1 - 2p^6\ {}^1S_0$ transition [Kasyanov *et al.*]. Kasyanov *et al.* also remeasured the lines of the basic $2s^22p^4 - 2s2p^5$ transition array (196–251 Å). Fawcett *et al.* list the stronger P VIII lines (55–251 Å) as observed in laser-produced plasmas, the classifications and wavelengths having been derived from Robinson's levels.

We have evaluated the $2s^22p^4$ and $2s2p^5$ levels using averages obtained from Robinson's data and from the wavelengths given by Kasyanov *et al.* Edlén [1983] derived the value given for the $2s^22p^4\ {}^1D_2$ level from an isoelectronic interpolation that would appear to be accurate to within a few $\mathrm{cm^{-1}}$; the singlet-triplet connection is based on this level, no intercombinations having been identified in P VIII. Most of the $2s^22p^4$ and $2s2p^5$ levels are probably accurate to $\pm 25\ \mathrm{cm^{-1}}$. The largest discrepancy between these values and values Edlén derived using isoelectronic data-smoothing is $35\ \mathrm{cm^{-1}}$, for the $2s2p^5\ {}^3P^\circ_0$ level; Edlén's value for the $2p^6\ {}^1S_0$ level is $65\ \mathrm{cm^{-1}}$ below the value here. The $2s^22p^3ns$ and nd levels ($n \geqslant 3$), all based on lines classified as transitions to the $2s^22p^4$ levels in the region below 70 Å, are uncertain by several hundred $\mathrm{cm^{-1}}$. The values of all the singlet levels have been adjusted as noted above.

The analysis of this type of spectrum routinely involves the derivation of some levels from single combinations, supported by isoelectronic and/or series regularities. Several levels lacking isoelectronic support are here given as tentative; the $2s^22p^3(^2P^\circ)3d\ {}^3F^\circ$ levels, for example, were not found in Si VII, and in P VIII these levels were derived from lines classified as forbidden transitions.

The ionization energy given here is an average of two values: we derived a value of $2\,496\,700\ \mathrm{cm^{-1}}$ by adjusting an isoelectronic formula of the Edlén type [1971] to the recent data, including Mg V; and we obtained a value of $2\,497\,500\ \mathrm{cm^{-1}}$ from an isoelectronically adjusted theoretical (Dirac-Fock) calculation. Our value agrees almost exactly with the limit obtained by fitting the $2s^22p^3(^4S^\circ)nd\ {}^3D^\circ_3$ series ($n=3, 4, 5$) to a linear Ritz (quantum-defect) formula. The highest member of Robinson's other three-member series, $2s^22p^3(^2D^\circ)5s\ {}^1D^\circ_2$, is given here as questionable because of the irregular series behavior with our value for the $(^2D^\circ_{5/2})$ limit.

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P VIII

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^4$	^3P	2	0
		1	5 760
		0	7 822
$2s^2 2p^4$	^1D	2	52 256
$2s^2 2p^4$	^1S	0	110 786
$2s2p^5$	$^3P^\circ$	2	*403 803*
		1	*408 906*
		0	*411 736*
$2s2p^5$	$^1P^\circ$	1	*560 501*
$2p^6$	^1S	0	943 569
$2s^2 2p^3(^4S^\circ)3s$	$^3S^\circ$	1	*1 462 340*
$2s^2 2p^3(^2D^\circ)3s$	$^3D^\circ$	1,2	*1 519 740*
		3	*1 520 030*
$2s^2 2p^3(^2D^\circ)3s$	$^1D^\circ$	2	*1 531 830*
$2s^2 2p^3(^2P^\circ)3s$	$^3P^\circ$	0	*1 559 500*
		1	*1 560 070*
		2	*1 561 260*
$2s^2 2p^3(^2P^\circ)3s$	$^1P^\circ$	1	*1 573 080?*
$2s^2 2p^3(^4S^\circ)3d$	$^3D^\circ$	1,2	*1 685 980*
		3	*1 686 280*
$2s^2 2p^3(^2D^\circ)3d$	$^3F^\circ$	4,3,2	*1 749 870?*
$2s^2 2p^3(^2D^\circ)3d$	$^3D^\circ$	3,2,1	*1 753 090*
$2s^2 2p^3(^2D^\circ)3d$	$^1P^\circ$	1	*1 753 640*
$2s^2 2p^3(^2D^\circ)3d$	$^3P^\circ$	2	*1 760 530*
		1	*1 762 400*
		0	
$2s^2 2p^3(^2D^\circ)3d$	$^1D^\circ$	2	*1 761 490*
$2s^2 2p^3(^2D^\circ)3d$	$^3S^\circ$	1	*1 767 880*
$2s^2 2p^3(^2D^\circ)3d$	$^1F^\circ$	3	*1 775 860*
$2s^2 2p^3(^2P^\circ)3d$	$^3P^\circ$	0	*1 787 090*
		1	*1 788 090*
		2	*1 789 690*
$2s^2 2p^3(^2P^\circ)3d$.	$^3F^\circ$	4	
		3	*1 790 480?*
		2	*1 795 030?*
$2s^2 2p^3(^2P^\circ)3d$	$^1D^\circ$	2	*1 795 240?*
$2s^2 2p^3(^2P^\circ)3d$	$^3D^\circ$	3	*1 796 240*
		2	*1 800 770*
		1	
$2s^2 2p^3(^2P^\circ)3d$	$^1P^\circ$	1	*1 800 570*
$2s^2 2p^3(^2P^\circ)3d$	$^1F^\circ$	3	*1 804 740*
$2s^2 2p^3(^4S^\circ)4s$	$^3S^\circ$	1	*1 958 370*
$2s^2 2p^3(^2D^\circ)4s$	$^3D^\circ$	3	*2 029 470*
$2s^2 2p^3(^2D^\circ)4s$	$^1D^\circ$	2	*2 033 130*
$2s^2 2p^3(^4S^\circ)4d$	$^3D^\circ$	3	*2 046 710*
$2s^2 2p^3(^2P^\circ)4s$	$^1P^\circ$	1	*2 073 570*
$2s^2 2p^3(^2D^\circ)4d$	$^3D^\circ$	3,2,1	*2 115 510*
$2s^2 2p^3(^2D^\circ)4d$	$^3P^\circ$	2	*2 119 360*
$2s^2 2p^3(^2D^\circ)4d$	$^3S^\circ$	1	*2 122 020*
$2s^2 2p^3(^2D^\circ)4d$	$^1F^\circ$	3	*2 123 380*
$2s^2 2p^3(^4S^\circ)5d$	$^3D^\circ$	3	*2 210 630*
$2s^2 2p^3(^2D^\circ)5s$	$^1D^\circ$	2	*2 240 730?*
P IX ($^4S^\circ_{3/2}$)	*Limit*		**2 497 100**
P IX ($^2D^\circ_{3/2}$)	*Limit*		*2 573 000*
P IX ($^2D^\circ_{5/2}$)	*Limit*		*2 573 600*
P IX ($^2P^\circ_{1/2}$)	*Limit*		*2 613 200*
P IX ($^2P^\circ_{3/2}$)	*Limit*		*2 614 200*

P IX

$Z=15$

N I isoelectronic sequence

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

Ionization energy 3 001 400 ± 1500 cm^{-1} (372.13 ± 0.19 eV)

Robinson first observed and analyzed this spectrum, his unpublished results including classified lines in the 194–315 Å and 40–70 Å regions. The connection between the quartet and doublet term systems here is based on Edlén's [1984] interpolated values for the $2s^22p^3\ ^2\mathrm{D}^\circ$ levels, the isoelectronic data showing Robinson's original intersystem connection to be in error by about 2700 cm^{-1}. We have tentatively reclassified a number of Robinson's lines in the 49–62 Å region using the new connection. Since the energy-level classifications and wavelengths for the P IX lines given by Fawcett *et al.* were obtained from Robinson's levels, the intercombination (quartet-doublet) classifications in their list are incorrect.

The isoelectronic comparisons indicate that Edlén's $2s^22p^3\ ^2\mathrm{D}^\circ$ levels are accurate to within a few cm^{-1}, and his value for the $2s^22p^3\ ^4\mathrm{S}^\circ_{3/2}-{}^2\mathrm{D}^\circ_{3/2}$ separation may have been confirmed to within about 3 cm^{-1} by the classification of a solar coronal line [Sandlin and Tousey]. Kasyanov *et al.* observed phosphorus spectra excited in laser-generated plasmas, remeasured the P IX spectrum in the 194–311 Å region, and correctly located the $2s2p^4\ ^2\mathrm{D}_{3/2}$, $2s2p^4\ ^2\mathrm{S}$, and $2p^5\ ^2\mathrm{P}^\circ$ levels. We evaluated the $2s^22p^3\ ^2\mathrm{P}^\circ$, $2s2p^4$, and $2p^5$ levels using their wavelengths or averages of their values and Robinson's where appropriate. Most of these levels are probably accurate within errors of ±20 to ±40 cm^{-1}. The $2p^5\ ^2\mathrm{P}^\circ_{1/2}$ level deviates most from the isoelectronically smoothed level values obtained by Edlén [1984], the value here being 54 cm^{-1} above Edlén's value.

We have also reevaluated all the higher levels, i.e., levels of the configurations of the types $2s^22p^2nl$ and $2s2p^3nl\ (n\geqslant 3)$. A number of previous levels obtained with the erroneous system connection and/or based on single faint lines have been omitted. Observation and analysis of the $2s^22p^23s-3p$ and $3p-3d$ transition arrays are needed to confirm and extend the upper-level system. Several of the more clearly questionable levels have been so designated. Some of the higher levels have uncertainties of several hundred cm^{-1}.

Edlén's [1971] isoelectronic extrapolation formula gives a value of 3 000 660 cm^{-1} for the P IX ionization energy. We obtained a value of 3 002 060 cm^{-1} for this quantity by semi-empirical correction of a theoretically calculated value. Our adopted value is the average of these values (rounded to the nearest 100 cm^{-1}), the error being estimated as about equal to the difference of the two values.

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P IX

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^3$	$^4\mathrm{S}^\circ$	$3/2$	*0*
$2s^2 2p^3$	$^2\mathrm{D}^\circ$	$3/2$	*75 896*
		$5/2$	*76 481*
$2s^2 2p^3$	$^2\mathrm{P}^\circ$	$1/2$	*116 109*
		$3/2$	*117 149*
$2s2p^4$	$^4\mathrm{P}$	$5/2$	345 412
		$3/2$	350 429
		$1/2$	353 042
$2s2p^4$	$^2\mathrm{D}$	$3/2$	475 299
		$5/2$	475 323
$2s2p^4$	$^2\mathrm{S}$	$1/2$	556 480
$2s2p^4$	$^2\mathrm{P}$	$3/2$	583 420
		$1/2$	589 684
$2p^5$	$^2\mathrm{P}^\circ$	$3/2$	*905 284*
		$1/2$	*913 434*
$2s^2 2p^2(^3\mathrm{P})3s$	$^4\mathrm{P}$	$1/2$	1 743 770?
		$3/2$	1 746 840
		$5/2$	1 751 930
$2s^2 2p^2(^3\mathrm{P})3s$	$^2\mathrm{P}$	$1/2$	1 767 900
		$3/2$	1 771 700
$2s^2 2p^2(^1\mathrm{D})3s$	$^2\mathrm{D}$	$3/2$	1 808 500
		$5/2$	1 809 900
$2s^2 2p^2(^3\mathrm{P})3d$	$^2\mathrm{P}$	$1/2$	
		$3/2$?	1 965 700
$2s2p^3(^5\mathrm{S}^\circ)3s$	$^4\mathrm{S}^\circ$	$3/2$	*1 966 000?*
$2s^2 2p^2(^3\mathrm{P})3d$	$^2\mathrm{F}$	$5/2$	1 973 100
		$7/2$	1 979 400
$2s^2 2p^2(^3\mathrm{P})3d$	$^4\mathrm{P}$	$1/2,3/2$	1 980 900
$2s^2 2p^2(^3\mathrm{P})3d$	$^2\mathrm{D}$	$3/2$	2 002 400
		$5/2$	2 004 600
$2s^2 2p^2(^1\mathrm{D})3d$	$^2\mathrm{D}$	$3/2$	
		$5/2$	2 034 500
$2s^2 2p^2(^1\mathrm{D})3d$	$^2\mathrm{P}$	$1/2$	2 041 300?
		$3/2$	2 045 100?
$2s2p^3(^5\mathrm{S}^\circ)3p$	$^4\mathrm{P}$	$1/2$–$5/2$	2 044 000
$2s2p^3(^5\mathrm{S}^\circ)3d$	$^4\mathrm{D}^\circ$	$1/2$–$7/2$	*2 161 200*
$2s^2 2p^2(^3\mathrm{P})4s$	$^4\mathrm{P}$	$1/2$	
		$3/2$	
		$5/2$	2 354 100?
$2s^2 2p^2(^3\mathrm{P})4s$	$^2\mathrm{P}$	$1/2$	
		$3/2$	2 362 300
....	....	....	....
P X ($^3\mathrm{P}_0$)	*Limit*		**3 001 400**

P X

$Z = 15$

C I isoelectronic sequence

Ground state $1s^22s^22p^2\ {}^3\mathrm{P}_0$

Ionization energy 3 423 200 ± 2000 cm^{-1} (424.43 ± 0.25 eV)

Kasyanov *et al.* have made the most complete observations of the $2s^22p^2-2s2p^3$ and $2s2p^3-2p^4$ lines of this spectrum (203−318 Å). We have mainly used their measurements in evaluating the levels of these configurations, but some of the levels are also based partly on values obtained by Edlén [1985] from an isoelectronic method. The $2p^4\ {}^1\mathrm{D}_2$ level was derived from Fawcett's [1975] wavelength for the $2s2p^3\ {}^1\mathrm{D}^\circ_2-2p^4\ {}^1\mathrm{D}_2$ line. Edlén's [1985] value for the $2s^22p^2\ {}^3\mathrm{P}_1-{}^1\mathrm{D}_2$ separation, used here to fix the triplet-singlet system connection, should be accurate to within a few cm^{-1}, and most of the $2s^22p^2$, $2s2p^3$, and $2p^4$ levels are probably accurate to ±20 to ±50 cm^{-1}. We evaluated the $2p^4\ {}^3\mathrm{P}_0$ level using Edlén's value for the $2p^4\ {}^3\mathrm{P}_0-{}^3\mathrm{P}_1$ interval; the observed wavelength of the line classified by Kasyanov *et al.* as $2s2p^3\ {}^3\mathrm{D}^\circ_1-2p^4\ {}^3\mathrm{P}_0$ (233.51 Å) differs unacceptably from Edlén's predicted wavelength of 233.656 Å.

No lines connecting the quintet levels with the triplet and singlet term systems have been classified. The position of the quintet system here is based on Edlén's [1985] predicted value for the $2s^22p^2\ {}^3\mathrm{P}_1-2s2p^3\ {}^5\mathrm{S}^\circ_2$ separation. The unknown correction "$+x$" is given with the quintet levels.

Robinson's analysis of transitions from high levels belonging to configurations of the types $2s^22p3l$ and $2s2p^23l$ (43−59 Å region) was hampered by inaccurate determinations of the low levels, uncertainties due to overlapping with the spectra of other ionization stages, etc. We have reevaluated and revised the levels on the basis of a new combination array using Robinson's unpublished line list and extensions and revisions by Fawcett and his collaborators [see, especially, Fawcett and Hayes, 1973; Bromage and Fawcett, 1977]. Some of these levels have expected errors of at least several hundred cm^{-1}. A number of the previously listed levels have been omitted, including several given as questionable by Robinson. Several of the retained levels also appear dubious, as indicated. The $2s2p^2(^4\mathrm{P})3d\ {}^5\mathrm{P}$ levels, for example, were derived from three lines having intensities in inverse order from that expected.

Edlén's [1971] isoelectronic formula for the C I sequence yields an ionization energy of 3 422 200 cm^{-1} for P X, as compared with a value of 3 424 200 cm^{-1} we obtained using semi-empirical corrections to theoretically calculated values for the sequence. The average of these values is adopted here with an estimated error equal to the difference of the two values.

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P X

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2$	^{3}P	0	0
		1	3 692
		2	9 045
$2s^2 2p^2$	^{1}D	2	59 690
$2s^2 2p^2$	^{1}S	0	119 960
$2s2p^3$	$^5\mathrm{S}^\circ$	2	*167 740+x*
$2s2p^3$	$^3\mathrm{D}^\circ$	2	*323 201*
		3	*323 234*
		1	*323 416*
$2s2p^3$	$^3\mathrm{P}^\circ$	1	*379 910*
		0	*379 929*
		2	*380 149*
$2s2p^3$	$^1\mathrm{D}^\circ$	2	*484 750*
$2s2p^3$	$^3\mathrm{S}^\circ$	1	*490 592*
$2s2p^3$	$^1\mathrm{P}^\circ$	1	*541 990*
$2p^4$	^{3}P	2	742 590
		1	749 011
		0	751 411
$2p^4$	^{1}D	2	793 130
$2s^2 2p3s$	$^3\mathrm{P}^\circ$	0	*1 954 000?*
		1	*1 956 300*
		2	*1 963 700*
$2s^2 2p3s$	$^1\mathrm{P}^\circ$	1	*1 976 900*
$2s2p^2(^4\mathrm{P})3s$	^{5}P	1	2 133 530+x?
		2	2 137 250+x
		3	2 141 250+x
$2s^2 2p3d$	$^3\mathrm{F}^\circ$	2	*2 140 900?*
		3	
		4	
$2s^2 2p3d$	$^1\mathrm{D}^\circ$	2	*2 147 600*
$2s^2 2p3d$	$^3\mathrm{D}^\circ$	1	
		2	*2 164 200*
		3	*2 167 500*
$2s^2 2p3d$	$^3\mathrm{P}^\circ$	2	*2 172 100*
		1	*2 173 800*
		0	
$2s^2 2p3d$	$^1\mathrm{F}^\circ$	3	*2 197 900*
$2s^2 2p3d$	$^1\mathrm{P}^\circ$	1	*2 198 400*
$2s2p^2(^4\mathrm{P})3p$	$^3\mathrm{S}^\circ$	1	*2 217 300*
$2s2p^2(^4\mathrm{P})3p$	$^3\mathrm{D}^\circ$	1	*2 258 500?*
		2	*2 259 500*
		3	*2 263 100*
$2s2p^2(^4\mathrm{P})3d$	^{5}P	3	2 343 400+x?
		2	2 344 920+x?
		1	2 346 130+x?
$2s2p^2(^4\mathrm{P})3d$	^{3}F	2	2 358 400
		3	2 360 850
		4	2 364 500
$2s2p^2(^4\mathrm{P})3d$	^{3}D	1	
		2	2 388 700
		3	2 389 750
$2s2p^2(^2\mathrm{D})3d$	^{3}F	2,3,4	2 467 700
$2s2p^2(^2\mathrm{D})3d$	^{3}D	1,2,3	2 476 500
P XI ($^2\mathrm{P}^\circ_{1/2}$)	***Limit***		***3 423 200***

P XI

$Z = 15$

B I isoelectronic sequence

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

Ionization energy 3 867 100 ± 1000 cm^{-1} (479.46 ± 0.12 eV)

We derived the values for the $2s^22p$, $2s2p^2$, and $2p^3$ doublet levels using mainly the wavelengths measured by Kasyanov *et al.* in the 231–360 Å region. In some cases we also took into account the relative values obtained by Edlén with his isoelectronic method. The $2p^3\ ^2D^\circ_{3/2}$ level was derived by using Edlén's value for the $2p^3\ ^2D^\circ_{5/2}-{}^2D^\circ_{3/2}$ interval. Fawcett [1970] first classified the two known $2p^3\ ^2D^\circ$ transitions, but the $^2D^\circ_{3/2}$ position given here is believed to be more accurate than a value obtained by using the measured $2s2p^2\ ^2P_{1/2}-2p^3\ ^2D^\circ_{3/2}$ wavelength. The $2s^22p\ ^2P^\circ$ interval is probably accurate to within a few cm^{-1}, and the Ritz-principle consistency of the data indicates that most of the $2s2p^2$ and $2p^3$ doublet levels should be accurate to within 40 cm^{-1}. It should be noted, however, that Edlén's values for the $2p^3\ ^2P^\circ$ levels are 46 cm^{-1} below the values here, and his value for the $2s2p^2\ ^2S_{1/2}$ level is 76 cm^{-1} below the value here.

The position of the quartet term system relative to the doublet system is based on Edlén's isoelectronically interpolated value of 175 931 cm^{-1} for the $2s^22p\ ^2P^\circ_{3/2}-2s2p^2\ ^4P_{5/2}$ separation. An unknown correction "$+x$" is given with each quartet level to indicate lack of an experimental value for the intersystem connection. The measurements of the $2s2p^2\ ^4P-2p^3\ ^4S^\circ$ lines by Kasyanov *et al.*, which were used to evaluate the relative positions of the levels of these two terms, should have accuracies comparable to the doublet-system measurements mentioned above.

Hansen calculated the relative strengths of the $2s^22p\ ^2P^\circ-2s2p^2\ ^4P$ forbidden transitions, and Sinanoğlu and Luken calculated oscillator strengths for the complete $2s^22p-2s2p^2$ array. Hansen's paper includes eigenvectors only for the $2s2p^2\ ^4P_{5/2}$, $2s2p^2\ ^2D_{5/2}$, and $2s^23d\ ^2D_{5/2}$ levels, and Sinanoğlu and Luken give eigenvectors only for the $2s2p^2\ ^4P_{1/2}$, $^2S_{1/2}$, and $^2P_{1/2}$ levels. The largest doublet percentages in the $2s2p^2\ ^4P$ eigenvectors are of magnitude 0.1%, so that the predicted $2s^22p\ ^2P^\circ-2s2p^2\ ^4P$ intercombination lines are relatively weak.

We evaluated the $2s^2nd$ and $2s2pnl$ ($n \geqslant 3$) levels using the wavelengths and classifications given by Fawcett and Hayes. Their data for the region 30–46 Å represent an extension of the original analysis by Robinson. We have also tentatively included the $2s^23s\ ^2S$ and $2p^23d\ ^4P$ terms using Robinson's data. Robinson's $2s2p3s$ terms have been omitted, none of these levels having been confirmed by more recent observations and the inverted structure of the $^4P^\circ$ term being inconsistent with the isoelectronic data. The $2s2p4d$ levels are given as tentative.

The $2s^23d$, $2s2p3p$, and $2s2p3d$ levels should be accurate to about ±500 cm^{-1}, but the $2s^24d$, $2s^25d$, and $2s2p4d$ levels may have errors of ±3000 cm^{-1} or so. The $2s^23d\ ^2D_{5/2}-{}^2D_{3/2}$ interval of 640 cm^{-1} agrees with theoretical and isoelectronic predictions [Kastner]; either measurement errors or an erroneous classification could account for the large deviation of the corresponding experimental $2s^24d\ ^2D_{5/2}-{}^2D_{3/2}$ interval (1500 cm^{-1}) from the expected value of about 240 cm^{-1}.

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. The resulting P XI ionization energy, given above, is consistent with the assumption of a linear Ritz quantum-defect formula for the $2s^2nd\ ^2D_{5/2}$ series ($n = 3, 4, 5$) to well within the level uncertainties; because of the $2s^2nd$ level uncertainties, the error in an ionization-energy value derived from the series would be much larger than the estimated error quoted above.

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P XI

Configuration	Term	*J*	Level (cm^{-1})
$2s^2 2p$	^{2}P°	1/2	*0*
		3/2	*9 699*
$2s2p^2$	^{4}P	1/2	177 177+x
		3/2	180 672+x
		5/2	185 630+x
$2s2p^2$	^{2}D	3/2	316 807
		5/2	316 905
$2s2p^2$	^{2}S	1/2	403 322
$2s2p^2$	^{2}P	1/2	426 877
		3/2	432 160
$2p^3$	^{4}S°	3/2	*558 973+x*
$2p^3$	^{2}D°	3/2	*631 961*
		5/2	*632 164*
$2p^3$	^{2}P°	1/2	*709 666*
		3/2	*710 749*
$2s^2 3s$	^{2}S	1/2	2 174 060?
$2s^2 3d$	^{2}D	3/2	2 347 470
		5/2	2 348 110
$2s2p(^3$P°$)3p$	^{2}P	1/2	
		3/2	2 441 300?
$2s2p(^3$P°$)3p$	^{2}S	1/2	2 515 400
$2s2p(^3$P°$)3d$	^{4}D°	1/2	
		3/2,5/2	*2 535 200+x*
		7/2	*2 539 500+x*
$2s2p(^3$P°$)3d$	^{2}D°	3/2	*2 538 800?*
		5/2	*2 539 800*
$2s2p(^3$P°$)3d$	^{4}P°	5/2	*2 546 850+x*
		3/2	*2 548 800+x?*
		1/2	
$2s2p(^3$P°$)3d$	^{2}F°	5/2	*2 577 600*
		7/2	*2 583 700*
$2s2p(^3$P°$)3d$	^{2}P°	3/2	*2 589 250*
		1/2	*2 592 000*
$2s2p(^1$P°$)3d$	^{2}F°	5/2,7/2	*2 697 900*
$2s2p(^1$P°$)3d$	^{2}D°	3/2	*2 709 500*
		5/2	*2 710 400*
$2p^2(^3$P$)3d$	^{4}P	5/2	2 856 300+x?
		3/2	2 858 450+x?
		1/2	
$2s^2 4d$	^{2}D	3/2	3 016 600
		5/2	3 018 100
$2s2p(^3$P°$)4d$	^{4}D°	7/2	*3 212 300+x?*
$2s2p(^3$P°$)4d$	^{2}F°	5/2	*3 226 300?*
		7/2	*3 230 700?*
$2s^2 5d$	^{2}D	5/2	3 326 400
$2s2p(^1$P°$)4d$	^{2}F°	7/2	*3 377 800?*
…………	…………	…………	…………
P XII (^{1}S$_0$)	***Limit***		3 867 100

P XII

$Z=15$

Be I isoelectronic sequence

Ground state $1s^22s^2\ ^1S_0$

Ionization energy 4 523 000 cm^{-1} (560.8 eV)

Robinson's analysis of this spectrum was extended by Fawcett and his coworkers, by Kasyanov *et al.*, and by Goldsmith *et al.* The $2s^2$, $2s2p$, and $2p^2$ levels given here are from Edlén [1983], who has smoothed the isoelectronic data by comparisons with theoretical values. The $2s2p\ ^3P_1^\circ$ and $^1P_1^\circ$ levels are probably accurate to ±10 cm^{-1}, the $2s2p\ ^3P_0^\circ$ and $^3P_2^\circ$ levels to ±20 cm^{-1}, and the $2p^2\ ^3P$ and ^1D levels to ±25 cm^{-1}. The singlet-triplet intersystem connection is accurately determined by the isoelectronically interpolated wavenumber for the $2s^2\ ^1S_0-2s2p\ ^3P_1^\circ$ transition, although this line has not yet been measured in P XII. No transitions involving the $2p^2\ ^1S_0$ level have been classified, but Edlén's interpolated value (given in brackets) would appear to be accurate to well within ±100 cm^{-1}.

We have reevaluated all the $2snl$ and $2pnl$ levels ($n \geqslant 3$) using appropriate wavelength averages for lines observed by more than one author. The uncertainties of most of the $2s3l$ and $2p3l$ levels are in the range ±500 to ±1000 cm^{-1}, and some of the higher $2snl$ and $2pnl$ series members may be in error by ±3000 cm^{-1} or more. The $2s4d$ levels have been evaluated by using the observed $2s2p-2s4d$ wavelengths; the results are consistent to within about ±800 cm^{-1} with the $2s3p\ ^3P^\circ-2s4d\ ^3D$ classifications of Fawcett and Ridgeley, but the combined data are probably not accurate enough to determine the $2s3p\ ^3P^\circ$ intervals. A few levels based on single lines, especially lines that are faint or doubly classified, have been marked as tentative or omitted.

The adopted ionization energy is about 100 cm^{-1} above a value we obtained from semi-empirical formulae for corrections to theoretically calculated values along the sequence. It is also in reasonable agreement with the value 4 523 700 cm^{-1} obtained from Edlén's [1971] formula for this isoelectronic sequence. Ionization-energy values derived from P XII data such as the $2snd\ ^3D$ series or the $2s4f$ position are consistent with the adopted value within their estimated uncertainties of several thousand cm^{-1}.

Transitions of the type $1s^22s^M2p^N-1s2s^M2p^{N+1}$ (M+N=2) in Be-like ions have been identified as contributing to satellite features near the $1s^2-1s2p$ resonance lines of the corresponding He-like ions in the spectra of a number of elements, including phosphorus [see, e.g., Boiko *et al.*]. Safronova and Lisina give a list of calculated wavelengths and other quantities for the transition arrays of this type. We have not included here any levels of P XII configurations involving such K-shell excitations ($1s2s^22p$, $1s2s2p^2$, $1s2p^3$).

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P XII

Configuration	Term	J	Level (cm^{-1})
$2s^2$	^1S	0	0
$2s2p$	$^3P^\circ$	0	*184 478*
		1	*187 690*
		2	*194 856*
$2s2p$	$^1P^\circ$	1	*359 343*
$2p^2$	^3P	0	483 195
		1	487 203
		2	493 285
$2p^2$	^1D	2	541 709
$2p^2$	^1S	0	[664 685]
$2s3s$	^3S	1	2 595 600
$2s3s$	^1S	0	2 629 500
$2s3p$	$^1P^\circ$	1	*2 677 800*
$2s3p$	$^3P^\circ$	0	
		1	*2 681 900*
		2	
$2s3d$	^3D	1	2 728 100
		2	2 728 600
		3	2 729 500
$2s3d$	^1D	2	2 761 500
$2p3s$	$^3P^\circ$	0	
		1	*2 830 600*
		2	*2 838 000*
$2p3s$	$^1P^\circ$	1	*2 880 200?*
$2p3p$	^1P	1	2 880 500?
$2p3p$	^3D	1	2 887 400?
		2	2 892 200?
		3	2 899 400
$2p3p$	^3S	1	2 912 800
$2p3p$	^3P	0	
		1	2 922 800
		2	2 926 100
$2p3d$	$^1D^\circ$	2	*2 939 800*
$2p3p$	^1D	2	2 948 100
$2p3d$	$^3D^\circ$	1	*2 961 600*
		2	*2 963 200*
		3	*2 966 800*
$2p3d$	$^3P^\circ$	2	*2 974 600*
		1	*2 977 400?*
		0	
$2p3d$	$^1F^\circ$	3	*3 004 100*
$2s4p$	$^1P^\circ$	1	*3 503 000*
$2s4d$	^3D	1	3 521 100
		2	3 521 300
		3	3 521 500
$2s4d$	^1D	2	3 531 200?
$2s4f$	$^3F^\circ$	4	*3 533 300*
$2s4f$	$^1F^\circ$	3	*3 536 000*
$2p4p$	^3P	2	3 727 900?
$2p4p$	^1D	2	3 735 200?
$2p4d$	$^3D^\circ$	3	*3 745 600*
$2p4d$	$^3P^\circ$	2	*3 748 200*
$2p4d$	$^1F^\circ$	3	*3 758 200?*
$2s5p$	$^1P^\circ$	1	*3 877 800?*
$2s5d$	^3D	2,3	3 885 400
$2p5d$	$^3D^\circ$	3	*4 106 400?*
$2p5d$	$^1F^\circ$	3	*4 111 000?*
P XIII ($^2S_{1/2}$)	*Limit*		4 523 000
P XIII ($^2P^\circ_{1/2}$)	*Limit*		*4 731 200*
P XIII ($^2P^\circ_{3/2}$)	*Limit*		*4 742 400*

P XIII

$Z=15$

Li I isoelectronic sequence

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

Ionization energy 4 934 000 ± 600 cm^{-1} (611.74 ± 0.07 eV)

The $1s^22p\ ^2P^\circ_{3/2}$ level is based on measurements of the transition to the $1s^22s\ ^2S_{1/2}$ ground level by Fawcett [1970], Kasyanov *et al.* [1973], and Dere [1978]. The measurements do not agree within the stated uncertainties, but the value given here should be accurate to about ±25 cm^{-1}. We have adopted Edlén's semi-empirical value for the $2p\ ^2P^\circ_{3/2}-{}^2P^\circ_{1/2}$ interval; the resulting $2p\ ^2P^\circ_{1/2}$ level is 53 cm^{-1} above the value obtained from the only measurement of the $2s\ ^2S_{1/2}-2p\ ^2P^\circ_{1/2}$ line [Fawcett, 1970].

Goldsmith *et al.* extended and revised Robinson's original analysis by classifying 13 lines in the 23 − 39 Å region as $2s-np$, $2p-3s$, and $2p-nd$ transitions. We evaluated the $3s$, $3p$, $3d$, $5d$, and $6d$ levels using their wavelength determinations. The $4p$ and $4f$ levels were derived by using the wavelengths for transitions to $n=3$ levels (102 − 111 Å) measured by Fawcett and Ridgeley. The $4d$ levels were evaluated by taking weighted averages of the $3p-4d$ measurements [Fawcett and Ridgeley] and the $2p-4d$ measurements [Goldsmith *et al.*]. No transitions from the $4s\ ^2S_{1/2}$ level have been observed; its position (given in brackets) was taken from Edlén's isoelectronically determined values for the $2p-4s$ separations.

The $n=3$ and $n=4$ levels in general are probably accurate within errors of about ±400 to ±600 cm^{-1}. The fine-structure intervals should be somewhat more accurate; for example, the expected (theoretical hydrogenic) $4f\ ^2F^\circ_{7/2}-{}^2F^\circ_{5/2}$ splitting is 217 cm^{-1}, as compared with the difference of 140 cm^{-1} between the two levels given here. We have given the two $5d\ ^2D$ levels at a single position because the uncertainty of the corresponding experimental wavenumbers is much greater than the expected splitting (see below).

Edlén has given series formulae for the entire $1s^2nl$ system. The levels here are in general agreement with his results within the expected experimental errors. Edlén's value for the ionization energy, 4 934 105 cm^{-1}, may be compared with the value 4 933 700 ± 600 cm^{-1} which we derived by adding the theoretical $4f\ ^2F^\circ$ term value to the corresponding experimental position. An ionization energy about 2000 cm^{-1} higher is obtained by assuming optimal Ritzian behavior of the $1s^2nd$ series, but quite possible errors of the order of 1000 cm^{-1} for the $5d$ and $6d$ levels could explain this discrepancy. The adopted ionization energy, 4 934 000 ± 600 cm^{-1}, thus agrees with the three quoted values within the errors.

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 P XIV $1s^2-1s2p$ resonance lines in the 5.8 Å region. Transitions from the $1s2s2p$ and $1s2p^2$ doublet terms (to $1s^22s\ ^2S$ and $1s^22p\ ^2P^\circ$, respectively) are among the strongest contributors to such features in the spectra of laser-produced plasmas [see, e.g., Aglitskii *et al.*, 1974, and Boiko, *et al.*, 1978a]. Since the experimental wavelengths obtained for such features usually refer to unresolved blends of several lines, we list the levels as derived from energy separations calculated by Vainshtein and Safronova [1975; see also their 1978 paper]. The $1s2s^2$ and $1s2p^2$ levels were evaluated by combining the calculated separations with the $1s^22p\ ^2P^\circ$ levels given here. The best available measurements indicate that the calculated levels are accurate within the experimental uncertainties of ±3000 to ±6000 cm^{-1}; most of the calculated fine-structure splittings are probably accurate to a few hundred cm^{-1}. Using a Doppler-tuned x-ray absorption technique, Deschepper *et al.* obtained an energy for the $1s^22s\ ^2S_{1/2}-1s2s2p\ ^4P^\circ_{5/2}$ transition equivalent to 17 036 700 ± 10 000 cm^{-1}, also in good agreement with the calculated value given here.

The energies of levels of some still 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 P XIV $1s^2-1s2p$ 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].

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P XIII

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$1s^2 2s$	^{2}S	$1/2$	0	P XIV (^{1}S$_0$)	***Limit***		**4 934 000**
$1s^2 2p$	^{2}P°	$1/2$	*208 204*	$1s2s^2$	^{2}S	$1/2$	[16 971 300]
		$3/2$	*219 430*				
				$1s(^2$S$)2s2p(^3$P°$)$	^{4}P°	$1/2$	*[17 024 500]*
$1s^2 3s$	^{2}S	$1/2$	2 788 650			$3/2$	*[17 027 500]*
						$5/2$	*[17 035 000]*
$1s^2 3p$	^{2}P°	$1/2$	*2 846 080*				
		$3/2$	*2 849 410*	$1s(^2$S$)2s2p(^3$P°$)$	^{2}P°	$1/2$	*[17 186 600]*
						$3/2$	*[17 192 500]*
$1s^2 3d$	^{2}D	$3/2$	2 870 540				
		$5/2$	2 871 530	$1s2p^2$	^{4}P	$1/2$	[17 247 000]
						$3/2$	[17 251 900]
$1s^2 4s$	^{2}S	$1/2$	[3 740 040]			$5/2$	[17 257 500]
$1s^2 4p$	^{2}P°	$1/2$	*3 763 020*	$1s(^2$S$)2s2p(^1$P°$)$	^{2}P°	$1/2$	*[17 261 300]*
		$3/2$	*3 764 550*			$3/2$	*[17 264 300]*
$1s^2 4d$	^{2}D	$3/2$	3 773 500	$1s2p^2$	^{2}D	$5/2$	[17 353 100]
		$5/2$	3 774 000			$3/2$	[17 354 200]
$1s^2 4f$	^{2}F°	$5/2$	*3 774 240*	$1s2p^2$	^{2}P	$1/2$	[17 378 500]
		$7/2$	*3 774 380*			$3/2$	[17 389 200]
$1s^2 5d$	^{2}D	$3/2, 5/2$	4 192 300	$1s2p^2$	^{2}S	$1/2$	[17 498 500]
$1s^2 6d$	^{2}D	$5/2$	4 419 350	P XIV $1s2s(^3$S$_1)$	*Limit*		[22 069 800]

P XIV

$Z=15$

He I isoelectronic sequence

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

Ionization energy 22 719 920 ± 350 cm^{-1} (2816.93 ± 0.04 eV)

Aglitskii *et al.* measured the $1s^2\ {}^1S_0-1s2p\ {}^3P^\circ_1$ and $1s^2\ {}^1S_0-1snp\ {}^1P^\circ_1$ ($n=2-7$) lines in the 4–6 Å region with estimated uncertainties corresponding to about ± 5000 cm^{-1} (~ 3 parts in 10^4). The recent measurements of the Ar XVII $1s^2\ {}^1S_0-1s2p\ {}^3P^\circ$ and $1s^2\ {}^1S_0-1s2p\ {}^1P^\circ$ lines by Deslattes *et al.* agree with Drake's calculations within the estimated experimental uncertainty of 1.2 parts in 10^5. We have thus given Drake's calculated values for the P XIV $1s2l$ levels (except as noted below), $1s3l$ levels, and ionization energy. An error of 2 parts in 10^5 for the $1s2p$ levels relative to the ground level corresponds to ± 350 cm^{-1}; an assumption of this value as the uncertainty for all the $1snl$ levels and the ionization energy is conservatively based on the agreement with experiment for Ar XVII. Hinterlong's determinations of the P XIV $1s2s\ {}^3S_1-1s2p\ {}^3P^\circ_0,\ {}^3P^\circ_2$ lines correspond to wavenumbers 122 977 ± 8 cm^{-1} and 135 139 ± 4 cm^{-1}. We have raised Drake's $1s2p\ {}^3P^\circ_0$ value by 5 cm^{-1} and lowered his $1s2p\ {}^3P^\circ_2$ value by 15 cm^{-1} to agree with these experimental results relative to $1s2s\ {}^3S_1$.

We previously obtained the Si XIII $1sns$ and $1snp$ levels by combining term values calculated by Ermolaev and Jones with Safronova's value for the limit [Martin and Zalubas]. Values for the Ar XVII $1s2p$ levels obtained in this way agree with the experiments cited above within a maximum deviation of 1.5 parts in 10^5; this corresponds to an error of about 200 cm^{-1} for the Si XIII $1s2p$ levels, as compared with the uncertainty of ± 800 cm^{-1} which we estimated. Fourteen of the 16 P XIV $1s2l$ and $1s3l$ levels as calculated by our previous methods [Martin and Zalubas; Martin] agree with Drake's values within ± 50 cm^{-1}, the largest deviation (for $1s3d\ {}^1D_2$) being only 67 cm^{-1}.

The $1sns$ and $1snp$ levels given here for $n=4,5$ were obtained from Ermolaev and Jones's term values, and the higher levels ($n=6$–10) were calculated from series formulae [Martin], Drake's value for the limit being used in all cases. The $1snl$ terms for $n\geqslant 4$, $l\geqslant 2$ (given complete through $n=6$) were also calculated from series formulae [Martin] and Drake's limit.

Transitions of the type $1snl-2l'nl''$ ($n\geqslant 2$) from doubly-excited configurations in P XIV give rise to satellite features near the P XV $1s\ {}^2S-2p\ {}^2P^\circ$ resonance doublet at 5.4 Å. Boiko *et al.*, for example, compare experimental and calculated intensities of several such features as observed in spectra of laser-produced plasmas. Most of the satellite lines are classified as blends of two or more transitions, the stronger features being assigned to $2s2p$ and $2p^2$ upper configurations. The relative positions of the levels of the $2s^2$, $2s2p$, and $2p^2$ configurations given here are from calculations by Vainshtein and Safronova [1976]; their values with respect to the ground level were reduced by 2400 cm^{-1}, so that the wavelengths for the important transitions of the type $1s2l-2l2l'$ given by the levels here agree with the corresponding wavelengths calculated by Vainshtein and Safronova [1978] to within 0.0002 Å. The wavelength of the $1s2p\ {}^1P^\circ_1-2p^2\ {}^1D_2$ line as measured by Boiko *et al.*, for example, is 0.0008 Å less than the calculated wavelength of 5.4493 Å, the difference being within the probable experimental uncertainty. We list the levels to the nearest 100 cm^{-1}.

The still higher configurations of the type $2l'nl''$ ($n\geqslant 3$) can give rise to satellites of both the $1s-2p$ and $1s-np$ resonance lines of P XV, the two transition types being $1snl-2l'nl''$ and $1s2l-2l'nl''$. Some transitions of the first type (for $n=3$) were assigned by Boiko *et al.* as contributing to features observed very near the P XV $1s\ {}^2S-2p\ {}^2P^\circ_{1/2}$ line. Vainshtein and Safronova [1980] give calculated wavelengths for such transitions.

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P XIV

Configuration	Term	J	Level (cm^{-1})
$1s^2$	^1S	0	0
$1s2s$	^3S	1	[17 135 769]
$1s2p$	$^3P^\circ$	0	[*17 258 746*]
		1	[*17 261 163*]
		2	[*17 270 908*]
$1s2s$	^1S	0	[17 268 828]
$1s2p$	$^1P^\circ$	1	[*17 360 546*]
$1s3s$	^3S	1	[20 271 101]
$1s3p$	$^3P^\circ$	0	[*20 304 936*]
		1	[*20 305 682*]
		2	[*20 308 579*]
$1s3s$	^1S	0	[20 306 284]
$1s3d$	^3D	1	[20 327 307]
		2	[20 327 351]
		3	[20 328 471]
$1s3d$	^1D	2	[20 329 412]
$1s3p$	$^1P^\circ$	1	[*20 332 953*]
$1s4s$	^3S	1	[21 350 958]
$1s4p$	$^3P^\circ$	0	[*21 364 940*]
		1	[*21 365 251*]
		2	[*21 366 469*]
$1s4s$	^1S	0	[21 365 193]
$1s4d$	^3D	1,2	[21 374 203]
		3	[21 374 685]
$1s4d$	^1D	2	[21 375 043]
$1s4f$	$^3F^\circ$,$^1F^\circ$	2,3,3,4	[*21 375 302*]
$1s4p$	$^1P^\circ$	1	[*21 376 454*]
$1s5s$	^3S	1	[21 846 994]
$1s5p$	$^3P^\circ$	0	[*21 854 063*]
		1	[*21 854 223*]
		2	[*21 854 847*]
$1s5s$	^1S	0	[21 854 145]
$1s5d$	^3D	1,2	[21 858 780]
		3	[21 859 026]
$1s5d$	^1D	2	[21 859 210]
$1s5f$	$^3F^\circ$,$^1F^\circ$	2,3,3,4	[*21 859 341*]
$1s5g$	^3G,^1G	3,4,4,5	[21 859 465]
$1s5p$	$^1P^\circ$	1	[*21 859 894*]
$1s6s$	^3S	1	[22 115 189]
$1s6p$	$^3P^\circ$	0	[*22 119 265*]
		1	[*22 119 357*]
		2	[*22 119 717*]
$1s6s$	^1S	0	[22 119 283]
$1s6d$	^3D	1,2	[22 121 979]
		3	[22 122 121]
$1s6d$	^1D	2	[22 122 227]
$1s6f$	$^3F^\circ$,$^1F^\circ$	2,3,3,4	[*22 122 303*]
$1s6g$	^3G,^1G	3,4,4,5	[22 122 371]
$1s6h$	$^3H^\circ$,$^1H^\circ$	4,5,5,6	[*22 122 413*]
$1s6p$	$^1P^\circ$	1	[*22 122 612*]
$1s7s$	^3S	1	[22 276 398]
$1s7p$	$^3P^\circ$	0	[*22 278 955*]
		1	[*22 279 013*]
		2	[*22 279 240*]
$1s7s$	^1S	0	[22 278 958]
$1s7p$	$^1P^\circ$	1	[*22 281 053*]
$1s8s$	^3S	1	[22 380 789]
$1s8s$	^1S	0	[22 382 497]
$1s8p$	$^3P^\circ$	0	[*22 382 498*]
		1	[*22 382 537*]
		2	[*22 382 689*]
$1s8p$	$^1P^\circ$	1	[*22 383 900*]
$1s9s$	^3S	1	[22 452 235]
$1s9s$	^1S	0	[22 453 431]
$1s9p$	$^3P^\circ$	0	[*22 453 433*]
		1	[*22 453 461*]
		2	[*22 453 567*]
$1s9p$	$^1P^\circ$	1	[*22 454 416*]

P XIV—Continued

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
1s10s	^{3}S	1	[22 503 270]	2p^2	^{3}P	0	[35 639 000]
						1	[35 645 300]
1s10s	^{1}S	0	[22 504 140]			2	[35 655 100]
1s10p	^{3}P°	0	[*22 504 143*]	2p^2	^{1}D	2	[35 711 600]
		1	[*22 504 163*]				
		2	[*22 504 240*]	2s2p	^{1}P°	1	[*35 717 100*]
1s10p	^{1}P°	1	[*22 504 858*]	2p^2	^{1}S	0	[35 894 000]
……………	……………	……………	……………	P XV 2p(^{2}P$^\circ_{1/2}$)	*Limit*		[*41 283 970*]
P XV (^{2}S$_{1/2}$)	***Limit***		**[22 719 920]**				
2s^2	^{1}S	0	[35 498 500]				
2s2p	^{3}P°	0	[*35 526 700*]				
		1	[*35 531 900*]				
		2	[*35 544 000*]				

P XV

$Z=15$

H I isoelectronic sequence

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

Ionization energy $24\,759\,942.5 \pm 3.0\ \mathrm{cm}^{-1}$ (3069.866 ± 0.008 eV)

The ionization energy and the $2s$ and $2p$ levels are from Mohr's calculations. His estimate of $\pm 3.0\ \mathrm{cm}^{-1}$ for the uncertainty of the ionization energy would also apply to the $1s-2s$ and $1s-2p$ separations. Mohr gives an uncertainty of $\pm 0.1\ \mathrm{cm}^{-1}$ for the $2p\ ^2P^\circ_{3/2}-^2P^\circ_{1/2}$ interval and $\pm 0.3\ \mathrm{cm}^{-1}$ for the $2s-2p$ separations. Pellegrin *et al.* used a laser resonance method to measure the $2s\ ^2S_{1/2}-2p\ ^2P^\circ_{3/2}$ separation as $17\,999 \pm 6.5\ \mathrm{cm}^{-1}$ (one standard-deviation error), which agrees with Mohr's value $17\,994.7 \pm 0.3\ \mathrm{cm}^{-1}$ and disagrees with the value $17\,984.8 \pm 2.0\ \mathrm{cm}^{-1}$ from Erickson's calculations. Experimental results agreeing with Mohr's evaluation of the $2s\ ^2S_{1/2}$ Lamb shift and indicating that Erickson's values are too large have also been obtained for Cl XVII [Wood *et al.*] and Ar XVIII [Gould and Marrus].

The levels for $n \geqslant 3$ were obtained by subtraction of the binding energies calculated by Erickson from Mohr's value for the ionization energy. (The $3s$ and $4s\ ^2S_{1/2}$ levels were decreased by 2.8 and $1.2\ \mathrm{cm}^{-1}$, respectively, before being rounded to the nearest cm^{-1}; these are estimated corrections to the Lamb shifts.) We list all levels through $n=5$ and the ns and np levels through $n=10$. Erickson's table of levels is complete through $n=11$ and has the ns, np, and nl ($l=n-1$) levels through $n=20$. The uncertainty of all the excited levels with respect to the $1s\ ^2S_{1/2}$ ground level is about equal to the ionization-energy uncertainty.

It should be noted that the hyperfine splittings of the lower ^{31}P XV ns levels are far from negligible compared to the estimated errors of the levels. Kastner gives a value $a_{1s}=64.9\ \mathrm{cm}^{-1}$ for the hfs splitting factor of the $1s$ electron; thus the expected positions of the actual $F=0$ and $F=1$ hyperfine levels are $\sim 49\ \mathrm{cm}^{-1}$ below and $\sim 16\ \mathrm{cm}^{-1}$ above the $1s$ ground level as given here.

The experimental uncertainties of measurements of the P XV $1s-np$ resonance lines made thus far are larger by some three orders of magnitude than the estimated errors of the theoretical wavelengths. Aglitskii *et al.* measured the wavelengths of the $1s\ ^2S-2p\ ^2P^\circ$ doublet near 5.38 Å with estimated uncertainties of ±0.0010 Å, which corresponds to $\pm 3500\ \mathrm{cm}^{-1}$. The larger of the deviations from the theoretically predicted wavelengths is 0.0011 Å for the $2p\ ^2P^\circ_{3/2}$ transition, which is almost within the estimated experimental uncertainty.

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P xv

Configuration	Term	J	Level (cm^{-1})
1s	^2S	1/2	0
2p	$^2P°$	1/2	[*18 564 051.6*]
		3/2	[*18 582 721.9*]
2s	^2S	1/2	[18 564 727.2]
3p	$^2P°$	1/2	[*22 008 289*]
		3/2	[*22 013 822*]
3s	^2S	1/2	[22 008 491]
3d	^2D	3/2	[22 013 812]
		5/2	[22 015 647]
4p	$^2P°$	1/2	[*23 213 012*]
		3/2	[*23 215 345*]
4s	^2S	1/2	[23 213 097]
4d	^2D	3/2	[23 215 341]
		5/2	[23 216 115]
4f	$^2F°$	5/2	[*23 216 114*]
		7/2	[*23 216 500*]
5p	$^2P°$	1/2	[*23 770 302*]
		3/2	[*23 771 496*]
5s	^2S	1/2	[23 770 346]
5d	^2D	3/2	[23 771 494]
		5/2	[23 771 890]
5f	$^2F°$	5/2	[*23 771 890*]
		7/2	[*23 772 088*]
5g	^2G	7/2	[23 772 087]
		9/2	[23 772 206]
6p	$^2P°$	1/2	[*24 072 892*]
		3/2	[*24 073 583*]
6s	^2S	1/2	[24 072 918]
7p	$^2P°$	1/2	[*24 255 282*]
		3/2	[*24 255 717*]
7s	^2S	1/2	[24 255 298]
8p	$^2P°$	1/2	[*24 373 628*]
		3/2	[*24 373 920*]
8s	^2S	1/2	[24 373 639]
9p	$^2P°$	1/2	[*24 454 748*]
		3/2	[*24 454 953*]
9s	^2S	1/2	[24 454 756]
10p	$^2P°$	1/2	[*24 512 763*]
		3/2	[*24 512 912*]
10s	^2S	1/2	[24 512 769]
	Limit		**[24 759 942.5]**