Energy Levels of Magnesium, Mg I through Mg XII

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Energy level data are given for the atom and all positive ions of magnesium ($Z=12$). These data have been critically compiled, mainly from published 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 value 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 wherever available. Ionization energies are given for all spectra.

Key words: Atomic energy levels; atomic spectra; electron configurations; ionization potentials; magnesium.

Contents

1. Introduction

This compilation is one of a series being published by the NBS Atomic Energy Levels Data Center. The main program of this center is the critical compilation of energy level data, with emphasis at present on the first 30 elements. The more recent publications include compilations for Al I-XIII [Martin and Zalubas, 1979], K I-XIX [Corliss and Sugar, 1979a], Ca I-XX [Sugar and Corliss, 1979], Sc I-XXI [Sugar and Corliss, 1980], Ti I-XXII [Corliss and Sugar, 1979], V I-XXIII [Sugar and Corliss, 1978], Cr I-XXIV [Sugar and Corliss, 1977], Mn I-XXV [Corliss and Sugar, 1977], and Fe I-XXVI [Reader and Sugar, 1975]. Similar compilations for Na and Ni are in progress.

2. Procedures, Explanation of Material Preceding Each Table

Except for Mg XI (He-like) and Mg XII (H-like), the levels are derived almost entirely from analyses of optical spectra. We have tried to give the most accurate data and theoretical interpretations that can be obtained from the available observations and analysis of each spectrum. We made combination arrays for most of the spectra, took weighted averages of different wavelength measurements where appropriate, and recalculated or derived the level values as necessary. Fairly detailed reviews of the analyses appeared warranted for a number of the spectra. The analyses of several of the higher spectra in the region below 100 Å, for example, are complicated by overlapping of spectra from different ionization stages and lack of intersystem transitions.

In the preparation of the tables, the data were transferred to punched cards in a flexible code that accommodates the standard configuration and term notations of atomic spectroscopy. The punched-card records, as revised and expanded to include new material up to the cutoff date (June 1979 for most of the spectra), were transferred to magnetic storage and edited to produce a final tape for automatic typesetting.

Data, Comments, and References Preceding Each Table

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

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8065.479±0.021 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. Questionable points in some of the analyses, with regard to either the levels or their interpretation, are indicated, and omissions of levels or designations from the compilations are mentioned. The estimated errors of the levels are quoted from the references or were deduced from stated wavelength errors. Our discussions of some of the spectra extend beyond necessary explanation of the tabulated material and citation of sources to include some of the more interesting results of the calculations and analysis, mention of superseded but important earlier papers, papers exemplary of a particular kind of research on the spectrum, etc.

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; Fuhr, Miller, and Martin, 1978]. Our starting point in collecting the references was Moore's *Atomic Energy Levels,* Vol. I. We also found Edlén's 1964 article very helpful, especially the information on several isoelectronic sequences that include Mg spectra. Our references for particular spectra generally do not include secondary sources or data compilations. Some of the more recent such publications that include Mg are the tables of spectral lines of Striganov and Sventitskii [1968], Kelly and Palumbo [1973], Fawcett [1975], the energy-level and Grotrian diagrams of Bashkin and Stoner [1975], and the Line Spectra of the Elements tables [Reader and Corliss, 1978].

The symbols following the references indicate types of data or other content according to a code explained in the *Bibliography on Atomic Energy Levels and Spectra* publications [Hagan and Martin, 1972; Hagan, 1977]. 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.

3. Format, Arrangement of the Tables

Some variation in the notations for configurations, parentages, terms of different coupling schemes, etc., occurs in the literature on atomic spectroscopy. The notations used in energy-level compilations of the AEL Data Center are described fully in a recent publication [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. Some features of the arrangement of the tables are summarized here.

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 (*not J* value), and terms are listed in order of lowest levels, ungrouped levels being treated as terms.

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 commmon (second) term, this second-percentage term is usually printed only for the first level of the group.

Any variation for the above conventions for the "Leading Percentages" is made obvious by the notation and is mentioned in the comments.

4. Acknowledgments

Prof. Bengt Edlén kindly supplied new estimates for several energy separations in Mg spectra; we very much appreciate his sending these results before their publication. We are also grateful to Dr. Marie-Christine Artru and Dr. Victor Kaufman for making available their unpublished data for several Mg spectra. We thank Arlene Albright for valuable assistance in several phases of this work, including the assembly of references and preparation of both tables and text in computer readable form. Allison Elton also helped in several ways, especially with the preparation of combination arrays. We are also grateful for assistance, in matters related to computer typesetting, by the Data Systems group in the Office of Standard Reference Data, particularly Carla Messina, and by Rebecca Morehouse and the Electronic Typesetting group of the Technical Information and Publications Division.

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5. Tables of Energy Levels

Mg I

$Z=12$

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

Ionization energy 61 671.02±0.10 cm^{-1} (7.64629±0.00002 eV)

Levels Below the Ionization Limit

Paschen [1931, 1932] gave the lower members of the $3snl$ series, as well as higher members of several series to $n=13$ or 14, and also the doubly-excited $3p^2\ {}^3P$, $3p3d\ {}^1D°$, and $3p3d\ {}^3D°$ terms. Most of the levels given here below 61 000 cm^{-1} are from Risberg [1965], who reobserved the spectrum and measured about 160 lines between 2025 and 26 393 Å. She derived more accurate values for the levels and also found some new terms. Risberg notes that levels derived from wavelengths measured by Meissner [1938a, 1938b] and levels from "several longer wavelengths in this work may be correct to 0.01 cm^{-1} or better. It has therefore seemed appropriate to give the values of such levels with three decimal places." She also states that the estimated errors "are in general less than 0.02 cm^{-1}."

Using fast-beam level-crossing spectroscopic techniques, Isaksen, Andersen, Andersen, and Ramanujam [1979] have determined the fine-structure separations of the $3s3d\ {}^3D$ and $3s4d\ {}^3D$ levels to higher accuracies than can be obtained from the three-place levels in our main table. Their results are given below in MHz (the unit they used) and in cm^{-1}:

Fine-structure Separation		MHz	cm^{-1}
$3s3d$	${}^3D_3 - {}^3D_2$	532 ± 4	0.01775 ± 0.00013
	${}^3D_3 - {}^3D_1$	-379 ± 4	-0.01264 ± 0.00013
$3s4d$	${}^3D_3 - {}^3D_2$	-1146 ± 9	-0.0382 ± 0.0003
	${}^3D_3 - {}^3D_1$	-2377 ± 12	-0.0793 ± 0.0004

Risberg's values for the separations agree very well with the new measurements; we changed her values for the 3s3d ${}^3D_2$, ${}^3D_1$ and $3s4d\ {}^3D_1$ levels by only -0.001 to +0.002 cm^{-1} to obtain three-place agreement between the separations in the main table and those above.

The $3s^2\ {}^1S_0$—$3snp\ {}^1P^\circ_1$ series has been observed in the vacuum-ultraviolet region ($n\geqslant5$) by Codling [1961], by Goorvitch, Mehlman-Balloffet, and Valero [1970], and by Brown, Naber, Tilford, and Ginter [1973]. The $3snp\ {}^1P°$ levels given here are mainly from the data of Goorvitch et al. and Brown et al. for $8\leqslant n\leqslant12$, and from the latter authors for $n\geqslant13$; the probable errors are less than 0.2 cm^{-1}. Bradley, Ewart, Nicholas, and Shaw [1975] observed the $3s3p\ {}^1P°$—$3snd\ {}^1D_2$ series to $n=24$ in absorption, their technique involving excitation to the lower level by the second harmonic of light from a dye laser. Codling's [1961] absorption data include wavelengths for the electric-quadrupole transitions $3s^2\ {}^1S_0$—$3snd\ {}^1D_2$ ($20\leqslant n\leqslant25$), the original identification of the upper levels as $3snp\ {}^3P^\circ_1$ having been corrected by Brown, Tilford, and Ginter [1975]. The $3snd\ {}^1D_2$ levels given here for $14\leqslant n\leqslant25$ are from Ewart's [1977] remeasurement of the $3s3p\ {}^1P^\circ_1$—$3snd\ {}^1D_2$ series and from Codling, suitable averages being taken in the region of overlap. The higher of these levels have probable errors of about ±1 cm^{-1}. Camus [1974] observed $3sns\ {}^3S_1$ and $3snd\ {}^3D$ series in absorption from $3s3p\ {}^3P°$ levels (to $20s$ and $19d$, respectively), but did not report the wavelengths.

Some Mg I series have been observed to higher members in the solar spectrum than in laboratory spectra [Moore, 1971; Swensson and Risberg, 1966, and references therein]. Swensson and Risberg list 219 solar features attributed wholly or partly to Mg I. We have included their series-formulae values for a few $3sns$, $3snd$ and $3snf$ levels in brackets, the predicted values probably being more accurate than values based on wavelengths of weak and/or blended solar features. The series-formula values given by Swensson and Risberg for the higher $3snd\ {}^1D_2$ levels (to $n=21$) are probably more accurate than the values given here, but we have preferred the laboratory experimental results.

Brown et al. [1973] derived an ionization energy of 61 671.20±0.18 cm^{-1} from the long $3snp\ {}^1P^\circ_1$ series observed by them (to $n=59$). The value obtained by Camus from the two series mentioned above was 61 670.9 ±0.1 cm^{-1}. These values agree satisfactorily with the value given here, which was derived by Risberg from the $3snf\ {}^1F°$ and ${}^3F°$ series ($n=4$ to 12) and confirmed by the $3sns\ {}^3S$ series. Risberg did not estimate the uncertainty of her value, but the average deviation of the $3snf$ terms ($n=7$ to 12) from her Ritz formulae predictions is less than 0.01 cm^{-1}. The uncertainty in the ionization energy in units of eV is due to the relatively large uncertainty in the conversion factor.

Levels Above the Ionization Limit

Most of the levels given between the Mg II $3s\ {}^2S$ and $3p\ {}^2P°$ limits were determined from wavelengths of resonance features observed in photoabsorption from the ground state

[Esteva, Mehlman-Balloffet, and Romand, 1972; Baig and Connerade, 1978]. Such levels are mainly $^1P_1^{\circ}$ in character or have significant $^1P_1^{\circ}$ components, and are subject to autoionization. The $3pns$ $^1P^{\circ}$, $3pns$ $^3P^{\circ}$, $3pnd$ $^1P^{\circ}$ and $4snp$ $^1P^{\circ}$ levels were derived from measurements in the 760–1300 Å region by Baig and Connerade. Their improvement and extension of earlier observations gave wavelengths for transitions to higher members of these series than are represented here. The widths of the resonances and thus the accuracies of the level positions vary greatly. The strong asymmetric $3p4s$ $^1P^{\circ}$ feature has an apparent width of the order of 3000 cm^{-1} (the $3p4s$ $^3P^{\circ}$ resonance being observed as a slight irregularity on the long-wave shoulder) whereas the $3pnd$ resonances are relatively sharp. The levels are rounded to either the nearest 10 cm^{-1} or to the nearest cm^{-1}. The wavelength measurements by Baig and Connerade were made at the absorption maxima, which may not correspond to the theoretical resonance centers of asymmetric features. Esteva et al. measured the $3pns$ $^1P^{\circ}$ features at positions to the long wavelength side of the maxima, the resulting value for the $3p4s$ $^1P^{\circ}$ level, for example, being 1850 cm^{-1} below the maximum absorption position.

Autoionization is also allowed in the above region for even-parity S and D levels. The value for the $3p^2$ $^1S_0$ autoionizing level is based on a wavelength of 3009 Å for the $3s3p$ $^1P_1^{\circ}$—$3p^2$ $^1S_0$ transition, as determined by Bradley et al. From ejected-electron spectra, Rassi et al. obtained energies for the $3pnp$ ^1S levels (to $n=8$) and $3pnp$ ^1D levels (to $n=12$), which are not included here. (Theoretical results for the $3p^2$ ^1D level are cited in the next section.)

The values given for the $3p3d$ $^1D^{\circ}$ and $^3D^{\circ}$ levels were obtained by Risberg from accurate measurements of emission lines above 2000 Å. Autoionization from these levels is forbidden in the Russell-Saunders approximation, no odd-parity continuum for $L=2$ being available below the Mg II $3p$ $^2P^{\circ}$ limit. Although some of the lines from these levels are marked "diffuse", their widths must be small compared to strongly autoionizing levels. Rassi et al. identified a feature in their ejected-electron spectra as arising from the level at 80 693 cm^{-1}, previously designated $3p3d$ $^1F^{\circ}$ but changed to $3p3d$ $^1D^{\circ}$ by Risberg. The assignments of several other resonances to $3pnd$ $^1F^{\circ}$ and $3pnd$ $^1D^{\circ}$ series by Rassi et al. are inconsistent with Risberg's designation of the $3p3d$ $^1D^{\circ}$ level.

The very high autoionizing $J=1$ odd levels arising from configurations including the $2p^5$ open shell are also based on photoabsorption from the ground level. Ederer, Lucatorto, and Mehlman [1979] have made the most complete observations (170–226 Å) using synchrotron radiation as a source. In the region 442 000–470 000 cm^{-1}, we have also used the measurements of Newsom [1971] and Esteva and Mehlman [1974] in obtaining average values for the levels. Most of the level designations in this region are due to Newsom, with several changes by Mansfield and Connerade [1972] or by Ederer et al. being included here. Mansfield and Connerade give predicted energies for terms of seven configurations based on the $2p^5$ $^2P^{\circ}$ core, as calculated in single-configuration approximations. The tentative configuration and parentage assignments of the resonances above 489 000 cm^{-1} by Ederer et al. are listed here with question marks. These authors note that extensive configuration-interaction calculations including the appropriate continua would be required for a detailed analysis of the spectrum. The positions of several high Mg II levels based on the excited $2p^5$ core are listed as limits, some of the term designations being only nominal (see Mg II).

Some of the autoionization resonances observed in ejected-electron spectra of Mg arise from configurations not observed in photoabsorption. Pejčev, Ottley, Rassi, and Ross [1977], for example, give measurements of ejected-electron energies for Mg I and Mg II and include references to earlier observations and interpretations of such spectra. The Mg I data of this type have not been included in this compilation.

Theoretical Results

The Mg I $3s3p$ configuration is discussed extensively in the literature in connection with transition probabilities of both allowed and forbidden lines, hyperfine structure, etc. [see, e.g., Garstang, 1962; Lurio, Mandel, and Novick, 1962; Kluge and Sauter, 1974; Bauche, Couarraze, and Labarthe, 1974; Fischer, 1975a; numerous additional references are given in these papers]. Russell-Saunders coupling is very pure for this configuration, the mixing of the $^1P_1^{\circ}$ and $^3P_1^{\circ}$ levels being only about 0.0004% [Swagel and Lurio, 1968]. The eigenvector percentages given here are from Fischer, who used the multiconfiguration Hartree-Fock approximation to calculate $3snp$ and $3snd$ terms [1975a] and also $3s^2$ and $3sns$ terms [1975b]. All second percentages result from configuration interactions, the (very small) intermediate coupling having been neglected by Fischer.

One of the configurations included in Fischer's ^1D and ^1S calculations was $3p^2$, the strong interaction of $3p^2$ ^1D with the $3snd$ ^1D series having been established by a number of investigations since the early 1930's. Interaction with the (higher) $3p^2$ ^1D depresses the $3snd$ ^1D levels to positions below the corresponding ^3D terms. (The $3snf$ $^1F^{\circ}$ levels are similarly below the corresponding $^3F^{\circ}$ terms for at least $n=4$ to 6.) The interaction is made evident by large second percentages of $3p^2$ ^1D in the compositions of the $3snd$ ^1D levels; Fischer's calculations give about half the total $3p^2$ ^1D composition distributed amongst the first six $3snd$ ^1D levels ($n=3$ through 8). According to Lu [1974], "the fact that [the $3p^2$ ^1D level] interacts so strongly with the whole series of $3snd$ ^1D and with the adjacent continuum indicates that it should not exist as a well-defined term. Its oscillator strength is presumably distributed over the whole spectral region of transitions with levels in the $3snd$ ^1D series and of the adjacent $3s\epsilon d$ ^1D continuum."

Thompson, Hibbert, and Chandra [1974] give the results of calculations of photoionization from the $3s3p$ $^1P^{\circ}$ level *via* the ^1D and ^1S channels of $3p^2$ and $3pnp$ configurations. Additional references for calculations of levels above the principal ionization limit are cited by Baig and Connerade, who give the results of their calculations for $3pns$, $3pnd$, and $4snp$ configurations (to $n=10$). Calculated energies for $^1P^{\circ}$ (and $3pns$ $^3P_1^{\circ}$) levels are included, and the effects of coupling changes are discussed.

The *nd* ²D levels are inverted in the first few spectra of the Na I isoelectronic sequence, an irregularity that has been explained by relativistic and/or correlation effects [see Mg II]. Laughlin and Victor [1974] introduced experimental splittings of the Mg II *nd* ²D terms into their calculations of the Mg I 3*snd* ³D fine structures, the inversions of which are presumably related, but the resulting Mg I separations do not agree very well with the experimental values [see also Isaksen et al.]. No calculation of the Mg I structures including relativistic and correlation effects is yet available.

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Mg I

Configuration	Term	*J*	Level (cm⁻¹)	Leading percentages		
3*s*²	¹S	0	0.000	93	7	3*p*² ¹S
3*s*3*p*	³P°	0	*21 850.405*	98	1	3*p*3*d* ³P°
		1	*21 870.464*	98	1	
		2	*21 911.178*	98	1	
3*s*3*p*	¹P°	1	*35 051.264*	94	6	3*p*3*d* ¹P°
3*s*4*s*	³S	1	41 197.403	98	2	3*d*² ³S
3*s*4*s*	¹S	0	43 503.333	96	2	3*d*² ¹S
3*s*3*d*	¹D	2	46 403.065	77	22	3*p*² ¹D
3*s*4*p*	³P°	0	*47 841.119*	99	1	3*p*3*d* ³P°
		1	*47 844.414*	99	1	
		2	*47 851.162*	99	1	
3*s*3*d*	³D	2	47 957.027	98	1	3*p*4*f* ³D
		3	47 957.045	98	1	
		1	47 957.058	98	1	
3*s*4*p*	¹P°	1	*49 346.729*	97	2	3*p*3*d* ¹P°

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s5s$	^{3}S	1	51 872.526	100		
$3s5s$	^{1}S	0	52 556.206	99	1	$3d^2$ ^{1}S
$3s4d$	^{1}D	2	53 134.642	87	13	$3p^2$ ^{1}D
$3s4d$	^{3}D	3	54 192.256	100		
		2	54 192.294	100		
		1	54 192.335	100		
$3s5p$	^{3}P°	0	*54 248.809*	100		
		1	*54 250.086*	100		
		2	*54 252.726*	100		
$3s4f$	^{1}F°	3	*54 676.438*			
$3s4f$	^{3}F°	2,3,4	*54 676.710*			
$3s5p$	^{1}P°	1	*54 706.536*	99	1	$3p3d$ ^{1}P°
$3s6s$	^{3}S	1	55 891.80	100		
$3s6s$	^{1}S	0	56 186.873	99		
$3s5d$	^{1}D	2	56 308.381	93	7	$3p^2$ ^{1}D
$3s5d$	^{3}D	3	56 968.218	100		
		2	56 968.248	100		
		1	56 968.271	100		
$3s6p$	^{3}P°	0	*57 017.078*	100		
		1	*57 017.724*	100		
		2	*57 019.025*	100		
$3s5f$	^{1}F°	3	*57 204.163*			
$3s5f$	^{3}F°	2,3,4	*57 204.275*			
$3s6p$	^{1}P°	1	*57 214.992*	99		
$3p^2$	^{3}P	0	57 812.77			
		1	57 833.40			
		2	57 873.94			
$3s7s$	^{3}S	1	57 855.214			
$3s7s$	^{1}S	0	58 009.41	100		
$3s6d$	^{1}D	2	58 023.246	96	4	$3p^2$ ^{1}D
$3s6d$	^{3}D	3	58 442.843	100		
		2	58 442.853	100		
		1	58 442.874	100		
$3s7p$	^{3}P°	0	*58 476.689*	100		
		1	*58 477.020*	100		
		2	*58 477.760*	100		

Mg I—Continued

Configuration	Term	J	Level (cm⁻¹)	Leading percentages
3s6f	$^1F°$	3	*58 575.487*	
3s6f	$^3F°$	2,3,4	*58 575.518*	
3s7p	$^1P°$	1	*58 580.23*	100
3s8s	^3S	1	58 962.739	
3s7d	^1D	2	59 041.019	97 3 $3p^2\ ^1D$
3s8s	^1S	0	59 053.52	
3s7d	^3D	3	59 318.764	100
		2	59 318.775	100
		1	59 318.793	100
3s8p	$^3P°$	0,1,2	*59 342.51*	
3s7f	$^3F°,^1F°$	2,3,3,4	*59 400.763*	
3s8p	$^1P°$	1	*59 403.18*	
3s9s	^3S	1	59 649.15	
3s8d	^1D	2	59 689.991	98 2 $3p^2\ ^1D$
3s9s	^1S	0	59 707.11	
3s8d	^3D	3	59 881.168	100
		2	59 881.181	100
		1	59 881.196	100
3s9p	$^3P°$	0,1,2	*59 897.86*	
3s8f	$^3F°,^1F°$	2,3,3,4	*59 935.370*	
3s9p	$^1P°$	1	*59 936.63*	
3s10s	^3S	1	60 104.00	
3s9d	^1D	2	60 127.239	
3s10s	^1S	0	60 143.23	
3s9d	^3D	1,2,3	60 263.583	
3s9f	$^3F°,^1F°$	2,3,3,4	*60 301.283*	
3s10p	$^1P°$	1	*60 302.30*	
3s11s	^3S	1	60 420.87	
3s10d	^1D	2	60 435.099	
3s10d	^3D	1,2,3	60 535.34	

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
3*s*10*f*	$^3F°,^1F°$	2,3,3,4	*60 562.637*	
3*s*11*p*	$^1P°$	1	*60 563.35*	
3*s*12*s*	^3S	1	60 650.46	
3*s*11*d*	^1D	2	60 659.69	
3*s*11*d*	^3D	1,2,3	60 735.38	
3*s*11*f*	$^3F°,^1F°$	2,3,3,4	*60 755.764*	
3*s*12*p*	$^1P°$	1	*60 756.13*	
3*s*13*s*	^3S	1	[60 822.17]	
3*s*12*d*	^1D	2	60 828.41	
3*s*12*d*	^3D	1,2,3	60 886.83	
3*s*12*f*	$^3F°,^1F°$	2,3,3,4	*60 902.50*	
3*s*13*p*	$^1P°$	1	*60 902.93*	
3*s*14*s*	^3S	1	[60 953.90]	
3*s*13*d*	^1D	2	60 958.31	
3*s*13*d*	^3D	1,2,3	61 004.33	
3*s*13*f*	$^3F°,^1F°$	2,3,3,4	[*61 016.60*]	
3*s*14*p*	$^1P°$	1	*61 016.93*	
3*s*14*d*	^1D	2	61 060.5	
3*s*14*d*	^3D	1,2,3	[61 097.27]	
3*s*14*f*	$^3F°,^1F°$	2,3,3,4	[*61 107.05*]	
3*s*15*p*	$^1P°$	1	*61 107.34*	
3*s*15*d*	^1D	2	61 142.1	
3*s*15*f*	$^3F°,^1F°$	2,3,3,4	[*61 179.97*]	
3*s*16*p*	$^1P°$	1	*61 180.24*	
3*s*16*d*	^1D	2	61 208.2	
3*s*17*p*	$^1P°$	1	*61 239.83*	
3*s*17*d*	^1D	2	61 262.9	
3*s*18*p*	$^1P°$	1	*61 289.19*	
3*s*18*d*	^1D	2	61 308.4	

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
3s19p	$^1P°$	1	*61 330.55*	
3s19d	^1D	2	61 346.7	
3s20p	$^1P°$	1	*61 365.55*	
3s20d	^1D	2	61 379.2	
3s21p	$^1P°$	1	*61 395.43*	
3s21d	^1D	2	61 407	
3s22p	$^1P°$	1	*61 421.14*	
3s22d	^1D	2	61 432	
3s23p	$^1P°$	1	*61 443.41*	
3s23d	^1D	2	61 452	
3s24p	$^1P°$	1	*61 462.82*	
3s24d	^1D	2	61 471	
3s25p	$^1P°$	1	*61 479.87*	
3s25d	^1D	2	61 487	
3s26p	$^1P°$	1	*61 494.90*	
3s27p	$^1P°$	1	*61 508.24*	
3s28p	$^1P°$	1	*61 520.12*	
3s29p	$^1P°$	1	*61 530.73*	
3s30p	$^1P°$	1	*61 540.26*	
3s31p	$^1P°$	1	*61 548.81*	
3s32p	$^1P°$	1	*61 556.63*	
3s33p	$^1P°$	1	*61 563.68*	
3s34p	$^1P°$	1	*61 570.11*	
3s35p	$^1P°$	1	*61 575.99*	
3s36p	$^1P°$	1	*61 581.34*	
3s37p	$^1P°$	1	*61 586.33*	
3s38p	$^1P°$	1	*61 590.82*	
3s39p	$^1P°$	1	*61 595.02*	
3s40p	$^1P°$	1	*61 598.87*	
3s41p	$^1P°$	1	*61 602.44*	
3s42p	$^1P°$	1	*61 605.74*	
3s43p	$^1P°$	1	*61 608.86*	
3s44p	$^1P°$	1	*61 611.67*	
3s45p	$^1P°$	1	*61 614.40*	

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s46p$	$^1P°$	1	*61 616.88*	
$3s47p$	$^1P°$	1	*61 619.23*	
$3s48p$	$^1P°$	1	*61 621.43*	
$3s49p$	$^1P°$	1	*61 623.49*	
$3s50p$	$^1P°$	1	*61 625.45*	
$3s51p$	$^1P°$	1	*61 627.17*	
$3s52p$	$^1P°$	1	*61 628.94*	
$3s53p$	$^1P°$	1	*61 630.60*	
$3s54p$	$^1P°$	1	*61 631.99*	
$3s55p$	$^1P°$	1	*61 633.43*	
$3s56p$	$^1P°$	1	*61 634.87*	
$3s57p$	$^1P°$	1	*61 636.20*	
$3s58p$	$^1P°$	1	*61 637.27*	
$3s59p$	$^1P°$	1	*61 638.48*	
....	....	....	....	
Mg II ($^2S_{1/2}$)	***Limit***		**61 671.02**	
$3p^2$	^1S	0	68 275	
$3p4s$	$^3P°$	1	*76 940*	
$3p4s$	$^1P°$	1	*78 660*	
$3p3d$	$^1D°$	2	*80 693.01*	
$3p3d$	$^3D°$	1 2 3	*83 511.25* *83 520.47* *83 536.84*	
$3p3d$	$^1P°$	1	*85 925*	
$3p5s$	$^3P°$	1	*87 580*	
$3p5s$	$^1P°$	1	*88 060*	
$3p4d$	$^1P°$	1	*90 777*	
$3p6s$	$^3P°$	1	*91 620*	
$3p6s$	$^1P°$	1	*91 840*	
$3p5d$	$^1P°$	1	*93 152*	
$3p7s$	$^3P°$	1	*93 540*	
$3p7s$	$^1P°$	1	*93 680*	
$3p6d$	$^1P°$	1	*94 420*	

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3p8s$	$^3P^\circ$	1	*94 650*	
$3p8s$	$^1P^\circ$	1	*94 770*	
$3p7d$	$^1P^\circ$	1	*95 223*	
$3p9s$	$^3P^\circ$	1	*95 352*	
$3p9s$	$^1P^\circ$	1	*95 440*	
$3p8d$	$^1P^\circ$	1	*95 736*	
$3p10s$	$^1P^\circ$	1	*95 895*	
$3p9d$	$^1P^\circ$	1	*96 089*	
$3p11s$	$^1P^\circ$	1	*96 200*	
$3p10d$	$^1P^\circ$	1	*96 346*	
$3p12s$	$^1P^\circ$	1	*96 436*	
Mg II $3p(^2P^\circ_{1/2})$	*Limit*		*97 340.33*	
Mg II $3p(^2P^\circ_{3/2})$	*Limit*		*97 431.90*	
$4s4p$	$^1P^\circ$	1	*114 540*	
$4s5p$	$^1P^\circ$	1	*122 940*	
$4s6p$	$^1P^\circ$	1	*125 930*	
$4s7p$	$^1P^\circ$	1	*127 720*	
Mg II $4s(^2S_{1/2})$	*Limit*		131 475.97	
....	....	....	....	
$2p^5(^2P^\circ_{3/2})3s^2\,4s_{1/2}$	$(3/2,1/2)^\circ$	1	*442 000*	
$2p^5(^2P^\circ)3s3p^2(^4P)$	$^3P^\circ$	1	*443 300*	
$2p^5(^2P^\circ_{1/2})3s^2\,4s_{1/2}$	$(1/2,1/2)^\circ$	1	*444 130*	
$2p^5(^2P^\circ_{3/2})3s^2\,3d$	$^2[3/2]^\circ$ } $^2[1/2]^\circ$ }	1 } 1 }	*447 570*	
$2p^5(^2P^\circ)3s3p^2(^2D)$	$^1P^\circ$	1	*449 070*	
$2p^5(^2P^\circ_{1/2})3s^2\,3d$	$^2[3/2]^\circ$	1	*450 370*	
$2p^5(^2P^\circ_{3/2})3s^2\,5s_{1/2}$	$(3/2,1/2)^\circ$	1	*453 910*	
$2p^5(^2P^\circ_{3/2})3s^2\,4d$	$^2[3/2]^\circ$?	1	*454 430*	
$2p^5(^2P^\circ_{3/2})3s^2\,4d$	$^2[1/2]^\circ$	1	*454 620?*	

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{1/2})3s^2\,5s_{1/2}$	$(1/2,1/2)^\circ$	1	456 060	
$2p^5(^2P^\circ_{1/2})3s^2\,4d$	$^2[3/2]^\circ$	1	456 540	
$2p^5(^2P^\circ_{3/2})3s^2\,6s_{1/2}$	$(3/2,1/2)^\circ$	1	457 940	
$2p^5(^2P^\circ_{3/2})3s^2\,5d$	$^2[3/2]^\circ$ } $^2[1/2]^\circ$ }	1 } 1 }	458 250	
$2p^5(^2P^\circ_{1/2})3s^2\,6s_{1/2}$	$(1/2,1/2)^\circ$	1	460 050	
$2p^5(^2P^\circ_{1/2})3s^2\,5d$ } $2p^5(^2P^\circ_{3/2})3s^2\,6d$ }	$^2[3/2]^\circ$ } $^2[3/2]^\circ$ }	1 } 1 }	460 380	
$2p^5(^2P^\circ_{3/2})3s^2\,7d$	$^2[3/2]^\circ$ } $^2[1/2]^\circ$ }	1 } 1 }	461 480	
$2p^5(^2P^\circ_{1/2})3s^2\,7s_{1/2}$	$(1/2,1/2)^\circ$	1	462 170	
$2p^5(^2P^\circ_{1/2})3s^2\,6d$	$^2[3/2]^\circ$	1	462 530	
Mg II $(^2P^\circ_{3/2})3s^2$	*Limit*		464 130	
$2p^5(^2P^\circ_{1/2})3s^2\,9s_{1/2}$?	$(1/2,1/2)^\circ$?	1	464 150	
$2p^5(^2P^\circ_{1/2})3s^2\,8d$?	$^2[3/2]^\circ$?	1	464 470	
Mg II $(^2P^\circ_{1/2})3s^2$	*Limit*		466 300	
$2p^5(^2P^\circ)3s3p^2(^2S)$	$^1P^\circ$	1	468 340	
$2p^5(^2P^\circ)3s3p^2(^2P)$	$^1P^\circ$	1	476 190	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2P_{3/2})4p$?		1	489 380	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})4p$?		1	491 910	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})4p$?		1	493 220	
$2p^5(^2P^\circ)3s3p(^3P^\circ)4p$?		1	494 020	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2P_{3/2})5p$?		1	495 340	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})5p$?		1	498 930	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})6p$?		1	501 860	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})7p$?		1	503 450	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})8p$?		1	504 390	
$2p^5(^2P^\circ)3s3p(^3P^\circ)\ (^2S_{1/2})9p$?		1	504 920	
$2p^5(^2P^\circ)3s3p(^1P^\circ)\ (^2S_{1/2})4p$?		1	508 130	
$2p^5(^2P^\circ)3p^2(^1D)\ (^2P^\circ_{3/2})4s$?		1	513 720	

Mg I—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ)3s3p(^1P^\circ)$ $(^2S_{1/2})5p$?		1	*515 280*	
		1	*526 510*	
		1	*529 800*	
		1	*532 820*	
$2p^5(^2P^\circ)3p^2(^3P)$ $(^2P^\circ)4s$?		1	*533 600*	
$2p^5(^2P^\circ)3s3d^2$?		1	*537 780*	
Mg II $(^2P^\circ)3p^2(^1D)$ $(^2P^\circ_{1/2})$	*Limit*		*539 160*	
Mg II $(^2P^\circ)3p^2(^1D)$ $(^2P^\circ_{3/2})$	*Limit*		*539 930*	
$2p^5(^2P^\circ)3s3d(^3D)$ $(^2P^\circ_{3/2})4d$?		1	*544 870*	
$2p^5(^2P^\circ)3s3d(^3D)$ $(^2P^\circ_{3/2})4d$?		1	*546 060*	
$2p^5(^2P^\circ)3s3d(^3D)$ $(^2P^\circ_{1/2})4d$?		1	*546 360*	
$2p^5(^2P^\circ)3p^2(^3P)$ $(^2P^\circ)3d$?		1	*547 350*	
$2p^5(^2P^\circ)3s3d(^3D)$ $(^2P^\circ_{1/2})5d$?		1	*549 270*	
$2p^5(^2P^\circ)3p^2(^1S)$ $(^2P^\circ_{3/2})4s$?		1	*552 490*	
$2p^5(^2P^\circ)3p^2(^1S)$ $(^2P^\circ_{1/2})4s$?		1	*553 710*	
Mg II $(^2P^\circ)3s3d(^3D)$ $(^2P^\circ_{3/2})$	*Limit*		*554 430*	
Mg II $(^2P^\circ)3s3d(^3D)$ $(^2P^\circ_{1/2})$	*Limit*		*555 470*	

Mg II

$Z=12$

Na I isoelectronic sequence

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

Ionization energy 121 267.61±0.05 cm^{-1} (15.03539±0.00004 eV)

Levels Below the Ionization Limit

Most of the levels in this region are from P. Risberg [1955], who gives observed wavelengths for 93 lines between 2790 and 11 620 Å. He estimates an error limit of ±0.05 cm^{-1} in the wavenumbers of 17 vacuum-ultraviolet lines (1307–1753 Å) calculated from the level values. Goorvitch, Mehlman-Balloffet, and Valero [1970] measured 34 Mg II lines between 946 and 2937 Å with estimated wavenumber errors of ±0.32 to ±0.06 cm^{-1}. Several of their wavelength determinations, particularly in the regions near 1480 Å and 1750 Å, differ from Risberg's calculated values by more than the combined estimated errors. We have retained Risberg's level values as being supported by internal Ritz-principle consistency. G. Risberg [1965] measured a number of Mg II lines in the 2329–4332 Å and 17 717–21 432 Å regions; she found good agreement with the corresponding wavenumber differences of P. Risberg's levels and confirmed the $6h\ ^2H^\circ$ position.

The Mg II vacuum-ultraviolet wavelengths measured by Sulmont and Felenbok [1967] and by Esteva, Mehlman-Balloffet, and Romand [1972] are less accurate than values calculated from Risberg's levels. Since the absorption measurements of the principal series by Esteva et al. extended to $3s$–$10p$, we give the $10p\ ^2P^\circ$ levels as calculated from Risberg's series formulae; these levels are probably accurate to ±0.1 cm^{-1}.

Andersen, Isaksen, Iversen, and Ramanujam [1978] have determined the $5d$, $6d$, $7d\ ^2D$ and $4f$, $5f$, $6f\ ^2F^\circ$ fine-structure separations by fast-beam level-crossing and anticrossing techniques. The known ^2D and $^2F^\circ$ splittings are now as follows:

Term	Interval (cm^{-1})
3d ^{2}D	−0.882 ± 0.002
4d ^{2}D	−0.52 ± 0.02
5d ^{2}D	−0.3030 ± 0.0006
6d ^{2}D	−0.1850 ± 0.0005
7d ^{2}D	−0.1189 ± 0.0005
4f ^{2}F°	0.1177 ± 0.0002
5f ^{2}F°	0.0586 ± 0.0003
6f ^{2}F°	0.0334 ± 0.0003

The $^2F^\circ$ intervals given by Andersen et al. have been changed from units of MHz to cm^{-1}. We derived the $3d\ ^2D$ interval from the $4f\ ^2F^\circ$ interval combined with Mundie and Meissner's [1944] measurement of the separation of the two strong $3d\ ^2D$—$4f\ ^2F^\circ$ fine-structure lines as 1.000 ±0.002 cm^{-1}. The $4d\ ^2D$ separation is from P. Risberg; in the main table below we have slightly adjusted several of Risberg's other ^2D and $^2F^\circ$ levels with respect to the term baricenters to agree with the above intervals to ±0.01 cm^{-1}.

Andersen et al. give references to some recent theoretical calculations of the anomalous negative ^2D intervals in Mg II. Similar inversions of ^2D terms are observed in the isoelectronic spectra Na I, Al III, and Si IV.

The g values measured by Lott, Roos, and Ginter [1966] for the $3s\ ^2S_{1/2}$, $3p\ ^2P^\circ_{1/2}$, and $^2P^\circ_{3/2}$ levels (1.96, 0.69, 1.33, respectively) agree with the LS-coupling values to within the probable accuracy of the determinations.

P. Risberg obtained the ionization limit by fitting the lowest five ^2G terms to a Ritz formula. We take the uncertainty of this limit as equal to his estimated error for the high levels of Mg II relative to the ground level, the average deviation of members of several series from Ritz formulae being only about 0.01 cm^{-1}. (The predictions of series formulae of either the Ritz type or core-polarization type [Bockastén, 1956] are sufficiently accurate in Mg II to make three-place experimental term values useful in comparisons.) The uncertainty of the limit in eV units is due to the uncertainty of the conversion factor.

Levels Above the Ionization Limit

Esteva and Mehlman [1974] observed Mg photoabsorption spectra in the range 100–250 Å using time and space scanning of the absorbing plasma to distinguish Mg I, Mg II, and Mg III lines. The Mg II lines (184–248 Å) were classified as transitions from the $2p^6 3s\ ^2S_{1/2}$ ground level to upper configurations based on the excited $2p^5$ core. The allowed transitions are thus to levels having $J=\frac{1}{2}$ or $\frac{3}{2}$ and significant $2p^5 3snl\ ^2P^\circ$ eigenvector components ($nl=ns$ or nd), the system beginning with the $2p^5 3s^2\ ^2P^\circ$ term a little above 400 000 cm^{-1}. All 38 levels listed by Esteva and Mehlman for Mg II are included here; the values are given to the nearest 10 cm^{-1}, the probable errors being about ±100 cm^{-1}. The leading eigenvector percentages given for ten of these levels are from a Hartree-Fock calculation of the $2p^5 3p^2$, $2p^5 3s3d$, $2p^5 3s4d$ configurations including configuration interaction [Mehlman, Weiss, and Esteva, 1976]. Transitions to the four $^2P^\circ$ levels nominally belonging to

$2p^5(^2P°)3p^2(^1D)$ and $2p^5(^2P°)3p^2(^3P)$ were observed because of the large $2p^53s3d$ components. The configuration assignments of the remaining (higher) levels by Esteva and Mehlman are given tentatively. These authors also suggest J_1j-coupling designations for most of these levels, based on theoretical calculations. A detailed interpretation of these levels may require more extensive calculations of both positions and intensities of the transitions.

Excited-core levels of Mg II have also been deduced from ejected-electron spectra [Pegg, Haselton, Thoe, Griffin, Brown, and Sellin, 1975; Breuckmann, Schmidt, and Schmitz, 1976; Pejčev, Ottley, Rassi, and Ross, 1977]. We here include only a small and somewhat arbitrary selection of additional levels derived from such data, namely seven levels in the range 435 200 to 460 100 cm^{-1}. The positions are from the data of Pejčev et al., rounded to the nearest 100 cm^{-1}. The corresponding resonances were observed by all three groups referenced above, and were assigned to Mg II $2p^53s3p$ levels by Pegg et al. and by Pejčev et al. The interpretation of such spectra is difficult, but there is little doubt that a number of the observed features in this region arise from this even-parity configuration [see also McGuire, 1976]. Assignments of additional resonances to $2p^53s3p$ and to other excited-core configurations are given in the references.

The Mg III $2p^53s$ $^3P°_{2,1,0}$ and $^1P°_1$ limits are accurate to about ±3 cm^{-1} (see Mg III).

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Mg II

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s$	^2S	1/2	0.00	
$3p$	$^2P°$	1/2	*35 669.31*	
		3/2	*35 760.88*	
$4s$	^2S	1/2	69 804.95	
$3d$	^2D	5/2	71 490.19	
		3/2	71 491.06	
$4p$	$^2P°$	1/2	*80 619.50*	
		3/2	*80 650.02*	
$5s$	^2S	1/2	92 790.51	
$4d$	^2D	5/2	93 310.59	
		3/2	93 311.11	
$4f$	$^2F°$	5/2	*93 799.63*	
		7/2	*93 799.75*	
$5p$	$^2P°$	1/2	*97 455.12*	
		3/2	*97 468.92*	
$6s$	^2S	1/2	103 196.75	

Mg II—Continued

Configuration	Term	J	Level (cm⁻¹)	Leading percentages
5*d*	^{2}D	5/2	103 419.70	
		3/2	103 420.00	
5*f*	^{2}F°	5/2	*103 689.86*	
		7/2	*103 689.92*	
5*g*	^{2}G	7/2,9/2	103 705.66	
6*p*	^{2}P°	1/2	*105 622.34*	
		3/2	*105 629.72*	
7*s*	^{2}S	1/2	108 784.33	
6*d*	^{2}D	5/2	108 900.02	
		3/2	108 900.20	
6*f*	^{2}F°	5/2	*109 062.32*	
		7/2	*109 062.35*	
6*g*	^{2}G	7/2,9/2	109 072.05	
6*h*	^{2}H°	9/2,11/2	*109 074.00*	
7*p*	^{2}P°	1/2	*110 203.58*	
		3/2	*110 207.99*	
8*s*	^{2}S	1/2	112 129.20	
7*d*	^{2}D	5/2	112 197.05	
		3/2	112 197.17	
7*f*	^{2}F°	5/2,7/2	*112 301.47*	
7*g*	^{2}G	7/2,9/2	112 307.79	
7*h*	^{2}H°	9/2,11/2	*112 309.06*	
8*p*	^{2}P°	1/2	*113 030.25*	
		3/2	*113 033.09*	
9*s*	^{2}S	1/2	114 289.36	
8*d*	^{2}D	5/2	114 332.68	
		3/2	114 332.74	
8*f*	^{2}F°	5/2,7/2	*114 403.55*	
8*g*	^{2}G	7/2,9/2	114 407.88	
8*h*	^{2}H°	9/2,11/2	*114 408.74*	
9*p*	^{2}P°	1/2	*114 896.79*	
		3/2	*114 898.72*	
10*s*	^{2}S	1/2	115 764.99	
9*d*	^{2}D	3/2	115 794.41	

Mg II—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
9f	^{2}F°	5/2,7/2	*115 844.60*				
9g	^{2}G	7/2,9/2	115 847.67				
9h	^{2}H°	9/2,11/2	*115 848.28*				
10p	^{2}P°	1/2	[*116 193.7*]				
		3/2	[*116 195.1*]				
10f	^{2}F°	5/2,7/2	*116 875.25*				
10g	^{2}G	7/2,9/2	116 877.54				
10h	^{2}H°	9/2,11/2	*116 878.04*				
11g	^{2}G	7/2,9/2	117 639.51				
....	....	....	....				
Mg III 2p^6(^{1}S$_0$)	*Limit*		**121 267.61**				
2p^5 3s^2	^{2}P°	3/2	*402 460*				
		1/2	*404 630*				
2p^5 3s3p?			435 200				
2p^5 3s3p?			439 300				
2p^5 3s3p?			440 200				
2p^5 3s3p?			445 100				
2p^5 3s3p?			457 300				
2p^5 3s3p?			458 500				
2p^5 3s3p?			460 100				
2p^5(^{2}P°)3p^2(^{1}D)	^{2}P°	1/2	*477 490*	49		42	(^{2}P°)3s3d(^{1}D) ^{2}P°
		3/2	*478 260*	42		35	
2p^5(^{2}P°)3s4s(^{3}S)	^{2}P°	1/2	*491 330*	78		12	^{4}P°
		3/2	*491 590*	63		26	(^{2}P°)(^{1}S) ^{2}P°
2p^5(^{2}P°)3s3d(^{3}D)		3/2	*492 760*	48	^{2}D°	47	^{2}P°
2p^5(^{2}P°)3s3d(^{3}D)	^{2}P°	1/2	*493 800*	87		10	^{4}D°
2p^5(^{2}P°)3s4s(^{1}S)	^{2}P°	3/2	*494 390*	68		26	(^{2}P°)(^{3}S) ^{2}P°
		1/2	*495 050*	91		8	
2p^5(^{2}P°)3p^2(^{3}P)	^{2}P°	1/2	*501 730*	76		19	(^{2}P°)3s3d(^{1}D) ^{2}P°
		3/2	*505 780*	75		19	
2p^5 3s4d?			*516 420*				
2p^5 3s5s?			*517 060*				

Mg II—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5\,3s4d$?			517 300	
$2p^5\,3s4d$?			517 890	
$2p^5\,3s5s$?			518 560	
$2p^5\,3s4d$?			519 350	
$2p^5\,3s4d$?			519 750	
$2p^5\,3s5s$?			521 780	
$2p^5\,3s4d$?			522 030	
$2p^5\,3s4d$?			522 740	
$2p^5\,3s5d$?			528 070	
$2p^5\,3s5d$?			528 460	
$2p^5\,3s5d$?			529 070	
$2p^5\,3s5d$?			529 350	
$2p^5\,3s5d$?			530 390	
$2p^5\,3s6d$?			533 670	
$2p^5\,3s6d$?			534 220	
$2p^5\,3s6d$?			535 220	
$2p^5\,3s6d$?			536 280	
$2p^5\,3s7d$?			537 690	
$2p^5\,3s7d$?			538 820	
$2p^5\,3s6d$?			539 780	
$2p^5\,3s8d$?			541 100	
$2p^5\,3s9d$?			541 480	
$2p^5\,3s9d$?			542 560	
$2p^5\,3s7d$?			543 210	
Mg III $2p^53s(^3P^\circ_2)$	*Limit*		546 908	
Mg III $2p^53s(^3P^\circ_1)$	*Limit*		548 136	
Mg III $2p^53s(^3P^\circ_0)$	*Limit*		549 120	
Mg III $2p^53s(^1P^\circ_1)$	*Limit*		552 798	

Mg III

$Z=12$

Ne I isoelectronic sequence

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

Ionization energy 646 402±5 cm^{-1} (80.1443±0.0006 eV)

Most of the levels are taken from the paper by Andersson and Johannesson [1971], who extended and revised the previous analysis. They give 373 classified lines (721–7430 Å), the accuracies being such that the estimated relative error is less than 0.5 cm^{-1} for most of the levels given to one decimal place. Lundström's [1973] measurements of wavelengths of transitions from upper odd-parity levels ($J=1$) to the $2p^6$ $^1S_0$ ground level (157–235 Å) determined the system of excited levels with respect to the ground level to about ±3 cm^{-1}. Twelve of the high odd levels ($J=1$) in the range 605 356 to 634 111 cm^{-1} are taken directly from Lundström's measurements; these are given to the nearest cm^{-1} and have uncertainties of about ±20 cm^{-1}.

Andersson and Johannesson calculated the levels of most of the $2p^5nl$ configurations and gave at least partial results for $nl=3p$, $4p$, $3d$, $4f$, $5f$, and $5g$. The J_1l coupling scheme is more appropriate than the LS scheme for all such configurations except $nl=3s$, $3p$, and $3d$. Leading eigenvector percentages for levels of the three configurations having the largest deviations from pure coupling schemes, $2p^53p$, $4p$, and $3d$, are taken from Andersson and Johannesson. Although all these levels were assigned term names, the strongly mixed eigenvectors for several of them should be noted; four of the $2p^53p$ levels and six of the $2p^53d$ levels have second percentages in the 29–40% range, for example, and the eigenvectors of the two $2p^54p$ levels having $J=0$ are essentially equal mixtures of $(^2P^\circ_{3/2})\ ^2[^1/_2]^\circ$ and $(^2P^\circ_{1/2})\ ^2[^1/_2]^\circ$ components. The $2p^5np$ configurations deviate rather strongly from the single-configuration Slater-Condon approximation [Hansen, 1973], and Andersson and Johannesson omitted the $^3S_1$ level in fitting the theory to the $2p^53p$ and $2p^54p$ configurations. The eigenvector percentages for the levels of the $2p^53s$, $2p^54s$, and $2p^55s$ configurations are given in LS coupling, the $^3P^\circ+{}^1P^\circ$ mixing of the two $J=1$ levels in each case being taken from Gruzdev and Loginov.

The $2p^54f$, $5f$, and $5g$ configurations exhibit very pure J_1l coupling, the levels of the $2p^55g$ pairs not having been established separately by the experimental wavelengths. Andersson and Johannesson obtained the ionization energy from the levels of these three configurations by using a core-polarization formula.

The autoionizing series $2s^22p^6$ $^1S_0$—$2s2p^6np$ $^1P^\circ_1$ ($n\geqslant3$) has been observed in absorption in spark plasmas by Esteva and Mehlman [1974] and by Kastner, Crooker, Behring, and Cohen [1977]. The uncertainty of the Mg IV $2s2p^6$ $^2S_{1/2}$ limit as given here with respect to the Mg III $2s^22p^6$ $^1S_0$ ground level is less than 10 cm^{-1}, the corresponding wavelength limit of the series being 104.391 Å. All of the $2s2p^6np$ $^1P^\circ$ levels given by Esteva and Mehlman ($n=3$–8) are listed here (to the nearest 100 cm^{-1}), averages having been taken for those series members also measured by Kastner et al. ($n=3,4,5,7$). Most of the values are probably accurate to about ±400 cm^{-1}, but the behavior of the quantum defects is somewhat irregular, and the two measurements of the $2s2p^67p$ $^1P^\circ_1$ position differ by 1180 cm^{-1}.

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Mg III

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2p^6$	^1S	0	0			
$2p^5 3s$	$^3P^\circ$	2	*425 640.3*	100		
		1	*426 868.1*	95	5	$^1P^\circ$
		0	*427 852.1*	100		

Mg III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2p^5 3s$	$^1P^\circ$	1	*431 530.0*	95		5	$^3P^\circ$
$2p^5 3p$	^3S	1	467 378.5	99			
$2p^5 3p$	^3D	3	474 053.2	100			
		2	474 655.0	89			
		1	475 502.9	91			
$2p^5 3p$	^1D	2	477 435.7	61		36	^3P
$2p^5 3p$	^1P	1	478 374.5	61		30	^3P
$2p^5 3p$	^3P	2	478 846.1	62		30	^1D
		0	479 265.3	100			
		1	479 456.0	65		34	^1P
$2p^5 3p$	^1S	0	496 012.1	100			
$2p^5 3d$	$^3P^\circ$	0	*530 178.2*	100			
		1	*530 420.6*	98			
		2	*530 962.9*	93			
$2p^5 3d$	$^3F^\circ$	4	*531 563.0*	100			
		3	*531 833.1*	68		32	$^1F^\circ$
		2	*532 725.7*	77		14	$^1D^\circ$
$2p^5 3d$	$^1F^\circ$	3	*532 971.2*	52		29	$^3D^\circ$
$2p^5 3d$	$^3D^\circ$	1	*534 197.7*	60		40	$^1P^\circ$
		3	*534 923.6*	70		16	$^1F^\circ$
		2	*535 179.6*	56		37	$^1D^\circ$
$2p^5 3d$	$^1D^\circ$	2	*534 776.9*	46		31	$^3D^\circ$
$2p^5 3d$	$^1P^\circ$	1	*536 152.0*	59		39	$^3D^\circ$
$2p^5(^2P^\circ_{3/2})4s$	$^2[3/2]^\circ$	2	*545 820.4*	100	$^3P^\circ$		
		1	*546 531.6*	65	$^3P^\circ$	35	$^1P^\circ$
$2p^5(^2P^\circ_{1/2})4s$	$^2[1/2]^\circ$	0	*548 034.4*	100	$^3P^\circ$		
		1	*548 720.7*	65	$^1P^\circ$	35	$^3P^\circ$
$2p^5(^2P^\circ_{3/2})4p$	$^2[1/2]$	1	559 987.1	87		13	$(^2P^\circ_{1/2})\ ^2[1/2]$
		0	564 300.0	51		49	
$2p^5(^2P^\circ_{3/2})4p$	$^2[5/2]$	3	561 798.7	100			
		2	562 136.1	82		13	$^2[3/2]$
$2p^5(^2P^\circ_{3/2})4p$	$^2[3/2]$	1	562 634.2	91			
		2	562 939.5	84		15	$^2[5/2]$
$2p^5(^2P^\circ_{1/2})4p$	$^2[3/2]$	1	564 289.8	91			
		2	564 664.6	95			
$2p^5(^2P^\circ_{1/2})4p$	$^2[1/2]$	1	564 731.6	87		13	$(^2P^\circ_{3/2})\ ^2[1/2]$
		0	570 112.8	51		49	

Mg III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{3/2})4d$	$^2[1/2]^\circ$	0	*581 567.5*	
		1	*581 734.7*	
$2p^5(^2P^\circ_{3/2})4d$	$^2[3/2]^\circ$	2	*582 074.4*	
		1	*583 450.5*	
$2p^5(^2P^\circ_{3/2})4d$	$^2[7/2]^\circ$	4	*582 134.8*	
		3	*582 290.1*	
$2p^5(^2P^\circ_{3/2})4d$	$^2[5/2]^\circ$	2	*582 747.3*	
		3	*582 839.7*	
$2p^5(^2P^\circ_{3/2})4f$	$^2[3/2]$	1	584 345.7	
		2	584 354.1	
$2p^5(^2P^\circ_{3/2})4f$	$^2[9/2]$	5	584 462.4	
		4	584 463.5	
$2p^5(^2P^\circ_{3/2})4f$	$^2[5/2]$	3	584 563.9	
		2	584 571.1	
$2p^5(^2P^\circ_{1/2})4d$	$^2[5/2]^\circ$	2	*584 628.5*	
		3	*584 733.4*	
$2p^5(^2P^\circ_{3/2})4f$	$^2[7/2]$	3	584 687.9	
		4	584 689.2	
$2p^5(^2P^\circ_{1/2})4d$	$^2[3/2]^\circ$	2	*584 737.9*	
		1	*585 466.2*	
$2p^5(^2P^\circ_{1/2})4f$	$^2[7/2]$	3	586 777.9	
		4	586 779.5	
$2p^5(^2P^\circ_{1/2})4f$	$^2[5/2]$	3	586 785.1	
		2	586 791.6	
$2p^5(^2P^\circ_{3/2})5s$	$^2[3/2]^\circ$	2	*588 768.9*	100 $^3P^\circ$
		1	*589 126.8*	53 $^1P^\circ$ 47 $^3P^\circ$
$2p^5(^2P^\circ_{1/2})5s$	$^2[1/2]^\circ$	0	*590 984.2*	100 $^3P^\circ$
		1	*591 220.7*	53 $^3P^\circ$ 47 $^1P^\circ$
$2p^5(^2P^\circ_{3/2})5d$	$^2[1/2]^\circ$	1	*605 356*	
$2p^5(^2P^\circ_{3/2})5d$	$^2[3/2]^\circ$	1	*606 248*	
$2p^5(^2P^\circ_{3/2})5f$	$^2[3/2]$	1	606 713.1	
		2	606 719.4	
$2p^5(^2P^\circ_{3/2})5f$	$^2[9/2]$	5	606 774.5	
		4	606 775.4	
$2p^5(^2P^\circ_{3/2})5f$	$^2[5/2]$	3	606 830.7	
		2	606 834.7	
$2p^5(^2P^\circ_{3/2})5g$	$^2[5/2]^\circ$	3,2	*606 841.9*	
$2p^5(^2P^\circ_{3/2})5g$	$^2[11/2]^\circ$	6,5	*606 861.0*	

Mg III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{3/2})5f$	$^2[7/2]$	3	606 891.1	
		4	606 891.8	
$2p^5(^2P^\circ_{3/2})5g$	$^2[7/2]^\circ$	4,3	*606 896.8*	
$2p^5(^2P^\circ_{3/2})5g$	$^2[9/2]^\circ$	5,4	*606 916.6*	
$2p^5(^2P^\circ_{1/2})5d$	$^2[3/2]^\circ$	1	*608 295*	
$2p^5(^2P^\circ_{1/2})5f$	$^2[5/2]$	3	609 045.2	
		2	609 050.5	
$2p^5(^2P^\circ_{1/2})5f$	$^2[7/2]$	3	609 045.4	
		4	609 045.7	
$2p^5(^2P^\circ_{1/2})5g$	$^2[9/2]^\circ$	5,4	*609 111.4*	
$2p^5(^2P^\circ_{1/2})5g$	$^2[7/2]^\circ$	4,3	*609 111.6*	
$2p^5(^2P^\circ_{3/2})6s$	$^2[3/2]^\circ$	1	*609 262*	
$2p^5(^2P^\circ_{1/2})6s$	$^2[1/2]^\circ$	1	*611 389*	
$2p^5(^2P^\circ_{3/2})6d$	$^2[3/2]^\circ$	1	*618 601*	
$2p^5(^2P^\circ_{1/2})6d$	$^2[3/2]^\circ$	1	*620 702*	
$2p^5(^2P^\circ_{3/2})7d$	$^2[3/2]^\circ$	1	*626 013*	
$2p^5(^2P^\circ_{1/2})7d$	$^2[3/2]^\circ$	1	*628 149*	
$2p^5(^2P^\circ_{3/2})8d$	$^2[3/2]^\circ$	1	*630 827*	
$2p^5(^2P^\circ_{1/2})8d$	$^2[3/2]^\circ$	1	*632 988*	
$2p^5(^2P^\circ_{3/2})9d$	$^2[3/2]^\circ$	1	*634 111*	
....	....	....	....	
Mg IV $(^2P^\circ_{3/2})$	*Limit*		***646 402***	
Mg IV $(^2P^\circ_{1/2})$	*Limit*		*648 631*	
$2s2p^6\,3p$	$^1P^\circ$	1	*790 500*	
$2s2p^6\,4p$	$^1P^\circ$	1	*874 700*	
$2s2p^6\,5p$	$^1P^\circ$	1	*908 000*	
$2s2p^6\,6p$	$^1P^\circ$	1	*925 200*	
$2s2p^6\,7p$	$^1P^\circ$	1	*934 700*	
$2s2p^6\,8p$	$^1P^\circ$	1	*940 700*	
Mg IV $2s2p^6(^2S_{1/2})$	*Limit*		957 934	

Mg IV

$Z=12$

F I isoelectronic sequence

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

Ionization energy 881 285±10 cm^{-1} (109.2663±0.0012 eV)

Artru and Kaufman [1972], Johannesson, Lundström, and Minnhagen [1972], and Johannesson and Lundström [1973] have greatly extended the analysis by Söderqvist [1934]. Classified lines in the 118–1957 Å region are given in the first two of the above references. The analyses described in these two references are for the most part in good agreement, and in general the values of the levels included in both papers agree to within the combined estimated uncertainties. Johannesson et al. [1972] include a number of higher levels not found by Artru and Kaufman. The designations or J values of a few high even levels, mainly belonging to $2p^4 5d$, are given as tentative; these assignments were left in question by the analyses or by comparison of the analyses. For similar reasons, we have also indicated as doubtful the positions of two even levels and two odd levels (assigned to $2p^4(^3P)4d$ and to $2s2p^5(^3P^\circ)3s\ ^2P^\circ$, respectively). Johannesson and Lundström found the $2p^4 4f$, $5f$ and $5g$ levels by classifying additional lines in the 715–1131 Å and 2470–2536 Å regions.

The ground-term $^2P^\circ_{3/2}$–$^2P^\circ_{1/2}$ interval and the $2s2p^6\ ^2S_{1/2}$ level are accurate to about ±2 cm^{-1} [Artru and Kaufman, 1972]. The higher levels given to one decimal place are from Johannesson et al. and from Johannesson and Lundström. The estimated uncertainty of these levels with respect to the ground level is about ±4 to ±5 cm^{-1}. The *relative* uncertainties vary considerably, and the references should be consulted for details; the range is from ±0.3 cm^{-1} ($2p^4(^3P)3s$, $3p$, $3d$ levels) to ±5 cm^{-1} (levels based on $2p^4\ ^1S$ with respect to levels based on $2p^4\ ^3P$ or ^1D). The levels given to the nearest cm^{-1} are from Johannesson et al. or are averages of their values with those of Artru and Kaufman. Some of these levels have uncertainties as large as ±30 cm^{-1}.

The theoretical interpretations of most of the levels of both parities are strongly supported by calculations. Eigenvector percentages are given here for levels of the five even configurations $2s2p^6$, $2p^4 3s$, $3d$, $4s$, and $4d$ as calculated with inclusion of the configuration interactions [Artru and Kaufman, 1973]. Although all these eigenvectors have high configurational purities, the effects of configuration interaction are nevertheless significant for some of the levels. The $2s2p^6\ ^2S$ level, for example, is depressed by about 5800 cm^{-1} through interactions with the $2p^4(^1D)3d\ ^2S$, $(^1D)4d\ ^2S$, $(^1S)3s\ ^2S$, and $(^1S)4s\ ^2S$ levels; the corresponding upward perturbations of the $(^1D)3d\ ^2S$ and $(^1D)4d\ ^2S$ levels are 3100 cm^{-1} and 2250 cm^{-1}, respectively. The percentages given for the levels of the odd configuration $2p^4 3p$ are also from Artru and Kaufman, who described the calculation and gave partial results in their 1972 paper. The importance of the effective interaction they called $D^1(2p,3p)$ was noted, and Hansen [1973] has discussed the physical significance of this parameter in some detail. The two $2p^4(^3P)3p$ levels having $J=\frac{1}{2}$ at 610 983 cm^{-1} and 612 943 cm^{-1} are followed by asterisks to indicate that the eigenvector assignments might possibly be reversed; we have omitted term names for these levels since the strong mixtures of ^2S and ^2P in the eigenvectors may obviate physically meaningful single-term designations in any case.

Leading percentages for the $2p^4 4f$ levels are given in the $J_1 l$ coupling scheme, second percentages less than 3% being omitted. The percentages are from Johannesson and Lundström, who also assigned the $2p^4 5f$ and $5g$ levels to $J_1 l$-coupling terms. The pairing of the $2p^4 5g$ levels is pronounced; no experimental determinations of the term splittings were made for any of the five $(^1D_2)5g$ pairs. Johannesson and Lundström derived the ionization energy by application of core-polarization theory to the $2p^4(^3P_2)4f$, $(^3P_2)5f$, and $(^3P_2)5g$ level groups. The quoted uncertainty does not include any systematic error possibly introduced by use of the polarization formula in this manner.

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Mg IV

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2s^2 2p^5$	$^2P^\circ$	3/2	*0*				
		1/2	*2 228*				
$2s2p^6$	^2S	1/2	311 532	99		1	$2p^4(^1D)3d\ ^2S$
$2s^2 2p^4(^3P)3s$	^4P	5/2	543 720.4	100			
		3/2	545 137.6	99		1	^2P
		1/2	545 955.4	100			
$2s^2 2p^4(^3P)3s$	^2P	3/2	553 666.1	99		1	^4P
		1/2	555 341.9	100			
$2s^2 2p^4(^1D)3s$	^2D	5/2	582 562.4	100			
		3/2	582 578.4	100			
$2s^2 2p^4(^3P)3p$	$^4P^\circ$	5/2	*596 521.8*	99		1	$^4D^\circ$
		3/2	*597 065.7*	99		1	$^4D^\circ$
		1/2	*597 583.6*	100			
$2s^2 2p^4(^3P)3p$	$^4D^\circ$	7/2	*603 138.1*	100			
		5/2	*604 003.1*	96		3	$^2D^\circ$
		3/2	*604 662.9*	98		1	$^2D^\circ$
		1/2	*605 033.5*	100			
$2s^2 2p^4(^3P)3p$	$^2D^\circ$	5/2	*607 891.7*	97		3	$^4D^\circ$
		3/2	*609 305.8*	96		3	$^2P^\circ$
$2s^2 2p^4(^3P)3p$		1/2	*610 983.2**	43	$^2P^\circ$	41	$^2S^\circ$
$2s^2 2p^4(^3P)3p$	$^4S^\circ$	3/2	*612 232.4*	93		4	$^2P^\circ$
$2s^2 2p^4(^3P)3p$	$^2P^\circ$	3/2	*612 501.6*	69		20	$(^1D)\ ^2P^\circ$
$2s^2 2p^4(^3P)3p$		1/2	*612 943.5**	58	$^2S^\circ$	31	$^2P^\circ$
$2s^2 2p^4(^1S)3s$	^2S	1/2	624 109.6	99		1	$2p^4(^1D)3d\ ^2S$
$2s^2 2p^4(^1D)3p$	$^2F^\circ$	5/2	*637 879.7*	100			
		7/2	*638 112.9*	100			
$2s^2 2p^4(^1D)3p$	$^2D^\circ$	3/2	*644 643.4*	99		1	$^2P^\circ$
		5/2	*644 786.4*	100			
$2s^2 2p^4(^1D)3p$	$^2P^\circ$	3/2	*650 061.6*	76		24	$(^3P)\ ^2P^\circ$
		1/2	*651 093.9*	75		25	
$2s^2 2p^4(^3P)3d$	^4D	7/2	670 786.1	98		2	^4F
		5/2	671 028.8	97		1	^4F
		3/2	671 324.1	98		1	^4P
		1/2	671 569.4	99			
$2s^2 2p^4(^3P)3d$	^4F	9/2	675 370.2	100			
		7/2	676 075.3	79		21	^2F
		5/2	676 826.4	88		9	^2F
		3/2	677 363.9	97		2	^2D
$2s^2 2p^4(^3P)3d$	^2F	7/2	677 451.9	79		20	^4F
		5/2	678 395.1	77		11	^4F

Mg IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^4(^3P)3d$	^4P	1/2	677 980.0	99		
		3/2	678 428.3	96	1	^2D
		5/2	679 100.8	89	6	^2F
$2s^2 2p^4(^3P)3d$	^2D	3/2	680 033.7	82	11	^2P
		5/2	680 493.2	83	8	^2F
$2s^2 2p^4(^3P)3d$	^2P	1/2	681 023.3	95	4	$(^1D)\ ^2P$
		3/2	682 472.8	85	12	^2D
$2s^2 2p^4(^1S)3p$	$^2P^\circ$	1/2	*682 851.3*	99	1	$(^3P)\ ^2P^\circ$
		3/2	*682 889.5*	99		
$2s^2 2p^4(^1D)3d$	^2G	9/2	709 068.1	100		
		7/2	709 071.2	100		
$2s^2 2p^4(^1D)3d$	^2P	3/2	711 632.7	97	3	$(^3P)\ ^2P$
		1/2	711 880.5	90	7	^2S
$2s^2 2p^4(^1D)3d$	^2S	1/2	712 124.5	91	7	^2P
$2s^2 2p^4(^1D)3d$	^2D	5/2	713 411.0	95	3	^2F
		3/2	713 682.5	97	2	$(^3P)\ ^2D$
$2s^2 2p^4(^1D)3d$	^2F	5/2	714 336.4	97	3	^2D
		7/2	714 352.8	100		
$2s^2 2p^4(^3P)4s$	^4P	5/2	719 784.8	100		
		3/2	721 043.6	88	12	^2P
		1/2	722 001.8	98	2	^2P
$2s^2 2p^4(^3P)4s$	^2P	3/2	723 267.3	88	12	^4P
		1/2	724 816.3	98	2	
$2s^2 2p^4(^1S)3d$	^2D	5/2	752 931.7	99	1	$(^1D)\ ^2D$
		3/2	752 997.4	99	1	
$2s^2 2p^4(^1D)4s$	^2D	5/2	756 866.1	100		
		3/2	756 875.8	100		
$2s^2 2p^4(^3P)4d$	^4P	1/2	767 339?	93	4	^4D
		3/2	767 780	70	16	^4F
		5/2	768 539	58	19	^4F
$2s^2 2p^4(^3P)4d$	^4F	9/2		100		
		7/2		58	40	^2F
		5/2	767 489	62	18	^2F
		3/2	768 294?	74	16	^4P
$2s^2 2p^4(^3P)4d$	^2P	1/2	769 356	94	4	^4D
		3/2	770 948	60	38	^2D
$2s^2 2p^4(^3P)4d$	^2D	3/2	769 421	52	34	^2P
		5/2	770 075	68	24	^2F
$2s^2 2p^4(^3P_2)4f$	$^2[4]^\circ$	9/2	*770 834.0*	97		
		7/2	*770 860.3*	73	24	$^2[3]^\circ$

Mg IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^4(^3P_2)4f$	$^2[3]^\circ$	5/2	*770 910.9*	97		
		7/2	*770 927.5*	73	24	$^2[4]^\circ$
$2s^2 2p^4(^3P_2)4f$	$^2[2]^\circ$	3/2	*771 129.2*	93	7	$(^3P_1)\ ^2[2]^\circ$
		5/2	*771 163.6*	94	6	
$2s^2 2p^4(^3P_2)4f$	$^2[5]^\circ$	11/2	*771 363.4*	100		
		9/2	*771 367.6*	100		
$2s^2 2p^4(^3P_2)4f$	$^2[1]^\circ$	1/2	*771 561.1*	100		
		3/2	*771 582.6*	100		
$2s^2 2p^4(^3P_1)4f$	$^2[2]^\circ$	3/2	*772 849.3*	93	7	$(^3P_2)\ ^2[2]^\circ$
		5/2	*772 861.8*	93	6	
$2s^2 2p^4(^3P_1)4f$	$^2[4]^\circ$	9/2	*772 932.1*	97		
		7/2	*772 945.4*	97		
$2s^2 2p^4(^3P_1)4f$	$^2[3]^\circ$	7/2	*773 228.7*	99		
		5/2	*773 242.1*	99		
$2s^2 2p^4(^3P_0)4f$	$^2[3]^\circ$	7/2	*773 747.0*	98		
		5/2	*773 757.6*	98		
$2s^2 2p^4(^3P)5s$	^4P	5/2				
		3/2	787 315			
		1/2				
$2s^2 2p^4(^3P)5s$	^2P	3/2	788 632			
		1/2	789 881			
$2s^2 2p^4(^1S)4s$	^2S	1/2	797 056	99	1	$2p^4(^1D)4d\ ^2S$
$2s^2 2p^4(^1D)4d$	^2P	3/2	802 244	100		
		1/2	802 306	99	1	$(^3P)\ ^2P$
$2s^2 2p^4(^1D)4d$	^2D	5/2	802 954	91	9	^2F
		3/2	803 054	99		
$2s^2 2p^4(^1D)4d$	^2S	1/2	803 754	98	1	$2p^4(^1S)4s\ ^2S$
$2s^2 2p^4(^1D_2)4f$	$^2[1]^\circ$	1/2	*806 309.7*	100		
		3/2	*806 312.5*	100		
$2s^2 2p^4(^1D_2)4f$	$^2[5]^\circ$	11/2 }	*806 803.4*	100		
		9/2 }		100		
$2s^2 2p^4(^1D_2)4f$	$^2[2]^\circ$	5/2	*806 909.2*	100		
		3/2	*806 911.5*	100		
$2s^2 2p^4(^1D_2)4f$	$^2[3]^\circ$	5/2	*807 455.0*	100		
		7/2	*807 456.0*	100		
$2s^2 2p^4(^1D_2)4f$	$^2[4]^\circ$	7/2	*807 607.8*	100		
		9/2	*807 610.1*	100		
$2s^2 2p^4(^3P)5d$	^4P	1/2	808 965			

Mg IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^4(^3P)5d$	^2F?	5/2	809 127	
$2s^2 2p^4(^3P)5d$		1/2?	809 265	
$2s^2 2p^4(^3P)5d$	^4F?	3/2	810 249	
$2s^2 2p^4(^3P)5d$	^4F?	5/2	810 366	
$2s^2 2p^4(^3P)5d$		1/2?	810 492	
$2s^2 2p^4(^3P)5d$		3/2?	810 590	
$2s^2 2p^4(^3P_2)5f$	$^2[4]^\circ$	9/2	*810 653.7*	
		7/2	*810 659.1*	
$2s^2 2p^4(^3P_2)5f$	$^2[5]^\circ$	11/2	*810 922.2*	
		9/2	*810 922.9*	
$2s^2 2p^4(^3P_2)5g$	$^2[5]$	11/2	810 957.2	
		9/2	810 958.8	
$2s^2 2p^4(^3P_2)5g$	$^2[4]$	7/2	810 959.5	
		9/2	810 960.7	
$2s^2 2p^4(^3P_2)5g$	$^2[3]$	5/2	811 016.8	
		7/2	811 018.2	
$2s^2 2p^4(^3P_2)5g$	$^2[6]$	11/2	811 058.9	
		13/2	811 059.2	
$2s^2 2p^4(^3P_2)5g$	$^2[2]$	3/2	811 097.4	
		5/2	811 100.9	
$2s^2 2p^4(^3P)5d$	^2D	5/2	811 254	
$2s^2 2p^4(^3P)5d$		3/2	811 888	
$2s^2 2p^4(^3P_1)5g$	$^2[3]$	5/2	812 757.0	
		7/2	812 757.9	
$2s^2 2p^4(^3P_1)5g$	$^2[5]$	9/2	812 778.6	
		11/2	812 779.8	
$2s^2 2p^4(^3P_1)5g$	$^2[4]$	9/2	812 859.0	
		7/2	812 859.2	
$2s^2 2p^4(^3P_0)5g$	$^2[4]$	9/2	813 539.9	
		7/2	813 540.8	
$2s^2 2p^4(^1D)5s$	^2D	5/2,3/2	822 734	
$2s2p^5(^3P^\circ)3s$	$^2P^\circ$	3/2	*843 034?*	
		1/2	*844 306?*	
$2s^2 2p^4(^1D)5d$?	^2P?	3/2	843 974	
		1/2	844 036	

Mg IV—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^4(^1S)4d$?	^{2}D?	$5/2$, $3/2$	844 424	100 100
	^{2}D?	$5/2, 3/2$	846 281	
$2s^2 2p^4(^1D_2)5g$	$^2[2]$	$5/2, 3/2$	846 780.7	
$2s^2 2p^4(^1D_2)5g$	$^2[6]$	$13/2, 11/2$	846 858.7	
$2s^2 2p^4(^1D_2)5g$	$^2[3]$	$7/2, 5/2$	846 926.3	
$2s^2 2p^4(^1D_2)5g$	$^2[4]$	$9/2, 7/2$	847 038.2	
$2s^2 2p^4(^1D_2)5g$	$^2[5]$	$11/2, 9/2$	847 048.2	
....	....	....	....	
Mg V ($^3P_2$)	***Limit***		881 285	
Mg V ($^3P_1$)	*Limit*		883 068	
Mg V ($^3P_0$)	*Limit*		883 807	
Mg V ($^1D_2$)	*Limit*		912 211	
Mg V ($^1S_0$)	*Limit*		958 564	

Mg V

$Z=12$

O I isoelectronic sequence

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

Ionization energy 1 139 420 cm^{-1} (141.27 eV)

Söderqvist [1934, 1946] carried out most of the analysis of this spectrum, his later paper giving more than 100 classified lines in the regions 92–119 Å and 351–355 Å. Johannesson, Lundström, and Minnhagen reevaluated the $2s^2 2p^4$ and $2s2p^5$ levels on the basis of their remeasurements of nine lines of the transition array between these configurations (251–355 Å), the $2s^2 2p^4\ {}^3P_2$—$2s2p^5\ {}^1P_1^\circ$ intercombination line at 251.58 Å having been classified by Edlén [1964]. Using the 10.7-m grazing-incidence spectrograph at the National Bureau of Standards, Artru and Kaufman have reobserved the spectrum over the regions covered by Söderqvist. They obtained more accurate wavelengths for all but a few of the lines given by Söderqvist and also measured several new or newly resolved Mg V lines; their wavelengths for the $2s^2 2p^4$—$2s2p^5$ lines agree well with the measurements by Johannesson et al. We have taken the levels of these two low configurations from Johannesson et al. and all but a few of the higher levels from the new determinations by Artru and Kaufman. The $2p^6\ {}^1S_0$ level is from the measurement and identification of the $2s2p^5$—$2p^6\ {}^1S_0$ line (376.665 Å) by Fawcett, Galanti, and Peacock.

The probable errors of the $2s^2 2p^4\ {}^3P$ and $2s2p^5\ {}^3P^\circ$ levels are less than 2 cm^{-1}, and the probable errors of the singlet levels of these configurations are perhaps 3 to 5 cm^{-1}. The probable errors of the $2s^2 2p^3 3s$ levels are about 5 cm^{-1}, and most of the higher levels should be accurate to ± 10 cm^{-1} to ± 20 cm^{-1}; a number of levels above 1 000 000 cm^{-1} with larger probable errors are given only to the nearest 10 cm^{-1}.

The leading percentages are from Artru and Kaufman, whose calculation of the $2s2p^5$, $2s^2 2p^3 3s$, and $2s^2 2p^3 3d$ levels included the interactions between these configurations. They found a number of new $2s^2 2p^3 3s$ and $3d$ levels, including the $2s^2 2p^3 ({}^2P^\circ) 3d\ {}^1P^\circ$ and ${}^1F^\circ$ levels at positions different from those given previously. The revised interpretation of the $2s2p^5\ {}^3P^\circ$—$2s2p^4({}^4P)3s\ {}^3P$ multiplet by Guennou, Sureau, Carillon, and Jamelot, was used in deriving the $2s2p^4({}^4P)3s\ {}^3P$ levels. Artru and Kaufman have made a few other revisions in the analysis of the higher levels, but the work is in progress and some of the results are preliminary. A number of Söderqvist's higher levels were derived from single, relatively weak lines; we have omitted several of these and given others as tentative. The designations of most of the levels above about 1 020 000 cm^{-1} are given here as questionable.

Söderqvist [1946] derived the quoted principal ionization energy. If his interpretation of the $2s^2 2p^3 5d$ levels is in general correct, the $2s^2 2p^3 nd$ series ($n=3,4,5$) confirm this value to within perhaps ± 200 cm^{-1}. We have rounded off the positions of all the limits to the nearest 10 cm^{-1}, more accurate relative values being given in the table for Mg VI.

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Mg V

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^4$	^3P	2	0.0	
		1	1 783.1	
		0	2 521.8	
$2s^2 2p^4$	^1D	2	35 926	
$2s^2 2p^4$	^1S	0	77 279	

Mg v—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s2p^5$	$^3P°$	2	*283 212.3*	100		
		1	*284 828.3*	100		
		0	*285 712.0*	100		
$2s2p^5$	$^1P°$	1	*397 482*	100		
$2p^6$	^1S	0	662 970			
$2s^2 2p^3(^4S°)3s$	$^3S°$	1	*684 541*	100		
$2s^2 2p^3(^2D°)3s$	$^3D°$	3	*727 742*	100		
		2	*727 763*	99		
		1	*727 782*	99		
$2s^2 2p^3(^2D°)3s$	$^1D°$	2	*735 546*	99		
$2s^2 2p^3(^2P°)3s$	$^3P°$	0	*756 545*	99	1	$2s^22p^3(^2D°)3d\ ^3P°$
		1	*756 566*	99	1	
		2	*756 641*	98	1	
$2s^2 2p^3(^2P°)3s$	$^1P°$	1	*764 628*	98	1	$2s^22p^3(^2D°)3d\ ^1P°$
$2s^2 2p^3(^4S°)3d$	$^3D°$	1	*821 974*	98	2	$(^2D°)\ ^3D°$
		2	*821 989*	98	2	
		3	*822 066*	98	2	
$2s^2 2p^3(^2D°)3d$	$^3D°$	3	*871 216*	98	2	$(^4S°)\ ^3D°$
		2	*871 357*	98	2	
		1	*871 390*	97	2	
$2s^2 2p^3(^2D°)3d$	$^1P°$	1	*873 456*	94	3	$(^2P°)\ ^1P°$
$2s^2 2p^3(^2D°)3d$	$^3P°$	2	*876 795*	96	2	$(^2P°)\ ^3P°$
		1	*877 283*	94	4	$^3S°$
		0	*877 463*	99	1	$2s^22p^3(^2P°)3s\ ^3P°$
$2s^2 2p^3(^2D°)3d$	$^1D°$	2	*877 611*	89	10	$(^2P°)\ ^1D°$
$2s^2 2p^3(^2D°)3d$	$^3S°$	1	*879 515*	96	4	$^3P°$
$2s^2 2p^3(^2D°)3d$	$^1F°$	3	*882 791*	99	1	$(^2P°)\ ^1F°$
$2s^2 2p^3(^2P°)3d$	$^3P°$	0	*898 757*	100		
		1	*898 962*	99	1	$(^2D°)\ ^3P°$
		2	*899 369*	97	2	$(^2D°)\ ^3P°$
$2s^2 2p^3(^2P°)3d$	$^1D°$	2	*901 474*	77	14	$^3D°$
$2s^2 2p^3(^2P°)3d$	$^3D°$	3	*902 152*	98		
		2	*902 509*	85	11	$^1D°$
		1	*902 766*	99		
$2s^2 2p^3(^2P°)3d$	$^1F°$	3	*905 370*	99	1	$(^2D°)\ ^1F°$
$2s^2 2p^3(^4S°)4s$	$^3S°$	1	*910 750*			
$2s^2 2p^3(^2P°)3d$	$^1P°$	1	*914 500*	97	3	$(^2D°)\ ^1P°$

Mg v—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s2p^4(^4P)3s$	^3P	2	940 449	
		1	941 944	
		0	942 634	
$2s^2 2p^3(^2D^\circ)4s$	$^3D^\circ$	3	*962 075*	
		2	*962 103*	
		1	*962 114*	
$2s^2 2p^3(^4S^\circ)4d$	$^3D^\circ$	1,2	*962 407*	
		3	*962 445*	
$2s^2 2p^3(^2D^\circ)4s$	$^1D^\circ$	2	*964 836*	
$2s^2 2p^3(^2P^\circ)4s$	$^3P^\circ$	0,1,2	*990 600?*	
$2s^2 2p^3(^2P^\circ)4s$	$^1P^\circ$	1	*993 349*	
$2s2p^4(^4P)3p$?		1,2	*1 003 912*	
$2s^2 2p^3(^2D^\circ)4d$	$^3D^\circ$	3	*1 013 839*	
		2	*1 013 897*	
		1	*1 013 931*	
$2s^2 2p^3(^2D^\circ)4d$	$^1P^\circ$	1	*1 015 615*	
$2s^2 2p^3(^2D^\circ)4d$	$^3P^\circ$	2	*1 017 620*	
		1	*1 018 000*	
		0		
$2s^2 2p^3(^2D^\circ)4d$	$^1D^\circ$	2	*1 018 430*	
$2s^2 2p^3(^2D^\circ)4d$	$^1F^\circ$	3	*1 019 500*	
$2s2p^4(^2D)3s$	^3D	1	1 020 345	
		2	1 020 419	
		3	1 020 522	
		1,2,3	*1 026 270?*	
$2s^2 2p^3(^4S^\circ)5d$?	$^3D^\circ$?	1,2,3	*1 026 780*	
$2s^2 2p^3(^2P^\circ)4d$?	$^3P^\circ$?	0		
		1	*1 042 570*	
		2	*1 042 800*	
$2s^2 2p^3(^2P^\circ)4d$?	$^3D^\circ$?	1,2,3	*1 043 860*	
$2s^2 2p^3(^2P^\circ)4d$	$^1F^\circ$	3	*1 045 350?*	
		2,3	*1 046 200?*	
$2s2p^4(^4P)3d$?	^3D?	1,2,3	1 075 090	
$2s^2 2p^3(^2D^\circ)5d$?	$^3P^\circ$?	1,2	*1 081 880*	
$2s^2 2p^3(^2D^\circ)5d$?		2,3	*1 082 090*	

Mg v—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^3(^2D°)5d$	$^1F°$	3	*1 082 450?*	
$2s^2 2p^3(^2P°)5d$	$^1D°$	2	*1 109 990?*	
....	....	....	....	
Mg VI ($^4S°_{3/2}$)	***Limit***		***1 139 420***	
$2s2p^4(^4P)4s$	^3P	2	1 161 770?	
$2s2p^4(^2D)3d$	^3D	3	1 166 530?	
		2	1 166 590?	
		1	1 166 650?	
Mg VI ($^2D°$)	*Limit*		*1 194 780*	
Mg VI ($^2P°_{1/2}$)	*Limit*		*1 223 340*	
Mg VI ($^2P°_{3/2}$)	*Limit*		*1 223 450*	
$2s2p^4(^4P)5s$	^3P	2	1 250 960?	
Mg VI ($^4P_{5/2}$)	*Limit*		1 387 370	

Mg VI

$Z=12$

N I isoelectronic sequence

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

Ionization energy 1 504 300 cm^{-1} (186.51 eV)

Most of the analysis is due to Söderqvist [1934, 1946], whose list of classified lines covers the region 72–404 Å. Fawcett [1970, 1975] observed and classified transitions from the $2p^5\ ^2P^\circ$ term to the $2s2p^4\ ^2P$ and ^2D terms (436–445 Å and 320–322 Å). Artru and Kaufman have made preliminary remeasurements of 23 Mg VI lines in the important 268–445 Å region using plates obtained with the 10.7-m grazing-incidence vacuum spectrograph at the National Bureau of Standards.

We have made a combination array and reevaluated the levels using all available data. The positions of the doublet levels relative to the $^4S^\circ_{3/2}$ ground level are based on measurements of three $2s^22p^3\ ^4S^\circ$—$2s^22p^3\ ^2P^\circ$, $^2D^\circ$ forbidden lines (near 1190 and 1806 Å) as observed in solar-corona spectra by Sandlin, Brueckner, and Tousey [1977]. The $2s^22p^3\ ^2D^\circ_{3/2}$, $^2P^\circ_{1/2}$, and $^2P^\circ_{3/2}$ levels are probably accurate to ± 1 to ± 2 cm^{-1} with respect to the ground level, and the $^2P^\circ$ interval of 108.4 cm^{-1} is probably accurate to better than ± 1 cm^{-1}; the latter is taken from the data of Artru and Kaufman, and is consistent with the solar-corona measurements. The $2s^22p^3\ ^2D^\circ_{5/2}$ level and most of the $2s2p^4$ and $2p^5$ levels are probably accurate to within ± 5 cm^{-1}, being mainly based on the wavelengths of Artru and Kaufman. The $2s^22p^23l$ and higher levels have been rounded to the nearest 10 cm^{-1}, but some of the higher levels, especially those representing unresolved terms, may be in error by more than 100 cm^{-1}.

Most of the levels assigned to the $2s^22p^23s$, $3d$ even configurations and to the $2s2p^33s$ odd configuration are supported by reasonably strong combinations and/or isoelectronic regularities. A few such levels are marked here as tentative, including some levels derived from single lines also classified as belonging to other ionization stages. A good part of the analysis for the region above 1 200 000 cm^{-1} may be doubtful. We have indicated as questionable a considerable number of levels in this region based on single, usually weak, combinations. A few levels have been omitted here pending confirmation. Some of the designations and J values should also probably be regarded as tentative. More complete and accurate observations might now be possible for the short wavelength portion of this spectrum. Such observations, as well as calculations of the principal configurations, are needed to yield an improved system of energy levels.

Edlén [1964] derived the quoted ionization energy from extrapolation formulae for the isoelectronic sequence. No estimate of the uncertainty was given.

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Mg VI

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^3$	$^4S^\circ$	3/2	*0.0*
$2s^2 2p^3$	$^2D^\circ$	5/2	*55 356*
		3/2	*55 372.8*
$2s^2 2p^3$	$^2P^\circ$	1/2	*83 920.0*
		3/2	*84 028.4*
$2s2p^4$	^4P	5/2	247 948
		3/2	249 584
		1/2	250 450

Mg vi—Continued

Configuration	Term	J	Level (cm^{-1})
$2s2p^4$	^{2}D	5/2	341 751
		3/2	341 793
$2s2p^4$	^{2}S	1/2	401 822
$2s2p^4$	^{2}P	3/2	425 190
		1/2	427 135
$2p^5$	^{2}P°	3/2	*651 867*
		1/2	*654 473*
$2s^2 2p^2(^3P)3s$	^{4}P	1/2	893 940
		3/2	894 890
		5/2	896 440
$2s^2 2p^2(^3P)3s$	^{2}P	1/2	908 410
		3/2	910 300
$2s^2 2p^2(^1D)3s$	^{2}D	3/2,5/2	938 830
$2s^2 2p^2(^1S)3s$	^{2}S	1/2	983 420?
$2s^2 2p^2(^3P)3d$	^{2}P	3/2	1 040 060
		1/2	1 040 680
$2s^2 2p^2(^3P)3d$	^{4}D	7/2	
		5/2,3/2	1 045 210?
		1/2	1 045 620?
$2s^2 2p^2(^3P)3d$	^{2}F	5/2	1 046 420
		7/2	1 048 380
$2s2p^3(^5S°)3s$	^{4}S°	3/2	*1 046 640*
$2s^2 2p^2(^3P)3d$	^{4}P	5/2	1 047 310
		3/2	1 047 990
		1/2	1 048 380
$2s^2 2p^2(^3P)3d$	^{2}D	3/2	1 062 050
		5/2	1 062 620
$2s^2 2p^2(^1D)3d$	^{2}F	7/2	1 083 340
		5/2	1 083 640
$2s^2 2p^2(^1D)3d$	^{2}D	3/2	1 086 570
		5/2	1 086 920
$2s^2 2p^2(^1D)3d$	^{2}P	1/2	1 093 760
		3/2	1 094 250
$2s^2 2p^2(^1D)3d$?	^{2}S?	1/2?	1 099 180
$2s2p^3(^5S°)3p$	^{4}P	1/2–5/2	1 100 150
$2s2p^3(^3D°)3s$	^{4}D°	1/2–7/2	*1 122 020*

Mg VI—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2(^1S)3d$	^2D	3/2,5/2	1 124 890
$2s2p^3(^3D^\circ)3s$	$^2D^\circ$	3/2,5/2	*1 150 840*
$2s2p^3(^3P^\circ)3s$	$^4P^\circ$	1/2–5/2	*1 172 610*
$2s2p^3(^5S^\circ)3d$	$^4D^\circ$	1/2–7/2	*1 175 400*
$2s2p^3(^3P^\circ)3s$	$^2P^\circ$	1/2	*1 192 330*
		3/2	*1 192 580*
$2s^2 2p^2(^3P)4s$	^4P	1/2	
		3/2	
		5/2	1 196 740?
$2s^2 2p^2(^3P)4s$	^2P	1/2	
		3/2	1 199 470
$2s2p^3(^3D^\circ)3p$	^2F	7/2	1 223 280?
		5/2	1 223 920?
$2s^2 2p^2(^1D)4s$	^2D	3/2,5/2	1 235 690
$2s^2 2p^2(^3P)4d$	^4D	7/2	
		5/2,3/2	1 248 830?
		1/2	1 249 500?
$2s^2 2p^2(^3P)4d$	^4P	5/2	1 252 240
		3/2	1 252 660
		1/2	1 252 870
$2s^2 2p^2(^3P)4d$	^2F	5/2	1 252 700?
		7/2	1 254 350?
$2s^2 2p^2(^3P)4d$	^2D	5/2	1 258 380?
$2s2p^3(^3D^\circ)3d$	$^4P^\circ$	5/2	*1 282 030*
		3/2	*1 282 400*
		1/2	*1 282 670*
$2s2p^3(^3D^\circ)3d$	$^4D^\circ$	1/2–7/2	*1 287 040*
$2s2p^3(^3D^\circ)3d$	$^4S^\circ$	3/2	*1 287 890?*
$2s^2 2p^2(^1D)4d$	^2F	7/2,5/2	1 288 310?
$2s2p^3(^3D^\circ)3d$	$^2F^\circ$	7/2	*1 289 600?*
		5/2	*1 290 470?*
$2s^2 2p^2(^1D)4d$	^2D	3/2,5/2	1 290 990
$2s^2 2p^2(^1D)4d$	^2P	1/2,3/2	1 294 150?
$2s^2 2p^2(^1D)4d$	^2S	1/2	1 296 520?

Mg VI—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2(^3P)5s$	^4P	1/2	
		3/2	1 317 700?
		5/2	1 318 670?
$2s2p^3(^5S°)4s$	$^4S°$	3/2	*1 323 610?*
$2s^2 2p^2(^1S)4d$	^2D	3/2,5/2	1 333 500?
$2s2p^3(^5S°)4p$	^4P	1/2–5/2	1 340 950?
$2s^2 2p^2(^3P)5d$	^2F	5/2	1 345 510?
		7/2	1 347 260?
$2s2p^3(^5S°)4d$	$^4D°$	1/2–7/2	*1 373 760*
$2s^2 2p^2(^1D)5d$	^2F	5/2,7/2	1 382 780?
$2s^2 2p^2(^1D)5d$?	^2D?	3/2,5/2	1 384 290
....	....	....	....
Mg VII ($^3P_0$)	***Limit***		**1 504 300**

Mg VII

Z=12

C I isoelectronic sequence

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

Ionization energy 1 814 300 cm^{-1} (224.95 eV)

Söderqvist [1934, 1946] carried out most of the analysis and classified more than 100 lines in the regions 58–112 Å and 276–435 Å. Fawcett [1970, 1971] located the $2p^4$ terms by observing and classifying the lines of the $2s2p^3$—$2p^4$ transition array (321–558 Å). Most of the lines in the 276–558 Å region have been remeasured by Artru and Kaufman [1977] using plates obtained with the 10.7-m grazing-incidence spectrograph at the National Bureau of Standards.

We have combined the available data to reevaluate all the triplet and singlet levels for this spectrum. The singlet-triplet intersystem connection is based on a measurement of the $2s^22p^2\ ^3P_1$—$2s^22p^2\ ^1S_0$ forbidden line (1189.82 Å) as observed in the solar-corona spectrum by Sandlin, Brueckner, and Tousey [1977]; the corresponding wave-number difference is probably accurate to ± 2 cm^{-1}. The other $2s^22p^2$ levels, the $2s2p^3$ singlet and triplet levels, and the $2p^4\ ^3P$ and ^1D levels were evaluated from preliminary new wavelengths obtained by Artru and Kaufman. The probable error for most of these levels is less than 10 cm^{-1}, but the relatively small (and irregular) fine-structure separations given for the $2s2p^3\ ^3P°$ levels are tentative, especially the $^3P^\circ_2$–$^3P^\circ_1$ interval. (The theoretical first-order spin-orbit splittings of both the $2s2p^3\ ^3D°$ and $^3P°$ terms are zero.) We have rounded off the levels above $2p^4\ ^1D_2$ (576 280 cm^{-1}) to the nearest 10 cm^{-1}; some of the higher levels may have errors greater than 100 cm^{-1}.

Each of the quintet levels is followed by "$+x$" to indicate the lack of an experimental connection of the quintet system with the triplet and singlet systems. Söderqvist's estimate for the relative position of the quintet system is adopted, to within a rounding of the lowest ($2s2p^3\ ^5S^\circ_2$) level to the nearest 100 cm^{-1}. The corresponding $2s2p^3\ ^3S°$–$^5S°$ separation implies a value of the exchange integral $G^1(2s2p)$ consistent with the observed $2s2p^3\ ^1D°$–$^3D°$ and $^1P°$–$^3P°$ separations; an absolute value of x greater than 2000 cm^{-1} seems unlikely.

We have used question marks to indicate some levels, term assignments and J values that appear tentative. These mostly occur in the region above 1 230 000 cm^{-1}, including several levels of the $2s2p^23s$, $3p$, and $3d$ configurations. Calculations of these and higher configurations to which terms have been assigned are needed for this isoelectronic sequence. Pending such support, most of the Mg VII level system above 1 400 000 cm^{-1} appears questionable. We have also omitted a few levels based on doubly classified lines or otherwise especially tentative.

Nussbaumer and Rusca [1979] give configuration-mixing coefficients for the three terms of the $2s^22p^2$ ground configuration as calculated in an eleven-configuration expansion. The corresponding two leading eigenvector percentages for each term, to the nearest 0.1%, are:

	$2s^22p^2$	$2p^4$
^3P	97.9	1.4
^1D	97.9	1.4
^1S	94.5	5.1

The coefficients for eight configurations along with their relative signs (not listed here), are tabulated in the reference.

The ionization energy was obtained by Edlén [1964] from extrapolation formulae for the isoelectronic sequence. No estimate of the uncertainty was given.

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Mg VII

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2$	^{3}P	0	0
		1	1 107
		2	2 924
$2s^2 2p^2$	^{1}D	2	40 948
$2s^2 2p^2$	^{1}S	0	85 153
$2s2p^3$	^{5}S°	2	*118 100+x*
$2s2p^3$	^{3}D°	3	*232 853*
		2	*232 957*
		1	*233 024*
$2s2p^3$	^{3}P°	1	*274 897*
		2	*274 904*
		0	*274 947*
$2s2p^3$	^{1}D°	2	*354 401*
$2s2p^3$	^{3}S°	1	*362 117*
$2s2p^3$	^{1}P°	1	*397 153*
$2p^4$	^{3}P	2	542 316
		1	544 393
		0	545 264
$2p^4$	^{1}D	2	576 280
$2p^4$	^{1}S	0	658 440
$2s^2 2p3s$	^{3}P°	0	*1 047 610*
		1	*1 048 400*
		2	*1 050 890*
$2s^2 2p3s$	^{1}P°	1	*1 061 030*
$2s^2 2p3p$	^{3}P	0	1 123 740?
		1	1 124 940
		2	1 125 840
$2s^2 2p3d$	^{3}F°	2	*1 178 750*
		3	
		4	
$2s2p^2(^4P)3s$	^{5}P	1	
		2	1 179 960+x
		3	1 181 440+x
$2s^2 2p3d$	^{1}D°	2	*1 180 910*
$2s^2 2p3d$	^{3}D°	1	*1 191 750*
		2	*1 192 170*
		3	*1 193 050*

Mg vii—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p3d$	$^3P°$	2	*1 196 750*
		1	*1 197 450*
		0	*1 197 850*
$2s2p^2(^4P)3s$	^3P	0	1 211 160?
		1	1 212 030
		2	1 213 670
$2s^2 2p3d$	$^1F°$	3	*1 211 810*
$2s^2 2p3d$	$^1P°$	1	*1 212 800*
$2s2p^2(^4P)3p$	$^3S°$?	1?	*1 235 310*
$2s2p^2(^4P)3p$	$^3D°$?	1	
		2	*1 264 810*
		3	*1 266 060?*
$2s2p^2(^4P)3p$	$^3P°$?	1,2	*1 276 500*
$2s2p^2(^2D)3s$	^3D	3	1 285 190?
$2s2p^2(^2D)3p$	$^3D°$?	1,2,3	*1 299 230*
$2s2p^2(^2D)3s$	^1D	2	1 305 300?
$2s2p^2(^4P)3d$	^5P	3	1 322 700+x
		2	1 323 370+x
		1	1 323 790+x
$2s2p^2(^4P)3d$	^3P	2	1 324 960
		1	1 326 020
		0	1 326 550?
$2s2p^2(^4P)3d$	^3F	2	1 333 170?
		3	1 334 100
		4	1 335 320
$2s2p^2(^2D)3p$	$^1F°$	3	*1 349 990*
$2s2p^2(^4P)3d$	^3D	1	1 350 640
		2	1 350 930
		3	1 351 340
$2s2p^2(^2D)3p$	$^1D°$	2	*1 357 170*
$2s2p^2(^2D)3d$	^3F?	2,3,4	1 414 290
$2s2p^2(^2D)3d$	^3D	1	
		2	1 422 020?
		3	1 422 600?
$2s2p^2(^2D)3d$	^3S	1	1 437 260?
$2s2p^2(^2D)3d$	^1F?	3?	1 438 340?
$2s^2 2p4d$	$^1D°$	2	*1 465 590?*

Mg VII—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p4d$	$^3D°$	1	
		2	*1 469 540?*
		3	*1 470 410?*
$2s^2 2p4d$	$^3P°$	2	*1 472 130?*
$2s^2 2p4d$	$^1F°$	3	*1 477 420?*
$2s^2 2p4d$	$^1P°$	1	*1 478 180?*
$2s2p^2(^4P)4s$	^5P	3	1 548 720+x?
$2s2p^2(^4P)4p$	$^3D°$	3	*1 580 310?*
$2s^2 2p5d$	$^3P°$	2	*1 597 920?*
$2s2p^2(^4P)4d$	^5P	3	1 599 650+x
		2	1 600 240+x
		1	1 600 610+x
$2s^2 2p5d$	$^1F°$	3	*1 600 470?*
$2s2p^2(^4P)4d$	^3F	2	1 604 840?
		3	1 605 600?
		4	1 606 730?
$2s^2 2p6d$	$^3P°$	0,1,2	*1 665 770?*
$2s2p^2(^2D)4d$	^3F	4	1 695 870?
$2s2p^2(^4P)5p$	$^3D°$	3	*1 717 720?*
$2s2p^2(^4P)5d$	^5P	3	1 726 700+x?
$2s2p^2(^4P)5d$	^3F	4	1 730 130?
$2s2p^2(^4P)6d$	^5P	3	1 794 830+x?
Mg VIII ($^2P°_{1/2}$)	***Limit***		**1 814 300**

Mg VIII

$Z=12$

B I isoelectronic sequence

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

Ionization energy $2\ 145\ 100 \pm 300$ cm^{-1} (265.96 ± 0.04 eV)

Most of the levels were located and interpreted by Söderqvist [1944], whose lists of classified lines extend from 52–437 Å. Fawcett [1970] first observed the $2s2p^2$—$2p^3$ doublet transitions in the 342–690 Å region. The short wavelength spectrum was reobserved by Hoory, Goldsmith, Feldman, Behring, and Cohen [1971], who list 12 newly classified lines in the 50–60 Å region. Artru and Kaufman [1977] have observed and remeasured this spectrum from 312 to 690 Å using mainly the 10.7-m grazing incidence spectrograph at the National Bureau of Standards.

We have reevaluated all the levels by combining the observations cited above. The $2s^2 2p\ ^2P^\circ_{1/2}$—$^2P^\circ_{3/2}$ interval is based on a measurement of the corresponding infrared forbidden line in the solar coronal spectrum [Münch, Neugebauer, and McCammon, 1967], the wavenumber equivalent being 3302.2 ± 2 cm^{-1}. The $2s2p^2$ and $2p^3$ doublet levels were determined from the preliminary wavelengths of Artru and Kaufman; the probable error of these levels varies from less than 10 to about 20 cm^{-1}. The higher levels (above 1 000 000 cm^{-1}) are in general less accurate, and in some cases errors larger than 200 cm^{-1} may be expected, particularly for "levels" representing unresolved terms (multiple J values).

No doublet-quartet intersystem lines have been identified, as is indicated by the addition of a quantity "x" to the quartet levels. We have taken the intersystem connection as derived by Edlén from a new treatment of the $2s^2 2p\ ^2P^\circ$—$2s2p^2\ ^4P$ separation along the isoelectronic sequence [Edlén, 1979; see Edlén et al., 1969]. Although the result is preliminary, Edlén notes that a change of more than about 30 cm^{-1} is not expected. We derived the $2s2p^2\ ^4P$—$2p^3\ ^4S^\circ$ level separations from the data of Artru and Kaufman, and of Fawcett.

Some of the levels based on single combinations and/or doubly classified lines are given here as tentative. A number of the higher levels of this type assigned to configurations having $2s2p$ or $2p^2$ excited cores appear especially questionable. We have also omitted a few levels derived from single weak lines, pending more complete observations and theoretical analysis.

Hoory et al. derived the ionization energy by application of a Ritz formula to the $2s^2nd\ ^2D$ series ($n=3$–6).

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Mg VIII

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p$	$^2P^\circ$	1/2	*0*
		3/2	*3 302*
$2s2p^2$	^4P	1/2	129 890+x
		3/2	131 030+x
		5/2	132 710+x
$2s2p^2$	^2D	5/2	232 274
		3/2	232 307
$2s2p^2$	^2S	1/2	298 282
$2s2p^2$	^2P	1/2	312 721
		3/2	320 725

Mg VIII—Continued

Configuration	Term	J	Level (cm^{-1})
$2p^3$	$^4S°$	3/2	*413 610+x*
$2p^3$	$^2D°$	5/2	*465 745*
		3/2	*465 818*
$2p^3$	$^2P°$	1/2	*524 652*
		3/2	*524 841*
$2s^2 3s$	^2S	1/2	1 210 690
$2s^2 3d$	^2D	3/2	1 335 860
		5/2	1 336 030
$2s2p(^3P°)3s$	$^4P°$	1/2	*1 351 390+x*
		3/2	*1 352 530+x*
		5/2	*1 354 550+x*
$2s2p(^3P°)3s$	$^2P°$	1/2	*1 381 450*
		3/2	*1 383 760*
$2s2p(^3P°)3p$	^2P	1/2	1 408 370
		3/2	1 409 400
$2s2p(^3P°)3p$	^2D	3/2	1 440 610
		5/2	1 442 830
$2s2p(^3P°)3p$	^2S	1/2	1 460 910
$2s2p(^3P°)3d$	$^4D°$?	1/2	
		3/2	*1 476 260+x?*
		5/2	*1 476 590+x*
		7/2	*1 477 410+x?*
$2s2p(^3P°)3d$	$^2D°$	3/2	*1 478 340*
		5/2	*1 478 690*
$2s2p(^3P°)3d$	$^4P°$	5/2	*1 483 690+x*
		3/2	*1 484 420+x*
		1/2	*1 484 910+x*
$2s2p(^1P°)3s$	$^2P°$	1/2,3/2	*1 486 970*
$2s2p(^3P°)3d$	$^2F°$	5/2	*1 504 990*
		7/2	*1 507 040*
$2s2p(^3P°)3d$	$^2P°$	3/2	*1 513 100?*
		1/2	*1 514 260?*
$2s2p(^1P°)3p$	^2D	3/2	
		5/2	1 548 850
$2s2p(^1P°)3p$	^2P	1/2	1 549 990
		3/2	1 550 560
$2s2p(^1P°)3p$	^2S	1/2	1 556 590

Mg VIII—Continued

Configuration	Term	J	Level (cm^{-1})
$2p^2(^3P)3s$	^4P	1/2	1 587 970+x
		3/2	1 589 200+x
		5/2	1 591 200+x
$2s2p(^1P°)3d$	$^2F°$	5/2,7/2	*1 597 480 ?*
$2s2p(^1P°)3d$	$^2D°$	3/2	*1 607 850*
		5/2	*1 608 210*
$2s2p(^1P°)3d$	$^2P°$	1/2,3/2	*1 610 670*
$2p^2(^1D)3s$	^2D	3/2,5/2	1 638 790
$2p^2(^3P)3p$	$^4D°$	7/2	*1 646 280+x?*
$2s^2 4s$	^2S	1/2	1 647 880
$2p^2(^3P)3p$	$^4P°$?	5/2?	*1 652 310+x*
$2p^2(^3P)3p$	$^4S°$?	3/2?	*1 674 020+x*
$2p^2(^1D)3p$	$^2F°$	5/2	*1 690 460?*
		7/2	*1 691 060?*
$2s^2 4d$	^2D	3/2,5/2	1 693 830
$2p^2(^3P)3d$	^2F	7/2	1 702 010?
$2p^2(^3P)3d$	^2D	5/2	1 703 280?
$2p^2(^3P)3d$	^4P	5/2	1 715 900+x
		3/2	1 716 710+x
		1/2	1 717 150+x
$2p^2(^1D)3d$	^2D	5/2	1 733 900?
$2p^2(^1D)3d$	^2F	7/2	1 752 130?
$2p^2(^1D)3d$	^2P	1/2	1 753 640?
		3/2	1 754 790?
$2s2p(^3P°)4s$	$^4P°$?	5/2	*1 788 830+x*
$2s2p(^3P°)4p$	^2P	3/2	1 814 170?
$2s2p(^3P°)4p$	^2D	3/2	1 823 050?
		5/2	1 825 260?
$2s2p(^3P°)4d$	$^4D°$	1/2	
		3/2	
		5/2	*1 837 110+x?*
		7/2	*1 837 250+x*
$2s2p(^3P°)4d$	$^2D°$	3/2,5/2	*1 837 640*

Mg VIII—Continued

Configuration	Term	J	Level (cm^{-1})
$2s2p(^3P°)4d$	$^4P°$	5/2	*1 838 790+x?*
		3/2	*1 839 350+x?*
		1/2	
$2s2p(^3P°)4d$	$^2F°$	5/2	*1 846 150?*
		7/2	*1 848 020?*
$2s^2 5d$	^2D	3/2	1 858 320
		5/2	1 858 420
$2s^2 6d$	^2D	3/2,5/2	1 946 060
$2s2p(^1P°)4d$	$^2F°$	5/2,7/2	*1 964 300?*
$2s2p(^1P°)4d$	$^2D°$	3/2,5/2	*1 968 690?*
$2s2p(^3P°)5d$	$^4D°$	1/2	
		3/2	
		5/2	*2 000 750+x?*
		7/2	*2 001 450+x*
$2s2p(^3P°)5d$	$^4P°$	5/2	*2 002 380+x*
$2s2p(^3P°)5d$	$^2F°$	5/2	*2 005 260?*
		7/2	*2 006 650?*
$2p^2(^3P)4p$	$^4D°$	7/2	*2 041 290+x?*
$2s2p(^3P°)6d$	$^2F°$	7/2	*2 092 940?*
$2s2p(^1P°)5d$	$^2F°$	5/2,7/2	*2 130 100?*
$2s2p(^1P°)5d$	$^2D°$	3/2,5/2	*2 132 420?*
....	....	....	....
Mg IX ($^1S_0$)	***Limit***		**2 145 100**

Mg IX

$Z=12$

Be I isoelectronic sequence

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

Ionization energy 2 644 700±400 cm^{-1} (327.90±0.05 eV)

The 65 classified lines given by Söderqvist [1944] for this spectrum extend from 46 to 444 Å. Fawcett [1970] observed six additional lines of the $2s2p$–$2p^2$ array, including the $^1P^\circ_1$—$^1D_2$ line at 749.55 Å. Hoory, Feldman, Goldsmith, Behring, and Cohen [1970] extended several of the series found by Söderqvist and classified 14 lines in the 40–47 Å region.

We have reevaluated the levels using wavelengths from several different investigations. The singlet-triplet connection is taken from Ridgeley and Burton's observations of the $2s^2\ ^1S_0$—$2s2p\ ^3P^\circ_1$ line in the solar limb spectrum (706.06±0.05 Å, equivalent to 141 631±10 cm^{-1}). The other $2s2p\ ^3P^\circ$ and $2p^2\ ^3P$ levels are mostly based on Artru's unpublished remeasurements of the lines connecting these terms in the 439–448 Å region. Although Fawcett's $2s2p\ ^3P^\circ_0$—$2p^2\ ^3P_1$ line at 441.20 Å is almost coincident with a Mg VI line, the resulting $2s2p\ ^3P^\circ_0$ level gives isoelectronic regularity in the $2s2p\ ^3P^\circ$ intervals ratio. The relative errors of the other $2s2p\ ^3P^\circ$ and $2p^2\ ^3P$ levels are probably within ±15 cm^{-1}, and the $2s2p\ ^1P^\circ$, $2p^2\ ^1D$ and $2p^2\ ^1S$ levels are probably accurate to about ±30 cm^{-1}. Edlén [1979] has derived new values for the $2s2p$ and $2p^2$ levels from semi-empirical treatments of the $2s^2$, $2s2p$, and $2p^2$ configurations along the isoelectronic sequence; the largest difference between his values and those given here is 7 cm^{-1} (his value for $2s2p\ ^1P^\circ_1$ being 271 694 cm^{-1}).

The errors of some of the higher levels, which have been rounded to the nearest 10 cm^{-1}, are likely to exceed 100 cm^{-1}. The $2p3p\ ^3D_1$ and $^3D_2$ levels are given here as tentative, each being derived from a single line not expected to be the strongest combination. We have omitted Söderqvist's $2p3p\ ^3P_0$ level because both the wavelength and relative intensity of the line on which it was based fit the expected strongest transition of the same multiplet, $2s2p\ ^3P^\circ_2$—$2p3p\ ^3P_2$. Although a significant number of the levels (including, for example, all the even-parity singlets above $2p^2\ ^1S_0$) are based on single combinations, their reality is in most cases assured by isoelectronic and series regularities.

We have rederived the ionization energy from quantum-defect plots for the $2snd\ ^3D_3$ and $^1D_2$ series ($n=3$–7). Both series yield the same limit, given above, which is significantly below the values obtained by Söderqvist and by Hoory et al. The estimated error is based on the deviations of the series from Ritz-formula behavior, which for the higher members may be partly due to experimental errors. We also graphed the $2pnd\ ^1F^\circ_3$ series, which might be relatively unperturbed and should approach the Mg X $1s^22p\ ^2P^\circ_{3/2}$ limit 2 808 700±400 cm^{-1} above the Mg IX $1s^22s^2\ ^1S_0$ ground level. The $2p3d$, $4d$, and $5d\ ^1F^\circ_3$ levels approach this limit with Ritzian behavior, but the quantum-defect deviations of the $2p6d$ and $2p7d\ ^1F^\circ_3$ levels from the indicated graph are equivalent to about 700 cm^{-1}; the discrepancy might be due in part to wavelength errors.

Using laser-produced plasma sources, Boiko et al. have observed and identified several spectral features in the vicinity of 9.4 Å as arising from Mg IX configurations having a $1s$ vacancy, *i.e.*, from transitions of the type $1s^22s^M2p^N$—$1s2s^M2p^{N+1}$ ($M+N=2$). The terms of such upper configurations lie far above the principal ionization limit, of course, and are subject to autoionization. Some of the levels of such terms that contributed to interpreted features are given here. Most of the features were classified as blends, the observed wavelengths agreeing with those expected from the contributing calculated transitions. We obtained the levels given in brackets from known lower levels and the theoretical wavelengths given by Boiko et al. Two of the autoionizing levels were derived from the measured wavelengths of apparently unblended lines. The calculated wavelengths given by Boiko et al. may be comparable in accuracy with the observations, the wavenumber uncertainty of the measurements being about ±2300 cm^{-1}.

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Mg IX

Configuration	Term	J	Level (cm^{-1})
$2s^2$	^1S	0	0
$2s2p$	$^3P^\circ$	0	*140 504*
		1	*141 631*
		2	*144 091*
$2s2p$	$^1P^\circ$	1	*271 687*
$2p^2$	^3P	0	365 856
		1	367 159
		2	369 330
$2p^2$	^1D	2	405 100
$2p^2$	^1S	0	499 633
$2s3s$	^3S	1	1 532 450
$2s3s$	^1S	0	1 558 080
$2s3p$	$^1P^\circ$	1	*1 593 600*
$2s3d$	^3D	1	1 631 040
		2	1 631 170
		3	1 631 320
$2s3d$	^1D	2	1 654 580
$2p3s$	$^3P^\circ$	0	*1 710 140*
		1	*1 711 250*
		2	*1 713 900*
$2p3s$	$^1P^\circ$	1	*1 743 040*
$2p3p$	^1P	1	1 748 120
$2p3p$	^3D	1	1 755 470?
		2	1 756 470?
		3	1 758 970
$2p3p$	^3S	1	1 770 380
$2p3p$	^3P	0	
		1	1 778 690
		2	1 779 990
$2p3d$	$^1D^\circ$	2	*1 789 640*
$2p3p$	^1D	2	1 795 870
$2p3d$	$^3D^\circ$	1	*1 807 320*
		2	*1 807 860*
		3	*1 808 860*
$2p3d$	$^3P^\circ$	2	*1 815 220*
		1	*1 816 210*
		0	*1 816 730*

Mg IX—Continued

Configuration	Term	J	Level (cm^{-1})
$2p3d$	$^1F^\circ$	3	*1 834 690*
$2p3d$	$^1P^\circ$	1	*1 841 560*
$2s4p$	$^1P^\circ$	1	*2 068 680*
$2s4d$	^3D	1,2	2 079 970
		3	2 080 050
$2s4d$	^1D	2	2 087 890
$2p4p$	^3D	3	2 229 730
$2p4p$	^3P	2	2 235 350
$2p4p$	^1D	2	2 241 080
$2p4d$	$^1D^\circ$	2	*2 241 210*
$2p4d$	$^3D^\circ$	3	*2 248 250*
$2p4d$	$^3P^\circ$	2	*2 249 450*
		1	*2 249 970*
		0	
$2p4d$	$^1F^\circ$	3	*2 256 570*
$2p4d$	$^1P^\circ$	1	*2 258 310*
$2s5p$	$^1P^\circ$	1	*2 280 870*
$2s5d$	^3D	2,3	2 284 920
$2s5d$	^1D	2	2 288 380
$2s6p$	$^1P^\circ$	1	*2 392 170*
$2s6d$	^3D	2,3	2 395 290
$2s6d$	^1D	2	2 397 490
$2p5p$	^3P	2	2 443 950
$2p5p$	^1D	2	2 446 550
$2p5d$	$^3D^\circ$	3	*2 451 620*
$2p5d$	$^1F^\circ$	3	*2 454 530*
$2s7p$	$^1P^\circ$	1	*2 460 750*
$2s7d$	^3D	2,3	2 462 300
$2s7d$	^1D	2	2 462 990
$2p6d$	$^1F^\circ$	3	*2 563 060?*

Mg IX—Continued

Configuration	Term	*J*	Level (cm^{-1})
$2p7d$	$^1F^\circ$	3	*2 628 160?*
....	....	....	....
Mg X ($^2S_{1/2}$)	***Limit***		**2 644 700**
Mg X ($^2P^\circ_{1/2}$)	*Limit*		*2 804 700*
Mg X ($^2P^\circ_{3/2}$)	*Limit*		*2 808 700*
$1s2s^2 2p$	$^1P^\circ$	1	[*10 657 600*]
$1s(^2S)2s2p^2(^2D)$	^3D	3	[10 763 400]
		2	[10 764 000]
		1	[10 764 600]
$1s(^2S)2s2p^2(^4P)$	^3P	0	[10 765 600]
		1	[10 767 000]
		2	[10 769 300]
$1s(^2S)2s2p^2(^2P)$	^3P	2	[10 865 600]
$1s(^2S)2s2p^2(^2P)$	^1P	1	10 917 900
$1s2p^3$	$^3P^\circ$	2	[*11 020 700*]
$1s2p^3$	$^1P^\circ$	1	*11 080 900*

Mg X

$Z=12$

Li I isoelectronic sequence

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

Ionization energy 2 963 970±250 cm^{-1} (367.49±0.03 eV)

Söderqvist [1944] classified the $2s$–$3p$,$4p$ and $2p$–$3s$,$3d$,$4d$ transitions in this spectrum. Since the $2s$—$2p$ resonance lines were not observed, he fixed the relative positions of the two resulting term systems by extrapolation of isoelectronic regularities. This procedure, together with an extrapolation-based value for the $3d\ ^2D$ quantum defect, also yielded a value for the ionization energy (2 963 810 cm^{-1}). Observations of the $2s$–np, $2p$–ns, and $2p$–nd series were extended to higher members by Feldman, Cohen, and Behring [1970], whose line list extends from 35 to 66 Å. Fawcett [1970] measured the $2s$–$2p$ resonance doublet (610 and 625 Å), and he also observed the $3p$–$4d$ and $3d$–$4f$ lines (near 182 and 187 Å), the latter as an unresolved blend [Fawcett, 1971].

We have reevaluated the levels below the $1s^2\ ^1S_0$ principal ionization limit by combining the available measurements. The $2p\ ^2P°$ levels are based on the wavelengths of the $2s$–$2p$ doublet as measured in the solar spectrum by Behring, Cohen, Feldman, and Doschek [1976]; these levels are probably accurate to ±3 cm^{-1}. The estimated errors of the higher levels vary from perhaps 150 cm^{-1} to about 1000 cm^{-1}. The $4p\ ^2P°$ term position near 2 270 900 cm^{-1} predicted by Edlén's [1979] isoelectronic treatment may well be more accurate than the position some 750 cm^{-1} lower obtained from Söderqvist's wavelengths for the $2s$–$4p$ line. The $n=3$ and $n=4$ levels are rounded to the nearest 10 cm^{-1} and the remaining higher levels (below the $1s^2\ ^1S_0$ limit) to the nearest 100 cm^{-1}. The $5d$ and $6d\ ^2D$ positions are averages obtained from the two diagonal $2p\ ^2P°$—$nd\ ^2D$ lines in each case, the experimental accuracy being insufficient to yield meaningful ^2D intervals.

A quantum-defect plot of the $nd\ ^2D$ series as now known ($n=3$–6) yields an ionization energy of 2 963 800 cm^{-1}, the same value as obtained by Söderqvist (to the nearest 100 cm^{-1}). The probable error of this result is several hundred cm^{-1}, due mainly to the experimental uncertainties of the $nd\ ^2D$ terms. We also derived the ionization energy by adding to the experimental $4f\ ^2F°$ position the theoretical hydrogenic $4f$ term value with respect to the limit (including the relativistic correction) and a small core-polarization term defect given by Edlén. The result, 2 963 970 cm^{-1}, is given above with an error somewhat larger than the estimated probable error of the experimental $4f\ ^2F°$ position. This ionization energy is consistent with the lower value obtained from the $nd\ ^2D$ series and with the values 2 964 030 to 2 964 100 cm^{-1} obtained by Edlén from isoelectronic regularities.

Several terms of configurations having a $1s$-electron vacancy are listed. Lines arising from such terms, which of course lie far above the $1s^2\ ^1S$ ionization limit, are mostly observed as "satellites" of lines from corresponding transitions in Mg XI. The $1s2s2p$ and $1s2p^2$ terms are based on wavelengths near 9.3 Å, mainly as measured by Aglitskii, Boiko, Zakharov, Pikuz, and Faenov [1974], but also with some use of the measurements of Peacock, Hobby, and Galanti [1973] and Flemberg [1942]. Aglitskii et al. and Peacock et al. used laser-produced plasma sources, the uncertainty of most of the wavelengths of Aglitskii et al. corresponding to about ±2000 cm^{-1}. Since the lines from the $1s(^2S)2s2p(^1P°)\ ^2P°$ term are blended with lines from other terms, we give a value of this term (rounded to the nearest 1000 cm^{-1}) obtained from theoretical wavelengths quoted in the review by Boiko, Faenov, and Pikuz [1978]. This paper includes experimental and theoretical wavelengths of lines from other autoionizing terms not given here, and also has numerous references to earlier research on such spectra.

Satellites of the Mg XI $1s^2\ ^1S$—$1s3p\ ^1P°$ line at 7.85 Å have also been measured and assigned to Mg X. Two $1s2s3p\ ^2P°$ terms and two $1s2p3p$ terms which contribute to such satellites are given here. Except for the $1s2p(^3P°)3p\ ^2D$ term, the positions are based on wavelengths measured by Boiko, Pikuz, Safronova, and Faenov [1978] and by Feldman, Doschek, Nagel, Cowan, and Whitlock [1974]. Since the lines from the ^2D term were not resolved from other lines, we derived the ^2D position using calculated wavelengths from Boiko, Pikuz, Safronova, and Faenov. Wavelengths for transitions from a number of terms not listed here are given in their paper.

The Mg XI $1s2s\ ^3S$ limit was obtained by combining a calculated value of this term (see Mg XI) with the adopted Mg XI $1s^2\ ^1S_0$ limit relative to the Mg X ground level.

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Mg x

Configuration	Term	*J*	Level (cm⁻¹)
$1s^2(^1S)2s$	^2S	1/2	0
$1s^2(^1S)2p$	$^2P^\circ$	1/2	*160 015*
		3/2	*163 990*
$1s^2(^1S)3s$	^2S	1/2	1 682 700
$1s^2(^1S)3p$	$^2P^\circ$	1/2	*1 726 520*
		3/2	*1 727 830*
$1s^2(^1S)3d$	^2D	3/2	1 743 500
		5/2	1 743 890
$1s^2(^1S)4p$	$^2P^\circ$	1/2,3/2	*2 270 150*
$1s^2(^1S)4d$	^2D	3/2	2 277 380
		5/2	2 277 700
$1s^2(^1S)4f$	$^2F^\circ$	5/2,7/2	*2 278 010*
$1s^2(^1S)5s$	^2S	1/2	2 511 600
$1s^2(^1S)5p$	$^2P^\circ$	1/2,3/2	*2 520 900*
$1s^2(^1S)5d$	^2D	3/2	2 524 400
		5/2	2 524 600
$1s^2(^1S)6p$	$^2P^\circ$	1/2,3/2	*2 656 500*
$1s^2(^1S)6d$	^2D	3/2,5/2	2 658 800
$1s^2(^1S)7p$	$^2P^\circ$	1/2,3/2	*2 738 400*
$1s^2(^1S)7d$	^2D	3/2,5/2	2 739 600
$1s^2(^1S)8p$	$^2P^\circ$	1/2,3/2	*2 791 200*
$1s^2(^1S)9p$	$^2P^\circ$	1/2,3/2	*2 827 600*
....	....	....	....
Mg XI ($^1S_0$)	***Limit***		**2 963 970**
$1s(^2S)2s2p(^3P^\circ)$	$^2P^\circ$	1/2,3/2	*10 772 000*
$1s(^2S)2s2p(^1P^\circ)$	$^2P^\circ$	1/2,3/2	[*10 829 000*]
$1s(^2S)2p^2(^1D)$	^2D	3/2,5/2	10 894 000
$1s(^2S)2p^2(^3P)$	^2P	1/2,3/2	10 922 000

Mg x—Continued

Configuration	Term	J	Level (cm^{-1})
$1s(^2S)2p^2(^1S)$	^2S	1/2	11 009 000
$1s2s(^3S)3p$	$^2P°$	1/2,3/2	*12 419 000*
$1s2s(^1S)3p$	$^2P°$	1/2,3/2	*12 504 000*
$1s2p(^3P°)3p$	^2P	1/2,3/2	12 518 000
$1s2p(^3P°)3p$	^2D	3/2,5/2	[12 561 000]
Mg XI ($1s2s\ ^3S_1$)	*Limit*		[13 700 400]

Mg XI

Z=12

He I isoelectronic sequence

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

Ionization energy 14 210 170±15 cm^{-1} (1761.851±0.005 eV)

1*sns* and 1*snp* Terms

The 1*sns* and 1*snp* levels for $n=2$–5, as well as the ionization energy, were obtained from calculated values given in an unpublished supplement to the paper by Ermolaev and Jones [1974]. The largest uncertainty estimate given by these authors corresponds to ±10 to ±15 cm^{-1} for the Mg XI levels. Even if the errors are significantly larger, the calculated levels are nevertheless expected to be more accurate than values derived from available observations; for example, Flemberg's measurements of the $1s^2\ ^1S_0$—1*snp* $^1P^\circ_1$ wavelengths (7.3–9.2 Å), which are among the most accurate observations of these lines, have estimated uncertainties corresponding to ±600 cm^{-1} or more. The three lowest $^1P^\circ_1$ levels ($n=2,3,4$) as derived from Flemberg's determinations agree with the values given here to within ±400 cm^{-1}. References to more recent observations and analysis of this spectrum in the 7–9 Å region are given by Boiko, Faenov, and Pikuz [1978].

The solar-coronal observations by Walker, Rugge, and Weiss [1974] extended identification of the $1s^2\ ^1S_0$—1*snp* $^1P^\circ_1$ series to $n=9$. We have derived the values of the 1*snp* $^1P^\circ_1$ levels for $n=6$–10 by a quantum-defect extrapolation based on Ermolaev and Jones' calculations (Figure 1). The accuracy of these levels may be comparable with the accuracy of the lower ($n=2$–5) calculated levels. Predictions of the $1s^2\ ^1S_0$—1*snp* $^1P^\circ_1$ series based on either Flemberg's observations or Ermolaev and Jones' calculations of the lower members indicate that the predicted wavelengths listed by Walker et al. for the higher members are in error by up to 0.01 Å (for $n=9$, at 7.12 Å).

1*snd* and 1*snf* Terms

We have also given theoretical values for the 1*snd* and 1*snf* terms for $n\leqslant5$. Transitions from the 1*snd* terms may have been observed in solar-flare spectra [Kastner, Neupert, and Swartz], but the theoretical values are preferred until definite identifications and measurements of unblended lines from these terms are available. The theoretical terms are based on variational calculations for 1*s*3*d* [Brown, 1968] and higher 1*snd* terms [Brown and Cortez, 1971] and for 1*snf* terms [Brown, 1969]. Since these calculations did not include relativistic and radiative corrections, we first combined the resulting 1*snl* term values (obtained from the total energies) with the Mg XII 1*s* ionization limit of Ermolaev and Jones (given above) to obtain 1*snl* levels effectively including these corrections for the 1*s* electron. As an approximation for the much smaller relativistic shift associated with the *nl* electron, we then assumed the hydrogenic Sommerfeld-Dirac correction for the baricenter of the corresponding *nl* term in a hydrogenic ion with core charge $Z_c=11$ [Edlén, p. 192, Table 51]. This latter relativistic lowering of the levels varies from 475 cm^{-1} for the 1*s*3*d* terms to 93 cm^{-1} for the 1*s*5*f* terms. A comparison with the 1*s*3*l* terms given by Vainshtein and Safronova [1976] is of interest, since their calculations included relativistic and radiative effects: their results give both the 1*s*3*d* ^{3}D and ^{1}D terms about 100 cm^{-1} lower relative to the 1*s*3*s* singlet-triplet mean position, or 150 cm^{-1} lower relative to the 1*s*3*p* mean position, than is obtained with the levels given here. The positions of the 1*s*3*l* levels with respect to the $1s^2\ ^1S_0$ ground level as calculated by Vainshtein and Safronova, however, are higher than the values here by 790 to 940 cm^{-1} for the 1*s*3*s* and 1*s*3*p* levels and by 750 cm^{-1} for the 1*s*3*d* levels. The fine-structure separations of the 1*s*3*d* ^{3}D levels are from Vainshtein and Safronova's results. All of the 1*snd* and 1*snf* levels are rounded to the nearest 10 cm^{-1}.

It is also of interest to compare the 1*snd* and 1*snf* terms with values obtained from the core-polarization theory of term defects in two-electron ions. We derived 1*snl* singlet-triplet mean positions using the core-polarization formulae (dipole plus quadrupole-polarizability approximation [Martin, 1970; Edlén, 1964, Sec. 20]) and the same *nl* relativistic shifts as above. The positions agree with the corresponding means of the term values given here to within 20 cm^{-1} for the 1*snd* terms and 3 cm^{-1} for the 1*snf* terms. These results indicate that relatively accurate values for all the 1*snl* ($l\geqslant2$) singlet-triplet mean energies can be similarly obtained.

Doubly-Excited Configurations

Satellites of the Mg XII 1*s* ^{2}S—2*p* ^{2}P° resonance doublet lines at 8.42 Å have been observed in both laboratory and solar spectra. The satellite lines are mainly blends of transitions of the type 1*snl'*—2*pnl'* in Mg XI, the stronger features being assigned to 2*s*2*p* and $2p^2$ upper configurations [see, for example, Boiko et al., 1978, and their references to earlier work]. Values for the levels of these two doubly-excited configurations are included here, all but one being derived from theoretical wavelengths calculated by Vainshtein and Safronova [1978] combined with lower (single-excitation) levels as given here. The $2p^2\ ^1D_2$ level is based on an average value for the 1*s*2*p* $^1P^\circ_1$—$2p^2\ ^1D_2$ wavelength as measured by Aglitskii et al. [1974] and by Feldman et al. [1974]. Transitions from the other doubly-excited terms apparently occur as components of blends, according to the more recent interpretations of some observers [for example, see Table 6 of Boiko et al., 1978, and Table 4 of Boiko et al., 1977]. The experimental error for the better measurements of such features corresponds to about $\pm 2000\ cm^{-1}$, and the theoretical calculations have been verified to within this error. Although the uncertainty of the theoretical levels is at least several hundred cm^{-1}, we give the values to the nearest 100 cm^{-1} to avoid rounding-off errors in the recovery of the original theoretical wavelengths. Transitions from upper terms belonging to configurations of the type $2l3l'$ have also been identified as contributing to satellite features in the spectra of laser-produced plasmas and solar flares. We have not included these terms here, but experimental and theoretical wavelengths for such transitions are given by Boiko et al. [1977] and Aglizki et al. [1978], for example.

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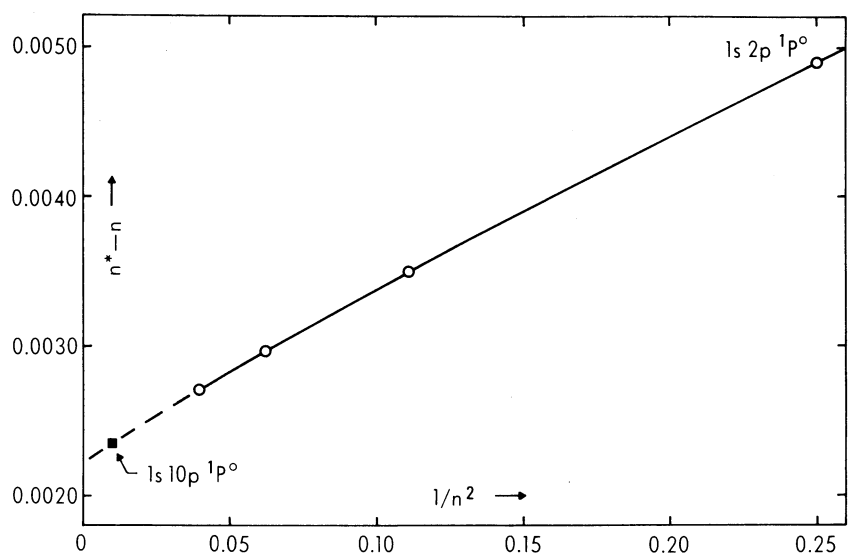

FIGURE 1. The negative of the quantum defect, n^*-n, vs. $1/n^2$ for the $1snp\ ^1P_1^\circ$ levels of Mg XI. The n^*-n values for $n=2$–5 (circles) were obtained from the expression $n^*=[121\ R/(\text{Limit}-E_n)]^{1/2}$, with $R=109734.85\ cm^{-1}$ for Mg, and the limit and $^1P_1^\circ$ level values (E_n) taken from Ermolaev and Jones. The n^* values for $n=6$–10 as obtained from the extrapolated (dashed) portion of the original curve are 6.00257, 7.00248, 8.00241, 9.00238, and 10.00237. The corresponding levels in the table were obtained from these n^* values and the quoted limit.

Mg XI

Configuration	Term	*J*	Level (cm^{-1})
$1s^2$	^1S	0	0
1*s*2*s*	^3S	1	[10 736 420]
1*s*2*p*	$^3P^\circ$	0	[*10 832 260*]
		1	[*10 833 090*]
		2	[*10 836 650*]
1*s*2*s*	^1S	0	[10 839 030]
1*s*2*p*	$^1P^\circ$	1	[*10 906 890*]
1*s*3*s*	^3S	1	[12 691 440]
1*s*3*p*	$^3P^\circ$	0	[*12 717 730*]
		1	[*12 717 990*]
		2	[*12 719 050*]
1*s*3*s*	^1S	0	[12 718 550]
1*s*3*d*	^3D	1	[12 733 490]
		2	[12 733 510]
		3	[12 733 900]
1*s*3*d*	^1D	2	[12 734 480]
1*s*3*p*	$^1P^\circ$	1	[*12 738 290*]
1*s*4*s*	^3S	1	[13 362 260]
1*s*4*p*	$^3P^\circ$	0	[*13 373 090*]
		1	[*13 373 200*]
		2	[*13 373 640*]
1*s*4*s*	^1S	0	[13 373 240]
1*s*4*d*	^3D	1,2,3	[13 379 660]
1*s*4*d*	^1D	2	[13 380 090]
1*s*4*f*	$^3F^\circ$	2,3,4	[*13 380 160*]
1*s*4*f*	$^1F^\circ$	3	[*13 380 170*]
1*s*4*p*	$^1P^\circ$	1	[*13 381 530*]
1*s*5*s*	^3S	1	[13 669 880]
1*s*5*p*	$^3P^\circ$	0	[*13 675 360*]
		1	[*13 675 420*]
		2	[*13 675 640*]
1*s*5*s*	^1S	0	[13 675 400]
1*s*5*d*	^3D	1,2,3	[13 678 690]

Mg XI—Continued

Configuration	Term	J	Level (cm^{-1})
1s5d	^{1}D	2	[13 678 940]
1s5f	^{3}F°,^{1}F°	2,3,3,4	[*13 678 960*]
1s5p	^{1}P°	1	[*13 679 630*]
1s6p	^{1}P°	1	[*13 841 650*]
1s7p	^{1}P°	1	[*13 939 380*]
1s8p	^{1}P°	1	[*14 002 830*]
1s9p	^{1}P°	1	[*14 046 330*]
1s10p	^{1}P°	1	[*14 077 450*]
....	....	....	....
Mg XII (^{2}S$_{1/2}$)	*Limit*		**[14 210 170]**
2s2p	^{3}P°	0 1 2	[*22 467 600*] [*22 469 800*] [*22 474 600*]
2p^2	^{3}P	0 1 2	[22 552 000] [22 554 400] [22 558 600]
2p^2	^{1}D	2	22 603 700
2s2p	^{1}P°	1	[*22 611 500*]
2p^2	^{1}S	0	[22 749 200]
Mg XII (2p ^{2}P°$_{1/2}$)	*Limit*		[*26 080 150*]

Mg XII

$Z=12$

H I isoelectronic sequence

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

Ionization energy 15 829 942±3 cm^{-1} (1962.678±0.005 eV)

The levels are based on Erickson's calculations, given with respect to zero for the ground level and adjusted to a nuclear mass of 24.2984 and to the Rydberg value determined by Goldsmith, Weber, and Hänsch (R_∞= 109 737.31476±0.00032 cm^{-1}). Erickson calculated the levels for the isotope Mg^{24}, whereas the nuclear mass quoted above corresponds to an atomic mass of 24.305, the value for Mg with natural isotopic abundances [IUPAC Commission on Atomic Weights, 1976]. The net result of the changes is to increase the effective Rydberg constant for Mg, R_M, by 2.74 parts in 10^7 above the value used by Erickson, all level separations being increased accordingly. The increases of 3.3 to 4.3 cm^{-1} in the values of the excited levels (and limit) with respect to the ground level, although negligible compared to the uncertainties attainable with present experimental techniques, are comparable to the standard-deviation error of ±3 cm^{-1} in Erickson's calculations of these separations. The errors for the separations of excited levels are smaller; details are given by Erickson, who lists each level to the number of decimal places appropriate for a quoted quantum-electrodynamics error. His table is complete through $n=11$ and also has the *ns*, *np*, and *nl* ($l=n-1$) levels through $n=20$. We list all levels through $n=5$ and give the *ns* and *np* levels through $n=10$.

The 1*s*–*np* resonance series has been observed from 2*p* to 6*p* (8.4 to 6.5 Å) in the spectra of laser-produced plasmas [see, for example, Aglitskii et al., 1974]. The experimental uncertainties of wavenumber determinations in this region are much greater than the uncertainties of the levels given here; the measurements by Aglitskii et al., for example, have wavenumber uncertainties of about ±2000 cm^{-1}. Experimental resolution of the nominal 1*s* $^2S_{1/2}$—2*p* $^2P^\circ_{1/2,3/2}$ doublet has shown that the intensity ratio of the two components can be very different from the statistical value of 0.5. Beigman, Boiko, Pikuz, and Faenov, for example, observed this ratio to vary from 0.7 to 1.7, depending on experimental conditions in a laser-produced plasma source. They suggest that collision-induced transitions from the 2*s* $^2S_{1/2}$ level, as well as optical-depth effects, significantly affect this ratio under some conditions. Such observations emphasize the need for caution in the assumption of particular theoretical values (such as the statistical-intensities baricenters) for the wavelengths of unresolved members of this series.

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Mg XII

Configuration	Term	*J*	Level (cm^{-1})
1*s*	^2S	1/2	0
2*p*	$^2P^\circ$	1/2	[*11 869 975.7*]
		3/2	[*11 877 602.3*]
2*s*	^2S	1/2	[11 870 287.2]
3*p*	$^2P^\circ$	1/2	[*14 070 804.8*]
		3/2	[*14 073 064.8*]
3*s*	^2S	1/2	[14 070 898.0]
3*d*	^2D	3/2	[14 073 060.9]
		5/2	[14 073 811.6]

Mg xii—Continued

Configuration	Term	J	Level (cm^{-1})
4p	^{2}P°	1/2	[*14 740 784.6*]
		3/2	[*14 841 737.9*]
4s	^{2}S	1/2	[14 840 824.0]
4d	^{2}D	3/2	[14 841 736.2]
		5/2	[14 842 053.0]
4f	^{2}F°	5/2	[*14 842 052.4*]
		7/2	[*14 842 210.6*]
5p	^{2}P°	1/2	[*15 197 042.8*]
		3/2	[*15 197 530.8*]
5s	^{2}S	1/2	[15 197 063.0]
5d	^{2}D	3/2	[15 197 529.9]
		5/2	[15 197 692.1]
5f	^{2}F°	5/2	[*15 197 691.8*]
		7/2	[*15 197 772.8*]
5g	^{2}G	7/2	[15 197 772.7]
		9/2	[15 197 821.3]
6p	^{2}P°	1/2	[*15 390 510.5*]
		3/2	[*15 390 792.8*]
6s	^{2}S	1/2	[15 390 522.2]
7p	^{2}P°	1/2	[*15 507 139.8*]
		3/2	[*15 507 317.6*]
7s	^{2}S	1/2	[15 507 147.2]
8p	^{2}P°	1/2	[*15 582 823.8*]
		3/2	[*15 582 942.9*]
8s	^{2}S	1/2	[15 582 828.8]
9p	^{2}P°	1/2	[*15 634 705.4*]
		3/2	[*15 634 789.0*]
9s	^{2}S	1/2	[15 634 708.8]
10p	^{2}P°	1/2	[*15 671 811.8*]
		3/2	[*15 671 872.7*]
10s	^{2}S	1/2	[15 671 814.3]
....	....	....	....
	Limit		[**15 829 942**]