Energy Levels of Germanium, Ge I through Ge XXXII

Jack Sugar and Arlene Musgrove

Atomic Physics Division, Physics Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899-0001

Received May 10, 1993; revised manuscript received June 15, 1993

Atomic energy levels of germanium have been compiled for all stages of ionization for which experimental data are available. No data have yet been published for Ge VIII through Ge XIII and Ge XXXII. Very accurate calculated values are compiled for Ge XXXI and XXXII. Experimental g-factors and leading percentages from calculated eigenvectors of levels are given. A value for the ionzation energy, either experimental when available or theoretical, is included for the neutral atom and each ion.

Key words: atomic; energy levels; germanium; ions; spectra.

Contents

1. Introduction

In 1952 C. E. Moore published a compilation of energy levels of germanium containing the results of extensive analyses of Ge I through Ge V. Today, we have experimental energy levels for most stages of ionization of Ge, predicted level values for Ge VIII (Mn-like), Ge XII (Sc-like), and Ge XIII (Ca-like), and very accurate calculated levels for Ge XXXI (He-like) and Ge XXXII (H-like). Only for the ions Ge IX through Ge XI are there no experimental or theoretical data. New results have been published on Ge I, Ge II, Ge IV, and Ge V, the spectra included in the 1952 compilation.

The present critical compilation of the atomic energy levels of germanium in all stages of ionization is part of an ongoing program of the National Institute of Standards and Technology (formerly the National Bureau of Standards) Atomic Energy Levels Data Center to compile similar data for all the elements. These publications include helium by Martin [1973, 1987], sodium, magnesium, aluminum, and silicon by Martin and Zalubas [1981, 1980, 1979, 1983], and phosphorus and sulfur by Martin, Zalubas, and Musgrove [1985, 1990], potassium through nickel by Sugar and Corliss [1985], copper, krypton, and molybdenum by Sugar and Musgrove [1990, 1991, 1988], and lanthanum through lutetium by Martin, Zalubas, and Hagan [1978].

Companion works containing wavelengths for the higher stages of ionization have been prepared in collaboration with the Japanese Atomic Energy Research Institute in Tokai-Mura, Japan. These include titanium by Mori *et al.* [1986] and vanadium, iron, cobalt, nickel, copper, and molybdenum by Shirai *et al.* [1992b, 1990, 1992a, 1987a, 1991, 1987b]. In addition, wavelength compilations including data for all stages of ionization have

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been published for Sc by Kaufman and Sugar [1988] and for Mg and Al by Kaufman and Martin [1991a, 1991b].

The strong lines of Ge I through Ge V are contained in "Line Spectra of the Elements" edited by Reader and Corliss [1991], which appears in the *CRC Handbook of Chemistry and Physics* [1991]. These data also appear in the NIST Standard Reference Database 38 [1992]. A compilation published by Kelly [1987] gives wavelengths of germanium spectra below 2000 Å and their energy level classifications.

In the present work all energy levels are given in units of cm^{-1}. An estimate of the uncertainty of the energy level values or wavelengths determining them is given in each case. Ionization energies are also given in eV with the conversion factor 8065.5410(24) cm^{-1}/eV published by Cohen and Taylor [1987].

We use without comment notations for various coupling schemes as appropriate. Martin, Zalubas, and Hagan [1978] give a complete summary of the coupling notations used here and tables of the allowed terms for equivalent electrons.

We have included under the heading "Leading percentages" the results of calculations that express the eigenvector percentage composition of levels (rounded to the nearest percent) in terms of the basis states of a single configuration, or more than one configuration where configuration interaction has been included. We give first the percentage of the basis state corresponding to the level's name; next the second largest percentage together with the related basis state. Generally, when the leading percentage is less than 40%, no name is given. However. when two different parent states give rise to the same final term type and the sum of their percentages is ≥40%, the level is designated by the higher percentage term. For an unnamed level, the term symbol for the leading percentage follows the percentage. The user should of course bear in mind that the percentages are model dependent, so that the results of different calculations may yield notably different percentages.

For configurations of equivalent d-electrons, several terms of the same LS type may occur. These are theoretically distinguished by their seniority number. In our compilations they are designated in the notation of Nielson and Koster [1963]. For example, in the $3d^5$ configuration there are three ^{2}D terms with seniorities of 1, 3, and 5. These terms are denoted as ^{2}D1, ^{2}D2, and ^{2}D3 respectively, by Nielson and Koster.

In cases where the ionization energies cannot be determined from the experimetnal data, we have calculated them with Cowan's [1981] Hartree Fock code (HFR) with relativistic and correlation corrections included. The uncertainty in these determinations varies from ±0.1% − 1.0%.

The text for each spectrum does not include a complete review of the literature but is intended to credit the major contributions. In assembling the data for each spectrum, we referred to the following bibliographies:

i. Papers cited by Moore (1952)
ii. C. E. Moore (1969)
iii. L. Hagan and W. C. Martin (1972)
iv. L. Hagan (1977)
v. R. Zalubas and A. Albright (1980)
vi. A. Musgrove and R. Zalubas (1985)
vii. Bibliographic file of publications since December 1983 maintained by the NIST Atomic Energy Levels Data Center

2. Acknowledgments

This work was supported in part by the U. S. Department of Energy, Division of Magnetic Fusion Energy.

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3. Tables of Energy Levels

Ge I

$Z=32$

Ge I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^{10}4s^24p^2\ ^3\mathrm{P}^{\circ}_0$

Ionization energy 63 713.24 ± 0.10 cm^{-1} (7.899 438 ± 0.000 012 eV)

Early observations of this spectrum combined to produce a list of 184 lines in the range of 1639 Å to 11 144 Å. These include major contributions from Gartlein [1928], Rao [1929], and Kiess [1940]. Gartlein classified 73 lines in the range of 1873 Å to 4685 Å and established all the levels of the ground configuration and 29 levels of $4pnl$ for $nl=5s-7s$, $4d$, $5d$. Rao extended the observations to 1630 Å and classified most of the 50 new lines, modifying some of Gartlein's levels and adding to the known excited configurations. Kiess extended the measurements to the region from 5265 Å to 11 144 Å, and classified 25 of 44 lines as transitions between the excited configurations $4p5s-4p5p$ and $6p$.

The $4s4p^3\ ^5\mathrm{S}^{\circ}_2$ term was discovered by Andrew and Meissner [1957], who recognized the two transitions to $4s^24p^2\ ^3\mathrm{P}_{2,1}$.

The spectrum was completely remeasured in the range of 1546 – 11 253 Å by Andrew and Meissner [1959] who used a low pressure arc in helium. From 4685 Å upward they measured more than 200 lines, most of which were new. From 4685 Å downward they observed 230 lines, 50 of which were new. Using these data they determined values and designations for 68 even and 88 odd levels. These include $4pns$ ($n=5-10$), $4pnp$ ($n=4-7$), $4pnd$ ($n=4-8$), and $4pnf$ ($n=4-7$), as well as $4s4p^3$. They obtained the value for the ionization energy from these series of 63 715 ± 10 cm^{-1}. Their wavelength uncertainty was ±0.03 Å for the spectrum observed in air above 2000 Å, and ±0.02 Å for vacuum ultraviolet observations below 2000 Å. Some interferometric measurements from 4600 Å to 11 125 Å were made with an uncertainty of ±0.005 Å.

Many interferometric studies of this spectrum have been carried out, beginning with Deverall *et al.* [1954]. Using an atomic beam crossed with an electron source they measured eight lines from 2592 – 3269 Å with an uncertainty of ±0.000 04 Å. They were unable to resolve isotopic splitting of the lines but determined that it is less than 0.005 cm^{-1}. With these measurements they redetermined the values of the $4p^2\ ^3\mathrm{P}$ and $^1\mathrm{D}$ levels and the $4p5s\ ^{1,3}\mathrm{P}^{\circ}$ with an uncertainty of ±0.0005 cm^{-1}.

Van Veld and Meissner [1956] measured 43 lines in the region of 2019 – 4685 Å using a Fabry-Perot interferometer and a hollow cathode light source. They estimate their wavelength uncertainty to be ±0.0004 Å. Using these measurements they were able to improve the values for the levels $4p^2\ ^1\mathrm{S}$, $4p4d\ ^{1,3}\mathrm{D}^{\circ}$, $^{1,3}\mathrm{F}^{\circ}$, $^{1,3}\mathrm{P}^{\circ}$, and seven additional higher-lying odd levels. With these values they predicted wavelengths of 29 lines from 1691 – 1998 Å with an uncertainty of ±0.0004 Å. These were proposed as secondary wavelength standards.

By making long wavelength interferometric measurements, Andrew and Meissner [1958, 1959] extended the number of precisely determined high even levels. These levels, combined with accurate wavelength measurements in the visible and infrared, were used to improve the values of many high odd levels. Transition wavelengths from these levels to the four even levels of the ground configuration are then accurately predicted from 1630 Å to 1997 Å. Using these as wavelength standards, Meissner *et al.* [1958] measured 30 additional Ge I lines from 1633 Å to 1944 Å with an uncertainty of ±0.002 Å.

A new systematic program of interferometric measurements was undertaken by Kaufman and Andrew [1962] in order to improve and increase the vacuum ultraviolet Ritz standards. Their observations extended from 4380 to 12 069 Å and were combined with those of Humphreys and Paul [1961] in the region of 11 255 to 19 284 Å, and with the earlier measurements from 2019 to 4685 Å by Van Veld and Meissner [1956] and Deverall *et al.* [1954] to improve the energy level values. They give 100 Ritz standards below 2000 Å and 95 interferometrically determined levels. The wavelength uncertainties do not exceed ±0.0009 Å, and 68 lines have uncertainties of ±0.0003 Å.

The number of measured lines was increased to 100 in the range of 11 252 to 23 922 Å by Humphreys and Andrew [1964]. This work was intended for establishing the levels of the $4pnf$ configurations that had been tentatively identified earlier by single lines. One $4p5d$ and two $4p6p$ levels were also found. Percentage compositions of the $4p4f$ levels were given by Cowan and Andrew [1965] in jl-coupling. Those levels still determined by a single line are denoted here by question marks.

A high resolution absorption spectrum from 1500 Å to 1900 Å was reported by Brown *et al.* [1977]. They observed 989 lines and determined 549 levels in long series approaching the two $4s^24p\ ^2\mathrm{P}^{\circ}$ limits. Their series include $4pns$, $4pnd$, and $4png$, most of whose levels are given for the first time. They determined the value for the series limit quoted here. A calculation of these series through $n=14$ with interaction among the series and $4s4p^3$ was carried out by Dembczynski [1986]. He gave eigenvectors for each of the levels in LS-coupling. These show that beyond $n=5$ LS designations are generally meaningless. We give LS names for odd levels of $n=4$ and for most levels of $n=5$, and then group the remaining odd levels in jj-coupling terms based on the quantum defects determined by Brown *et al.* in their Lu-Fano treatment of these series. Dembczynski found that the $^3D^\circ$ and $^3S^\circ$ terms of $4s4p^3$ reported by Andrew and Meissner contain only minor percentages of this configuration. The $4s4p^3$ $^3D^\circ$ component is absorbed into the $4pnd$ series. The $4s4p^3$ $^3S^\circ_1$ level of Andrew and Meissner was changed to $4s^24p6d$ $(^3/_2,^3/_2)^\circ$ with $J=2$ by Brown *et al.* We were unable to designate the following four levels as series members: 60 429.908 cm^{-1} with $J=3$, 60 516.308 cm^{-1} with $J=2$, 61 101.37 cm^{-1} with $J=1$, and 63 601.65 cm^{-1} with $J=2$.

We quote the energy level values from the following sources. The levels of $4p^2$ and $4p5s$ are from the interferometric atomic beam measurments of Deverall *et al.* The levels of $4p4d$ are from the interferometric hollow cathode measurements of Van Veld and Meissner based on the $4p^2$ levels of Deverall. Kaufman and Andrew extended the interferometric measurements from the visible to 12 000 Å by means of the spectrum emitted by electrodeless lamps. These data were combined with the measurements of Humphreys and Paul from 11 000 – 19 000 Å to extend the known levels to include $4p5p$ to $4p7p$, $4p5d$ to $4p9d$, and $4p6s$ to $4p9s$. Their results are quoted. The $4pnf$ levels are from Humphreys and Andrew and the earlier work by Andrew and Meissner [1959]. The long Rydberg series $4pns$, $4pnd$, and $4png$ are from the absorption spectra observed by Brown *et al.*

By atomic-beam magnetic resonance Childs and Goodman [1964] measured g-factors with an uncertainty in the fifth decimal place for the levels $4p^2$ $^3P_1$, $^3P_2$, and $^1D_2$. The rest of the observed values were obtained by Andrew *et al.* [1967] with an electrodeless lamp in a uniform magnetic field. They reported uncertainties in the second or third decimal place.

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Ge I

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$4s^24p^2$	^3P	0	0.0000				
		1	557.1341	1.50111			
		2	1 409.9609	1.49458			
$4s^24p^2$	^1D	2	7 125.2989	1.00639			
$4s^24p^2$	^1S	0	16 367.3332				
$4s^24p5s$	$^3P^\circ$	0	37 451.6893		100		
		1	37 702.3054	1.435	82	14	$4s^24p5s$ $^1P^\circ$
		2	39 117.9021	1.500	100		
$4s^24p5s$	$^1P^\circ$	1	40 020.5604	1.068	86	14	$4s^24p5s$ $^3P^\circ$
$4s4p^3$	$^5S^\circ$	2	41 926.726	2.011	100		
$4s^24p5p$	^3D	1	45 985.592				
		2	46 834.3798	1.182			
		3	48 104.1003	1.332			
$4s^24p5p$	^1P	1	46 765.2705	0.980			
$4s^24p5p$	^3P	0	47 502.6257				
		1	48 088.3504	1.362			
		2	48 726.1143	1.427			

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$4s^24p4d$	$^1\mathrm{D}^\circ$	2	*48 480.048*	0.981	74		14	$4s^24p4d\ ^3\mathrm{F}^\circ$
$4s^24p4d$	$^3\mathrm{D}^\circ$	2	*48 882.263*	1.008	57		23	$4s^24p4d\ ^3\mathrm{F}^\circ$
		1	*48 962.783*	0.556	77		14	$4s4p^3\ ^3\mathrm{D}^\circ$
		3	*49 144.397*	1.240	56		28	$4s^24p4d\ ^3\mathrm{F}^\circ$
$4s^24p5p$	$^3\mathrm{S}$	1	49 075.8917	1.862				
$4s^24p5p$	$^1\mathrm{D}$	2	49 649.5807	1.062				
$4s^24p4d$	$^3\mathrm{F}^\circ$	2	*50 068.954*	0.867	59		18	$4s^24p4d\ ^3\mathrm{D}^\circ$
		3	*50 323.465*	1.194	66		24	"
		4	*50 786.79*		99			
$4s^24p5p$	$^1\mathrm{S}$	0	51 011.4392					
$4s^24p4d$	$^3\mathrm{P}^\circ$	2	*51 437.802*	1.460	88		5	$4s^24p4d\ ^3\mathrm{D}^\circ$
		1	*51 705.020*	1.391	82		9	$4s^24p4d\ ^1\mathrm{P}^\circ$
		0	*51 978.15*		89		7	$4p6s\ ^3\mathrm{P}^\circ$
$4s^24p6s$	$(^1/_2,{}^1/_2)^\circ$	1	*52 148.726*	1.307				
		0	*52 170.504*					
$4s^24p4d$	$^1\mathrm{F}^\circ$	3	*52 592.224*	1.010	90		4	$4s^24p4d\ ^3\mathrm{F}^\circ$
$4s^24p4d$	$^1\mathrm{P}^\circ$	1	*52 847.215*	1.140	65		23	$4p6s\ ^3\mathrm{P}^\circ$
$4s^24p6s$	$(^3/_2,{}^1/_2)^\circ$	2	*53 911.624*					
		1	*54 174.928*	1.103				
$4s^24p6p$	$^3\mathrm{D}$	1	54 935.8479	0.690				
		2	55 266.0902	1.177				
		3	56 793.460	1.297				
$4s^24p6p$	$^1\mathrm{P}$	1	55 235.8344	1.383				
$4s^24p5d$	$^3\mathrm{D}^\circ$	2	*55 372.610*		47		15	$4p5d\ ^3\mathrm{P}^\circ$
		1	*55 474.668*	0.600	58		10	$4p4d\ ^3\mathrm{D}^\circ$
		3	*55 718.604*		42		29	$4p5d\ ^3\mathrm{F}^\circ$
$4s^24p6p$	$^3\mathrm{P}$	0	55 503.2026					
		1	56 687.1584	1.106				
		2	56 947.7693	1.357				
$4s^24p5d$	$^3\mathrm{F}^\circ$	2	*55 686.70*		52		37	$4s^24p5d\ ^1\mathrm{D}^\circ$
		3	*56 828.439*		51		16	$4s^24p5d\ ^3\mathrm{D}^\circ$
		4	*57 556.206*		98			
$4s^24p(^2\mathrm{P}^\circ_{1/2})4f$	$^2[^7/_2]$	3	56 765.748		77		23	$4s^24p(^2\mathrm{P}^\circ_{1/2})4f\ ^2[^5/_2]$
		4	56 771.466		100			
$4s^24p(^2\mathrm{P}_{1/2})4f$	$^2[^5/_2]$	3	56 768.663	1.200	77		23	$4s^24p(^2\mathrm{P}_{1/2})4f\ ^2[^7/_2]$
		2	56 772.750	0.859	99			
$4s^24p5d$		2	*56 921.345*		31	$4s^24p5d\ ^3\mathrm{F}^\circ$	24	$4s^24p5d\ ^1\mathrm{D}^\circ$
$4s^24p6p$	$^3\mathrm{S}$	1	57 083.2021	1.804				

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages				
$4s^24p7s$	$(^1/_2,^1/_2)^{\circ}$	0	*57 168.39*						
		1	*57 180.198*						
$4s^24p6p$	$^1\mathrm{D}$	2	57 250.9427	1.128					
$4s^24p5d$	$^3\mathrm{P}^{\circ}$	1	*57 398.852*	1.207	52			21	$4s^24p5d\ ^3\mathrm{D}^{\circ}$
		2	*57 430.924*		57			28	$4s^24p5d\ ^1\mathrm{D}^{\circ}$
		0	*57 828.98*		95			4	$4p7s\ ^3\mathrm{P}^{\circ}$
$4s^24p6p$	$^1\mathrm{S}$	0	57 670.326						
$4s^24p5d$	$^1\mathrm{P}^{\circ}$	1	*58 058.060*	1.19	40			37	$4s^24p5d\ ^3\mathrm{P}^{\circ}$
$4s^24p5d$	$^1\mathrm{F}^{\circ}$	3	*58 093.352*		63			16	$4s^24p5d\ ^3\mathrm{F}^{\circ}$
$4s^24p7p$	$^3\mathrm{D}$	1	58 414.660						
		2	58 586.8822	1.175					
		3	60 218.379						
$4s^24p(^2\mathrm{P}_{3/2})4f$	$^2[^7/_2]$	3	58 458.025		100				
		4	58 460.090		100				
$4s^24p(^2\mathrm{P}^{\circ}_{3/2})4f$	$^2[^5/_2]$	3	58 519.672		100				
		2	58 520.737	0.88	99				
$4s^24p5d$		2	*58 551.407*		21	$4s^24p5d\ ^3\mathrm{D}^{\circ}$		6	$4s4p^3\ ^3\mathrm{D}^{\circ}$
$4s^24p7p$	$^1\mathrm{P}$	1	58 560.827						
$4s^24p(^2\mathrm{P}^{\circ}_{3/2})4f$	$^2[^9/_2]$	5	58 575.02		100				
		4	58 578.867		100				
$4s^24p(^2\mathrm{P}^{\circ}_{3/2})4f$	$^2[^3/_2]$	1	58 642.22		100				
		2	58 645.062	1.10	100				
$4s^24p7p$	$^3\mathrm{P}$	0	58 733.515						
		1	60 187.58						
		2	60 320.616						
$4s^24p6d$	$(^1/_2,^3/_2)^{\circ}$	1	*58 741.040*						
		2	*58 747.644*						
$4s^24p7s$	$(^3/_2,^1/_2)^{\circ}$	2	*58 931.503*						
		1	*59 114.742*						
$4s^24p5d$		3	*58 943.436*	1.17					
$4s^24p(^2\mathrm{P}^{\circ}_{1/2})5f$	$^2[^7/_2]$	3	59 275.91						
		4	59 278.21						
$4s^24p(^2\mathrm{P}^{\circ}_{1/2})5f$	$^2[^5/_2]$	3	59 282.900						
		2	59 283.715						
$4s^24p8s$	$(^1/_2,^1/_2)^{\circ}$	0	*59 494.515*						
		1	*59 524.276*						

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p6d$	$(^{1}/_{2},^{5}/_{2})^{\circ}$	3	*59 658.391*		
		2	*59 690.604*		
		1	*59 727.511*		
$4s^24p6d$	$(^{3}/_{2},^{3}/_{2})^{\circ}$	2	*60 270.231*		
		1	*60 549.958*		
		0	*60 607.272*		
		3	*60 886.24*		
$4s^24p8p$	^{1}P	1	60 273.738		
$4s^24p7p$	^{3}S	1	60 354.624		
$4s^24p7d$	$(^{1}/_{2},^{3}/_{2})^{\circ}$	2	*60 403.365*		
		1	*60 857.12*		
$4s^24p7d$	$(^{1}/_{2},^{5}/_{2})^{\circ}$	3	*60 429.908*		
		2	*60 516.308*		
$4s^24p7p$	^{1}D	2	60 456.466	1.15	
$4s^24p6d$	$(^{3}/_{2},^{5}/_{2})^{\circ}$	4	*60 552.366*		
		2	*61 091.48*		
		1	*61 152.37*		
		3	*61 268.39*		
$4s^24p(^2P^{\circ}_{1/2})6f$	$^2[^7/_2]$	3	60 633.157		
		4	60 634.698		
$4s^24p(^2P^{\circ}_{1/2})6f$	$^2[^5/_2]$	3	60 634.467		
		2	60 635.152		
$4s^24p6g$	$(^{1}/_{2},^{7}/_{2})^{\circ}$	3	*60 658.13*		
$4s^24p7p$	^{1}S	0	60 673.064		
$4s^24p9s$	$(^{1}/_{2},^{1}/_{2})^{\circ}$	1	*60 749.318*		
		0	*60 769.238*		
$4s^24p(^2P^{\circ}_{3/2})5f$	$^2[^7/_2]$	3	61 002.709		
		4	61 004.356		
$4s^24p(^2P^{\circ}_{3/2})5f$	$^2[^5/_2]$	3	61 035.830		
		2	61 036.635		
$4s^24p(^2P^{\circ}_{3/2})5f$	$^2[^9/_2]$	5	61 060.41		
		4	61 063.611		
$4s^24p(^2P^{\circ}_{3/2})5f$	$^2[^3/_2]$	1	61 094.34?		
		2	61 095.40		
$4s^24p8s$	$(^{3}/_{2},^{1}/_{2})^{\circ}$	2	*61 254.02*		
		1	*61 343.172*		
$4s^24p8d$	$(^{1}/_{2},^{3}/_{2})^{\circ}$	2	*61 269.082*		
		1	*61 571.41*		
$4s^24p(^2P^{\circ}_{1/2})7f$	$^2[^7/_2]$	3	61 454.32		
		4	61 457.24?		

Ge I – Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p(^2P^\circ_{1/2})7f$	$^2[5/2]$	3	61 457.20		
		2	61 457.61?		
$4s^24p8d$	$(1/2,5/2)^\circ$	3	*61 522.73*		
		2	*61 542.72*		
$4s^24p10s$	$(1/2,1/2)^\circ$	0	*61 539.12*		
		1	*61 546.23*		
$4s^24p9d$	$(1/2,3/2)^\circ$	2	*61 849.22*		
		1	*61 997.14*		
$4s^24p7d$	$(3/2,3/2)^\circ$	2	*61 922.47*		
		0	*62 124.89*		
		1	*62 169.26*		
		3	*62 370.79*		
$4s^24p9d$	$(1/2,5/2)^\circ$	3	*61 930.04*		
		2	*62 054.745*		
$4s^24p8g$	$(1/2,7/2)^\circ$	3	*61 995.64*		
$4s^24p11s$	$(1/2,1/2)^\circ$	0	*62 041.45*		
		1	*62 044.93*		
$4s^24p12s$	$(1/2,1/2)^\circ$	0	*62 390.37*		
		1	*62 398.94*		
$4s^24p13s$	$(1/2,1/2)^\circ$	0	*62 639.15*		
		1	*62 647.61*		
$4s^24p14s$	$(1/2,1/2)^\circ$	0	*62 823.67*		
		1	*62 826.79*		
$4s^24p15s$	$(1/2,1/2)^\circ$	0	*62 964.21*		
		1	*62 965.59*		
$4s^24p16s$	$(1/2,1/2)^\circ$	1	*63 073.11*		
		0	*63 075.26*		
$4s^24p17s$	$(1/2,1/2)^\circ$	0	*63 162.09*		
		1	*63 165.54*		
$4s^24p18s$	$(1/2,1/2)^\circ$	0	*63 232.55*		
		1	*63 234.16*		
$4s^24p19s$	$(1/2,1/2)^\circ$	0	*63 290.65*		
		1	*63 293.33*		
$4s^24p20s$	$(1/2,1/2)^\circ$	0	*63 338*		
		1	*63 342.57*		
$4s^24p21s$	$(1/2,1/2)^\circ$	0	*63 378.68*		
		1	*63 380.02*		
$4s^24p22s$	$(1/2,1/2)^\circ$	0	*63 412.81*		
		1	*63 413.65*		
$4s^24p23s$	$(1/2,1/2)^\circ$	0	*63 441.91*		
		1	*63 442.57*		
$4s^24p24s$	$(1/2,1/2)^\circ$	0	*63 466.98*		
		1	*63 467.49*		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p25s$	$(1/2,1/2)^\circ$	0	*63 488.83*		
		1	*63 489.20*		
$4s^24p26s$	$(1/2,1/2)^\circ$	0	*63 507.77*		
		1	*63 508.13*		
$4s^24p27s$	$(1/2,1/2)^\circ$	0	*63 524.54*		
		1	*63 524.64*		
$4s^24p28s$	$(1/2,1/2)^\circ$	0	*63 539.41*		
		1	*63 539.50*		
$4s^24p29s$	$(1/2,1/2)^\circ$	0	*63 552.31*		
		1	*63 552.44*		
$4s^24p30s$	$(1/2,1/2)^\circ$	0	*63 563.99*		
		1	*63 564.13*		
$4s^24p31s$	$(1/2,1/2)^\circ$	0	*63 574.38*		
		1	*63 574.45*		
$4s^24p32s$	$(1/2,1/2)^\circ$	0	*63 583.73*		
		1	*63 583.80*		
$4s^24p33s$	$(1/2,1/2)^\circ$	0	*63 592.27*		
		1	*63 592.40*		
$4s^24p34s$	$(1/2,1/2)^\circ$	0	*63 599.89*		
		1	*63 600.03*		
$4s^24p35s$	$(1/2,1/2)^\circ$	1	*63 607.02*		
		0	*63 607.05*		
$4s^24p36s$	$(1/2,1/2)^\circ$	0	*63 613.13*		
$4s^24p37s$	$(1/2,1/2)^\circ$	0	*63 618.78*		
$4s^24p38s$	$(1/2,1/2)^\circ$	0	*63 624.34*		
$4s^24p39s$	$(1/2,1/2)^\circ$	0	*63 629.31*		
$4s^24p40s$	$(1/2,1/2)^\circ$	0	*63 633.64*		
$4s^24p41s$	$(1/2,1/2)^\circ$	0	*63 637.76*		
$4s^24p42s$	$(1/2,1/2)^\circ$	0	*63 641.58*		
$4s^24p43s$	$(1/2,1/2)^\circ$	0	*63 645.07*		
$4s^24p7d$	$(3/2,5/2)^\circ$	4	*62 125.233*		
		2	*62 454.86*		
		1	*62 467.79*		
		3	*62 522.98*		
$4s^24p10d$	$(1/2,5/2)^\circ$	3	*62 217.75*		
		2	*62 232.87*		
$4s^24p10d$	$(1/2,3/2)^\circ$	2	*62 264.43*		
		1	*62 355.15*		
$4s^24p9g$	$(1/2,7/2)^\circ$	3	*62 355.61*		
$4s^24p(^2P^\circ_{3/2})6f$	$^2[7/2]$	3	62 379.95?		
		4	62 381.86?		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p(^2P^\circ_{3/2})6f$	$^2[^9/_2]$	5	62 412.46		
		4	62 414.70?		
$4s^24p6g$	$(^3/_2,^7/_2)^\circ$	3	*62 437.63*		
$4s^24p9s$	$(^3/_2,^1/_2)^\circ$	2	*62 531.56*		
		1	*62 576.74*		
$4s^24p11d$	$(^1/_2,^3/_2)^\circ$	2	*62 545.56*		
		1	*62 639.17*		
$4s^24p12d$	$(^1/_2,^3/_2)^\circ$	2	*62 751.67*		
		1	*62 814.88*		
$4s^24p13d$	$(^1/_2,^3/_2)^\circ$	2	*62 906.37*		
		1	*62 948.76*		
$4s^24p14d$	$(^1/_2,^3/_2)^\circ$	2	*63 046.08*		
$4s^24p15d$	$(^1/_2,^3/_2)^\circ$	2	*63 128.81*		
		1	*63 156.45*		
$4s^24p16d$	$(^1/_2,^3/_2)^\circ$	2	*63 204.74*		
		1	*63 218.03*		
$4s^24p17d$	$(^1/_2,^3/_2)^\circ$	2	*63 267.51*		
		1	*63 290.86*		
$4s^24p18d$	$(^1/_2,^3/_2)^\circ$	2	*63 319.49*		
		1	*63 338.16*		
$4s^24p19d$	$(^1/_2,^3/_2)^\circ$	2	*63 362.52*		
		1	*63 377.61*		
$4s^24p20d$	$(^1/_2,^3/_2)^\circ$	2	*63 398.92*		
		1	*63 411.40*		
$4s^24p21d$	$(^1/_2,^3/_2)^\circ$	2	*63 429.94*		
		1	*63 440.39*		
$4s^24p22d$	$(^1/_2,^3/_2)^\circ$	2	*63 456.73*		
		1	*63 465.46*		
$4s^24p23d$	$(^1/_2,^3/_2)^\circ$	2	*63 479.74*		
		1	*63 487.23*		
$4s^24p24d$	$(^1/_2,^3/_2)^\circ$	2	*63 499.78*		
		1	*63 506.23*		
$4s^24p25d$	$(^1/_2,^3/_2)^\circ$	2	*63 517.32*		
		1	*63 523.00*		
$4s^24p26d$	$(^1/_2,^3/_2)^\circ$	2	*63 533.09*		
		1	*63 537.76*		
$4s^24p27d$	$(^1/_2,^3/_2)^\circ$	2	*63 546.3*		
		1	*63 550.78*		
$4s^24p28d$	$(^1/_2,^3/_2)^\circ$	1	*63 562.46*		
$4s^24p29d$	$(^1/_2,^3/_2)^\circ$	1	*63 572.90*		
$4s^24p30d$	$(^1/_2,^3/_2)^\circ$	1	*63 582.23*		
$4s^24p31d$	$(^1/_2,^3/_2)^\circ$	1	*63 590.62*		
$4s^24p32d$	$(^1/_2,^3/_2)^\circ$	1	*63 598.15*		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p\,33d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 605.06*		
$4s^24p\,34d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 611.24*		
$4s^24p\,36d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 622.05*		
$4s^24p\,37d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 626.76*		
$4s^24p\,38d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 631.12*		
$4s^24p\,39d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 635.17*		
$4s^24p\,40d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 638.98*		
$4s^24p\,41d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 642.53*		
$4s^24p\,42d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 645.72*		
$4s^24p\,43d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 648.99*		
$4s^24p\,44d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 651.91*		
$4s^24p\,45d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 654.63*		
$4s^24p\,46d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 657.22*		
$4s^24p\,47d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 659.69*		
$4s^24p\,48d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 661.94*		
$4s^24p\,49d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 664.10*		
$4s^24p\,50d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 666.10*		
$4s^24p\,51d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 667.95*		
$4s^24p\,52d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 669.81*		
$4s^24p\,53d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 671.46*		
$4s^24p\,54d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 673.04*		
$4s^24p\,55d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 674.47*		
$4s^24p\,56d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 675.93*		
$4s^24p\,57d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 677.24*		
$4s^24p\,58d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 678.56*		
$4s^24p\,59d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 679.74*		
$4s^24p\,60d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 680.84*		
$4s^24p\,61d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 682.03*		
$4s^24p\,62d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 683.1*		
$4s^24p\,63d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 684.03*		
$4s^24p\,64d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 684.87*		
$4s^24p\,65d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 685.70*		
$4s^24p\,66d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 686.70*		
$4s^24p\,67d$	$(^1/_2,{}^3/_2)^\circ$	1	*63 687.40*		
$4s^24p\,10g$	$(^1/_2,{}^7/_2)^\circ$	3	*62 614.61*		
$4s^24p\,11d$	$(^1/_2,{}^5/_2)^\circ$	3	*62 629.23*		
		2	*62 635.22*		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p\,12d$	$(^1/_2,^5/_2)^\circ$	3	*62 791.97*		
		2	*62 793.56*		
$4s^24p\,13d$	$(^1/_2,^5/_2)^\circ$	2	*62 926.05*		
		3	*62 930.26*		
$4s^24p\,14d$	$(^1/_2,^5/_2)^\circ$	2	*63 033.89*		
		3	*63 037.26*		
$4s^24p\,15d$	$(^1/_2,^5/_2)^\circ$	3	*63 113.76*		
		2	*63 117.23*		
$4s^24p\,16d$	$(^1/_2,^5/_2)^\circ$	2	*63 186.44*		
		3	*63 223.49*		
$4s^24p\,17d$	$(^1/_2,^5/_2)^\circ$	2	*63 294.10*		
		3	*63 302.32*		
$4s^24p\,18d$	$(^1/_2,^5/_2)^\circ$	3	*63 337.03*		
		2	*63 337.89*		
$4s^24p\,19d$	$(^1/_2,^5/_2)^\circ$	3	*63 374.34*		
		2	*63 375.62*		
$4s^24p\,20d$	$(^1/_2,^5/_2)^\circ$	3	*63 407.82*		
		2	*63 408.58*		
$4s^24p\,21d$	$(^1/_2,^5/_2)^\circ$	3	*63 436.95*		
		2	*63 437.27*		
$4s^24p\,22d$	$(^1/_2,^5/_2)^\circ$	2,3	*63 462.29*		
$4s^24p\,23d$	$(^1/_2,^5/_2)^\circ$	2	*63 484.12*		
		3	*63 484.37*		
$4s^24p\,24d$	$(^1/_2,^5/_2)^\circ$	2	*63 503.29*		
		3	*63 503.72*		
$4s^24p\,25d$	$(^1/_2,^5/_2)^\circ$	2	*63 520.23*		
		3	*63 520.69*		
$4s^24p\,26d$	$(^1/_2,^5/_2)^\circ$	2	*63 535.22*		
		3	*63 535.68*		
$4s^24p\,27d$	$(^1/_2,^5/_2)^\circ$	2	*63 548.46*		
		3	*63 549.00*		
$4s^24p\,28d$	$(^1/_2,^5/_2)^\circ$	2	*63 560.43*		
		3	*63 560.90*		
$4s^24p\,29d$	$(^1/_2,^5/_2)^\circ$	2	*63 571.11*		
		3	*63 571.58*		
$4s^24p\,30d$	$(^1/_2,^5/_2)^\circ$	2	*63 580.74*		
		3	*63 581.16*		
$4s^24p\,31d$	$(^1/_2,^5/_2)^\circ$	2	*63 589.46*		
		3	*63 589.77*		
$4s^24p\,32d$	$(^1/_2,^5/_2)^\circ$	2	*63 597.38*		
		3	*63 597.62*		
$4s^24p\,33d$	$(^1/_2,^5/_2)^\circ$	2	*63 604.41*		
$4s^24p\,34d$	$(^1/_2,^5/_2)^\circ$	2	*63 611.21*		
$4s^24p\,35d$	$(^1/_2,^5/_2)^\circ$	2	*63 617.0*		
$4s^24p\,36d$	$(^1/_2,^5/_2)^\circ$	2	*63 622.57*		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p\,37d$	$(^1/_2,^5/_2)^\circ$	2	63 627.36		
$4s^24p\,38d$	$(^1/_2,^5/_2)^\circ$	2	63 632.2		
$4s^24p\,39d$	$(^1/_2,^5/_2)^\circ$	2	63 635.90		
$4s^24p\,40d$	$(^1/_2,^5/_2)^\circ$	2	63 639.91		
$4s^24p\,41d$	$(^1/_2,^5/_2)^\circ$	2	63 643.50		
$4s^24p\,43d$	$(^1/_2,^5/_2)^\circ$	2	63 650.03		
$4s^24p\,44d$	$(^1/_2,^5/_2)^\circ$	2	63 652.94		
$4s^24p\,45d$	$(^1/_2,^5/_2)^\circ$	2	63 655.62		
$4s^24p\,46d$	$(^1/_2,^5/_2)^\circ$	2	63 658.17		
$4s^24p\,47d$	$(^1/_2,^5/_2)^\circ$	2	63 660.52		
$4s^24p\,48d$	$(^1/_2,^5/_2)^\circ$	2	63 662.83		
$4s^24p\,49d$	$(^1/_2,^5/_2)^\circ$	2	63 664.90		
$4s^24p\,50d$	$(^1/_2,^5/_2)^\circ$	2	63 666.78		
$4s^24p\,51d$	$(^1/_2,^5/_2)^\circ$	2	63 668.68		
$4s^24p\,52d$	$(^1/_2,^5/_2)^\circ$	2	63 670.44		
$4s^24p\,53d$	$(^1/_2,^5/_2)^\circ$	2	63 672.12		
$4s^24p\,54d$	$(^1/_2,^5/_2)^\circ$	2	63 673.57		
$4s^24p\,55d$	$(^1/_2,^5/_2)^\circ$	2	63 675.04		
$4s^24p\,56d$	$(^1/_2,^5/_2)^\circ$	2	63 676.45		
$4s^24p\,57d$	$(^1/_2,^5/_2)^\circ$	2	63 677.76		
$4s^24p\,58d$	$(^1/_2,^5/_2)^\circ$	2	63 679.02		
$4s^24p\,59d$	$(^1/_2,^5/_2)^\circ$	2	63 680.17		
$4s^24p\,60d$	$(^1/_2,^5/_2)^\circ$	2	63 681.27		
$4s^24p\,61d$	$(^1/_2,^5/_2)^\circ$	2	63 682.28		
$4s^24p\,62d$	$(^1/_2,^5/_2)^\circ$	2	63 683.36		
$4s^24p\,63d$	$(^1/_2,^5/_2)^\circ$	2	63 684.39		
$4s^24p\,64d$	$(^1/_2,^5/_2)^\circ$	2	63 685.26		
$4s^24p\,65d$	$(^1/_2,^5/_2)^\circ$	2	63 686.17		
$4s^24p\,66d$	$(^1/_2,^5/_2)^\circ$	2	63 686.96		
$4s^24p\,67d$	$(^1/_2,^5/_2)^\circ$	2	63 687.71		
$4s^24p\,68d$	$(^1/_2,^5/_2)^\circ$	2	63 688.52		
$4s^24p\,69d$	$(^1/_2,^5/_2)^\circ$	2	63 689.26		
$4s^24p\,70d$	$(^1/_2,^5/_2)^\circ$	2	63 689.94		
$4s^24p\,11g$	$(^1/_2,^7/_2)^\circ$	3	62 805.32		
$4s^24p\,12g$	$(^1/_2,^7/_2)^\circ$	3	62 950.30		
$4s^24p\,13g$	$(^1/_2,^7/_2)^\circ$	3	63 063.31		
$4s^24p\,15g$	$(^1/_2,^7/_2)^\circ$	3	63 224.64		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p\,8d$	$(3/2,3/2)^\circ$	2	*62 995.59*		
		0	*63 032.97*		
		1	*63 089.10*		
		3	*63 168.53*		
$4s^24p(^2P^\circ_{3/2})7f$	$^2[9/2]$	5	63 227.73		
$4s^24p\,8d$	$(3/2,5/2)^\circ$	2	*63 244.22*		
		1	*63 251.20*		
		3	*63 271.31*		
$4s^24p\,10s$	$(3/2,1/2)^\circ$	2	*63 305.19*		
		1	*63 330.45*		
$4s^24p\,9d$	$(3/2,3/2)^\circ$	2	*63 606.08*		
		0	*63 625.69*		
		3	*63 715*		
Ge II ($^2P^\circ_{1/2}$)	***Limit***		***63 713.24***		
$4s^24p\,9d$	$(3/2,5/2)^\circ$	1	*63 763.1*		
		3	*63 790*		
$4s^24p\,11s$	$(3/2,1/2)^\circ$	2	*63 809.51*		
		1	*63 827.3*		
$4s^24p\,12s$	$(3/2,1/2)^\circ$	2	*64 156.72*		
		1	*64 168.9*		
$4s^24p\,13s$	$(3/2,1/2)^\circ$	2	*64 405.88*		
		1	*64 415*		
$4s^24p\,14s$	$(3/2,1/2)^\circ$	2	*64 590.78*		
		1	*64 597.3*		
$4s^24p\,15s$	$(3/2,1/2)^\circ$	2	*64 731.78*		
		1	*64 737.0*		
$4s^24p\,16s$	$(3/2,1/2)^\circ$	2	*64 841.72*		
		1	*64 845.8*		
$4s^24p\,17s$	$(3/2,1/2)^\circ$	2	*64 929.13*		
		1	*64 932.3*		
$4s^24p\,18s$	$(3/2,1/2)^\circ$	2	*64 999.66*		
		1	*65 002.4*		
$4s^24p\,19s$	$(3/2,1/2)^\circ$	2	*65 057.56*		
		1	*65 059.8*		
$4s^24p\,20s$	$(3/2,1/2)^\circ$	2	*65 105.54*		
		1	*65 107.4*		
$4s^24p\,21s$	$(3/2,1/2)^\circ$	2	*65 145.83*		
		1	*65 147.4*		
$4s^24p\,22s$	$(3/2,1/2)^\circ$	2	*65 179.99*		
		1	*65 181.30*		
$4s^24p\,23s$	$(3/2,1/2)^\circ$	2	*65 209.14*		
		1	*65 210.2*		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p24s$	$({}^3/_2,{}^1/_2)^\circ$	2	*65 234.22*		
		1	*65 235.12*		
$4s^24p25s$	$({}^3/_2,{}^1/_2)^\circ$	2	*65 256.09*		
		1	*65 256.9*		
$4s^24p26s$	$({}^3/_2,{}^1/_2)^\circ$	2	*65 275.0*		
		1	*65 275.79*		
$4s^24p27s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 292.2*		
$4s^24p28s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 307.0*		
$4s^24p29s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 319.6*		
$4s^24p30s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 331.6*		
$4s^24p31s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 342.0*		
$4s^24p32s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 351.3*		
$4s^24p33s$	$({}^3/_2,{}^1/_2)^\circ$	1	*65 359.9*		
$4s^24p10d$	$({}^3/_2,{}^3/_2)^\circ$	1	*64 040*		
		3	*64 084*		
$4s^24p10d$	$({}^3/_2,{}^5/_2)^\circ$	1	*64 127*		
		3	*64 144*		
$4s^24p11d$	$({}^3/_2,{}^3/_2)^\circ$	0	*64 298.98*		
		1	*64 320*		
		3	*64 357*		
$4s^24p12d$	$({}^3/_2,{}^3/_2)^\circ$	1	*64 505*		
		3	*64 556*		
$4s^24p13d$	$({}^3/_2,{}^3/_2)^\circ$	0	*64 671.62*		
		1	*64 680*		
		3	*64 702*		
$4s^24p14d$	$({}^3/_2,{}^3/_2)^\circ$	0	*64 794.06*		
		1	*64 800*		
		3	*64 818*		
$4s^24p15d$	$({}^3/_2,{}^3/_2)^\circ$	0	*64 890.64*		
		1	*64 902*		
		3	*64 910*		
$4s^24p16d$	$({}^3/_2,{}^3/_2)^\circ$	0	*64 968.5*		
		1	*64 975*		
		3	*64 980*		
$4s^24p17d$	$({}^3/_2,{}^3/_2)^\circ$	0	*65 031.66*		
		1	*65 036*		
		3	*65 045*		
$4s^24p18d$	$({}^3/_2,{}^3/_2)^\circ$	0	*65 083.90*		
		1	*65 089*		
		3	*65 095*		
$4s^24p19d$	$({}^3/_2,{}^3/_2)^\circ$	1	*65 132*		
		3	*65 138.0*		
$4s^24p20d$	$({}^3/_2,{}^3/_2)^\circ$	0	*65 164.47*		
		1	*65 167*		
		3	*65 173*		

Ge I — Continued

Configuration	Term	*J*	Level (cm^{-1})	*g*	Leading percentages
$4s^24p21d$	$(^3/_2,^3/_2)^\circ$	0	*65 195.0*		
		1	*65 199*		
		3	*65 203*		
$4s^24p22d$	$(^3/_2,^3/_2)^\circ$	0	*65 222.66*		
		1	*65 225*		
		3	*65 229*		
$4s^24p23d$	$(^3/_2,^3/_2)^\circ$	1	*65 249*		
		3	*65 251.2*		
$4s^24p24d$	$(^3/_2,^3/_2)^\circ$	0	*65 266.37*		
		1	*65 268.8*		
		3	*65 270.5*		
$4s^24p25d$	$(^3/_2,^3/_2)^\circ$	1	*65 286*		
		3	*65 287.99*		
$4s^24p26d$	$(^3/_2,^3/_2)^\circ$	1	*65 301.0*		
		3	*65 303.17*		
$4s^24p27d$	$(^3/_2,^3/_2)^\circ$	1	*65 315*		
		3	*65 316.51*		
$4s^24p28d$	$(^3/_2,^3/_2)^\circ$	1	*65 327*		
		3	*65 328.64*		
$4s^24p29d$	$(^3/_2,^3/_2)^\circ$	1	*65 337.75*		
		3	*65 339.41*		
$4s^24p30d$	$(^3/_2,^3/_2)^\circ$	1	*65 347.9*		
		3	*58 348.99*		
$4s^24p31d$	$(^3/_2,^3/_2)^\circ$	1	*65 356.50*		
		3	*65 357.65*		
$4s^24p32d$	$(^3/_2,^3/_2)^\circ$	1	*65 364.38*		
		3	*65 365.48*		
$4s^24p33d$	$(^3/_2,^3/_2)^\circ$	1	*65 371.74*		
		3	*65 372.54*		
$4s^24p34d$	$(^3/_2,^3/_2)^\circ$	1	*65 378.40*		
		3	*65 378.91*		
$4s^24p35d$	$(^3/_2,^3/_2)^\circ$	1	*65 384.13*		
		3	*65 384.94*		
$4s^24p36d$	$(^3/_2,^3/_2)^\circ$	1	*65 389.68*		
		3	*65 390.24*		
$4s^24p37d$	$(^3/_2,^3/_2)^\circ$	1	*65 394.62*		
$4s^24p38d$	$(^3/_2,^3/_2)^\circ$	1	*65 399.90*		
$4s^24p39d$	$(^3/_2,^3/_2)^\circ$	1	*65 403.5*		
$4s^24p40d$	$(^3/_2,^3/_2)^\circ$	1	*65 407.3*		
$4s^24p41d$	$(^3/_2,^3/_2)^\circ$	1	*65 411.0*		
$4s^24p11d$	$(^3/_2,^5/_2)^\circ$	1	*64 382.4*		
		3	*64 396*		
$4s^24p12d$	$(^3/_2,^5/_2)^\circ$	1	*64 572.90*		
		3	*64 581.6*		

Ge I – Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p\,13d$	$(^3/_2,^5/_2)^\circ$	1	*64 717.9*		
		3	*64 724.4*		
$4s^24p\,14d$	$(^3/_2,^5/_2)^\circ$	1	*64 830.30*		
		3	*64 835.7*		
		2	*64 837*		
$4s^24p\,15d$	$(^3/_2,^5/_2)^\circ$	1	*64 920.14*		
		2	*64 922*		
		3	*64 924.1*		
$4s^24p\,16d$	$(^3/_2,^5/_2)^\circ$	1	*64 992.35*		
		2	*64 994*		
		3	*64 995.6*		
$4s^24p\,17d$	$(^3/_2,^5/_2)^\circ$	1	*65 051.60*		
		2	*65 052*		
		3	*65 054.1*		
$4s^24p\,18d$	$(^3/_2,^5/_2)^\circ$	1	*65 100.56*		
		2	*65 102*		
		3	*65 102.7*		
$4s^24p\,19d$	$(^3/_2,^5/_2)^\circ$	1	*65 141.72*		
		2	*65 142*		
		3	*65 143.2*		
$4s^24p\,20d$	$(^3/_2,^5/_2)^\circ$	1	*65 176.32*		
		2	*65 177*		
		3	*65 177.72*		
$4s^24p\,21d$	$(^3/_2,^5/_2)^\circ$	1	*65 206.13*		
		2	*65 207*		
		3	*65 207.2*		
$4s^24p\,22d$	$(^3/_2,^5/_2)^\circ$	1	*65 231.75*		
		2	*65 232*		
		3	*65 232.5*		
$4s^24p\,23d$	$(^3/_2,^5/_2)^\circ$	1	*65 253.80*		
		2	*65 254*		
		3	*65 254.5*		
$4s^24p\,24d$	$(^3/_2,^5/_2)^\circ$	1	*65 273.18*		
		3	*65 273.93*		
$4s^24p\,25d$	$(^3/_2,^5/_2)^\circ$	1	*65 290.15*		
		3	*65 290.5*		
$4s^24p\,26d$	$(^3/_2,^5/_2)^\circ$	1	*65 305.08*		
		3	*65 305.43*		
$4s^24p\,27d$	$(^3/_2,^5/_2)^\circ$	1	*65 318.34*		
		3	*65 318.6*		
$4s^24p\,28d$	$(^3/_2,^5/_2)^\circ$	1	*65 330.17*		
		3	*65 330.3*		
$4s^24p\,29d$	$(^3/_2,^5/_2)^\circ$	1	*65 340.78*		
		3	*65 341.1*		
$4s^24p\,30d$	$(^3/_2,^5/_2)^\circ$	1	*65 350.27*		
		3	*65 350.5*		
$4s^24p\,31d$	$(^3/_2,^5/_2)^\circ$	3	*65 358.8*		
		1	*65 358.93*		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p\,32d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 366.69		
		3	65 366.7		
$4s^24p\,33d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 373.66		
		3	65 373.8		
$4s^24p\,34d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 380.10		
		3	65 380.1		
$4s^24p\,35d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 385.93		
		3	65 386.1		
$4s^24p\,36d$	$({}^3/_2,{}^5/_2)^\circ$	3	65 391.2		
		1	65 391.31		
$4s^24p\,37d$	$({}^3/_2,{}^5/_2)^\circ$	3	65 396		
		1	65 396.14		
$4s^24p\,38d$	$({}^3/_2,{}^5/_2)^\circ$	3	65 400.6		
		1	65 400.67		
$4s^24p\,39d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 404.78		
		3	65 404.8		
$4s^24p\,40d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 408.59		
		3	65 408.6		
$4s^24p\,41d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 412.07		
		3	65 412.2		
$4s^24p\,42d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 415.38		
		3	65 415.5		
$4s^24p\,43d$	$({}^3/_2,{}^5/_2)^\circ$	3	65 418.5		
		1	65 418.59		
$4s^24p\,44d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 421.32		
		3	65 421.4		
$4s^24p\,45d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 424.01		
		3	65 424.2		
$4s^24p\,46d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 426.49		
		3	65 426.5		
$4s^24p\,47d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 428.86		
		3	65 428.9		
$4s^24p\,48d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 431.07		
		3	65 431.1		
$4s^24p\,49d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 433.02		
		3	65 433.1		
$4s^24p\,50d$	$({}^3/_2,{}^5/_2)^\circ$	3	65 435.1		
		1	65 435.15		
$4s^24p\,51d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 436.82		
		3	65 436.9		
$4s^24p\,52d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 438.51		
		3	65 438.6		
$4s^24p\,53d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 440.13		
		3	65 440.24		
$4s^24p\,54d$	$({}^3/_2,{}^5/_2)^\circ$	1	65 441.62		
		3	65 441.79		

Ge I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$4s^24p55d$	$(^3/_2,^5/_2)°$	1	65 443.1		
$4s^24p56d$	$(^3/_2,^5/_2)°$	1	65 444.42		
$4s^24p57d$	$(^3/_2,^5/_2)°$	1	65 445.69		
		3	65 445.85		
$4s^24p58d$	$(^3/_2,^5/_2)°$	1	65 446.93		
		3	65 446.99		
$4s^24p59d$	$(^3/_2,^5/_2)°$	1	65 448.12		
		3	65 448.19		
$4s^24p60d$	$(^3/_2,^5/_2)°$	1,3	65 449.16		
$4s^24p61d$	$(^3/_2,^5/_2)°$	1,3	65 450.29		
$4s^24p62d$	$(^3/_2,^5/_2)°$	1	65 451.12		
		3	65 451.28		
$4s^24p63d$	$(^3/_2,^5/_2)°$	1	65 452.16		
		3	65 452.28		
$4s^24p64d$	$(^3/_2,^5/_2)°$	1	65 453.02		
Ge II ($^2P^\circ_{3/2}$)	*Limit*		65 480.60		

Ge II

$Z = 32$

Ga I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p\ ^2\mathrm{P}^\circ_{1/2}$

Ionization energy 128 521.3 ± 0.2 cm^{-1} (15.93462 ± 0.00002 eV)

Lang [1928, 1929] observed this spectrum with a spark in air, in hydrogen and in vacuum and classified 33 lines in the range of 999 – 7147 Å. Gartlein [1950] extended the observations from 813 Å to 6484 Å and classified 131 lines. His unpublished results are quoted by Moore [1952].

Accurate measurements of 22 lines from 4741 to 7145 Å, twelve of them measured interferometrically with an uncertainty of ±0.005 Å, enabled Andrew and Meissner [1959] to determine the fine structure of the $4s^2nf$ terms with $n = 4 - 7$. They discovered that all of these terms are inverted.

New interferometric measurements of 23 lines with an uncertainty of ±0.001 Å were made by Kaufman and Andrew [1962] in the range of 2831 – 9475 Å. These data enabled them to improve energy level values and to calculate 12 Ritz standards from 999 to 1966 Å with an uncertainty of ±0.0009 Å.Their improved level values for the lower members of the nf and ng series were used to calculate the value for the ionization energy quoted here.

The spectrum was reobserved from 600 to 10 000 Å by Shenstone [1963] with a hollow cathode source and with a low pressure spark in helium. In addition to improving the energy level values and resolving some of the doublets, he established many levels above the ionization threshold and classified many diffuse lines as transitions from these levels.

New measurements of five lines from 1649 to 2007 Å with an uncertainty of ±0.001 Å were made by Kaufman *et al.* [1966]. Four of the lines are the spin-forbidden transitions from $4s4p^2\ ^4\mathrm{P}$ to the $4s^24p\ ^2\mathrm{P}^\circ$ ground term and one line is from $5s\ ^2\mathrm{S}$.

Kaufman and Ward [1966] measured 14 new lines in the range of 999 – 3224 Å with an uncertainty of ±0.001 Å or better, depending on the order of diffraction in which they were measured. They have revised the values of the energy levels and give 25 calculated lines from 843 to 1649 Å with an uncertainty of ±0.0006 Å.

We have derived level values from the following sources: those of $4s^24p$ and $4s4p^2\ ^4\mathrm{P}$ are from the wavelengths of Kaufman, Radziemski, and Andrew [1966], those of $4s^25s$, $6d$, and $7d$ are derived from the wavelengths of Kaufman and Ward [1966]. The levels of $4s4p^2$ $^2\mathrm{D}$, $4s^25p$, $6p$, $4d$, $5d$, $4f$, $6f$, $5g$, $6g$, and $7g$ are derived from the interferometric measurements by Kaufman and Andrew [1963]. The remaining levels are taken from the extensive analysis by Shenstone [1963].

The observed g-values were reported by Andrew *et al.* [1967].

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Ge II

Configuration	Term	J	Level (cm^{-1})	g
$4s^24p$	$^2P^\circ$	1/2	*0.000*	
		3/2	*1 767.357*	
$4s4p^2$	^4P	1/2	51 575.885	
		3/2	52 290.942	
		5/2	53 366.738	
$4s^25s$	^2S	1/2	62 403.028	2.003
$4s4p^2$	^2D	3/2	65 015.672	0.803
		5/2	65 184.738	1.197
$4s^25p$	$^2P^\circ$	1/2	*79 006.853*	0.668
		3/2	*79 366.494*	1.330
$4s^24d$	^2D	3/2	80 836.880	0.800
		5/2	81 012.598	1.200
$4s4p^2$	^2S	1/2	85 890.55	
$4s4p^2$	^2P	1/2	91 016.2	
		3/2	92 122.7	
$4s^26s$	^2S	1/2	94 784.381	1.996
$4s^25d$	^2D	3/2	100 089.970	0.797
		5/2	100 130.812	1.201
$4s^24f$	$^2F^\circ$	7/2	*100 317.283*	1.143
		5/2	*100 317.976*	0.857
$4s^26p$	$^2P^\circ$	1/2	*101 098.446*	
		3/2	*101 244.635*	
$4s^27s$	^2S	1/2	107 936.16	
$4s^26d$	^2D	3/2	110 378.07	
		5/2	110 397.63	
$4s^25f$	$^2F^\circ$	7/2	*110 504.58*	
		5/2	*110 505.22*	
$4s^25g$	^2G	7/2	110 868.453	
		9/2	110 868.486	
$4s^27p$	$^2P^\circ$	1/2	*111 016.30*	
		3/2	*111 091.55*	
$4s^28s$	^2S	1/2	114 638.47	
$4s^27d$	^2D	3/2	115 977.80	
		5/2	115 988.77	
$4s^26f$	$^2F^\circ$	7/2	*116 041.231*	
		5/2	*116 041.81*	
$4s^26g$	^2G	7/2,9/2	116 266.75	

Ge II — Continued

Configuration	Term	J	Level (cm^{-1})	g
$4s^28p$	$^2P^\circ$	1/2	*116 361.78*	
		3/2	*116 406.61*	
$4s^29s$	^2S	1/2	118 523.24	
$4s^28d$	^2D	3/2	119 339.11	
		5/2	119 345.75	
$4s^27f$	$^2F^\circ$	7/2	*119 373.92*	
		5/2	*119 374.34*	
$4s^27g$	^2G	7/2	119 521.835	
		9/2	119 521.837	
$4s^29p$	$^2P^\circ$	1/2	*119 577.60*	
		3/2	*119 607.77*	
$4s^210s$	^2S	1/2	120 977.05	
$4s^29d$	^2D	3/2	121 511.36	
		5/2	121 515.82	
$4s^28f$	^2F	7/2	121 532.26	
		5/2	121 532.56	
$4s^28g$	^2G	7/2,9/2	121 633.87	
$4s^210p$	$^2P^\circ$	1/2	*121 662.87*	
		3/2	*121 685.74*	
$4s4p(^3P^\circ)5s$	$^4P^\circ$	1/2	*122 694.3*	
		3/2	*123 401.2*	
		5/2	*124 732.4*	
$4s^210d$	^2D	3/2	122 995.45	
		5/2	122 998.43	
$4s^29f$	$^2F^\circ$	7/2	*123 008.73*	
		5/2	*123 008.96*	
$4s^29g$	^2G	7/2,9/2	123 081.34	
$4s^211p$	$^2P^\circ$	3/2	*123 102.60*	
$4s^210f$	$^2F^\circ$	5/2,7/2	*124 062.8*	
$4s^210g$	^2G	7/2,9/2	124 116.37	
$4s^211f$	$^2F^\circ$	5/2,7/2	*124 841.2*	
$4s^211g$	^2G	7/2,9/2	124 881.91	
$4s4p(^3P^\circ)4d$	$^2D^\circ$	3/2	*126 922.8*	
		5/2	*127 271.4*	
$4s4p(^3P^\circ)5s$	$^2P^\circ$	1/2	*127 081.8*	
		3/2	*127 916.3*	

Ge II — Continued

Configuration	Term	J	Level (cm^{-1})	g
....	....	....	....	....
Ge III ($^1S_0$)	***Limit***		**128 521.3**	
$4s4p(^3P^\circ)4d$	$^4F^\circ$	3/2	*130 412.8*	
		5/2	*130 777.7*	
		7/2	*131 348.9*	
		9/2	*132 150*	
$4s4p(^3P^\circ)4d$	$^4D^\circ$	1/2	*136 203.4*	
		3/2	*136 235.7*	
		5/2	*136 351.1*	
		7/2	*137 064.7*	
$4s4p(^3P^\circ)4d$	$^4P^\circ$	5/2	*138 187.5*	
		3/2	*138 567.0*	
		1/2	*138 761.8*	
$4s4p(^3P^\circ)5p$	^4D	1/2	138 720.5?	
		3/2	139 170?	
		5/2	139 913?	
$4p^3$	$^4S^\circ$	3/2	*139 760*	
$4s4p(^3P^\circ)5p$	^2P	1/2	140 016?	
		3/2	140 752?	
$4s4p(^3P^\circ)4d$	$^2P^\circ$	1/2	*140 432?*	
		3/2	*140 983*	
$4s4p(^3P^\circ)5p$	^4D	7/2	141 179.70	
$4s4p(^3P^\circ)4d$	$^2F^\circ$	5/2	*141 279.2*	
		7/2	*142 701.1*	
$4s4p(^3P^\circ)5p$	^4P	1/2	141 452	
		3/2	141 787	
		5/2	142 443.9	
$4p^3$	$^2D^\circ$	3/2	*149 238.2*	
		5/2	*149 393.1*	
$4p^3$	$^2P^\circ$	3/2	*156 013.0?*	
		1/2	*156 083.8?*	
$4s4p(^3P^\circ)6s$	$^4P^\circ$	1/2	*156 183.4*	
		3/2	*156 942?*	
		5/2	*158 353.4*	
$4s4p(^3P^\circ)5d$	$^2D^\circ$	3/2	*160 611.5*	
		5/2	*160 948.2*	
$4s4p(^3P^\circ)4f$	$^2F^\circ$	5/2	*161 858*	
$4s4p(^3P^\circ)4f$	$^4F^\circ$	7/2	*162 324?*	
		9/2	*162 454?*	
$4s4p(^3P^\circ)4f$	^4G	5/2	163 220?	
		7/2	163 573?	
		9/2	164 013?	
		11/2	164 535	

Ge II — Continued

Configuration	Term	J	Level (cm^{-1})	g
$4s4p(^3P^\circ)4f$	^2G	7/2	164 157	
		9/2	164 735	
$4s4p(^3P^\circ)4f$	$^4D^\circ$	7/2	*164 258*	
		5/2	*164 606?*	
		3/2	*164 768?*	
		1/2	*164 860?*	
Ge III $4s4p(^3P^\circ_0)$	*Limit*		*190 250*	

Ge III

$Z = 32$

Zn I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^{10}4s^2\ ^1S_0$

Ionization energy 274 693 ± 10 cm^{-1} (34.0576 ± 0.0010 eV)

The analysis was first carried out by Lang (1929) who classified 86 lines in the range of 540 – 5300 Å measured with an uncertainty of about ±0.05 Å. He determined values for levels of the configurations $4s4p$, $4p^2$, $4s4d$, $4s5s$, $4s5p$, $4p4d$, $4s4f$, $4s5d$, $4s6s$, and $4d^2$.

The spectrum was reobserved by Ryabstev *et al.* [1993] in the range of 300 – 7000 Å with an uncertainty of ±0.005 Å below 6000 Å and ±0.02 Å above 6000 Å. All level values were redetermined with improved accuracy. The previous levels $4p^2\ ^1D$, $4s5s\ ^1S$ and all $4p4d$ and $4d^2$ levels were discarded. The $4s4d\ ^1D_2$ was reassigned to $4p^2\ ^1D_2$. All of these levels except for the $^1F^\circ$ of the $4p4d$ configuration and the $^1P^\circ$ of the $4p5s$ were established. In addition, the $4sns$, np, nd, nf, and ng series were extended. A tentative assignment of a line at 377.031 Å to the inner-shell excitation $3d^{10}4s^2\ ^1S_0 - 3d^94s^24p\ ^1P_1^\circ$ was given.

We have adopted the energy level values given by Ryabstev *et al.* as well as their calculated percentage composition of the levels. We quote their value for the ionization energy derived from the $4sns\ ^3S$ series.

The g-values were derived by Moore [1952] from observed Zeeman patterns given by van den Bosch and Klinkenberg [1941].

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Ge III

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$4s^2$	^1S	0	0.00		97	3	$4p^2\ ^1S$
$4s4p$	$^3P^\circ$	0	*61 733.82*		100		
		1	*62 499.95*		100		
		2	*64 143.85*		100		
$4s4p$	$^1P^\circ$	1	*91 872.68*		97		
$4p^2$	^1D	2	144 974.86		64	32	$4s4d\ ^1D$
$4p^2$	^3P	0	147 685.45		99		
		1	148 640.09		100		
		2	150 371.74		97		
$4s5s$	^3S	1	158 565.02	1.99	100		
$4s4d$	^3D	1	162 840.25		100		
		2	162 910.34		100		
		3	163 016.95		100		
$4s5s$	^1S	0	163 532.53		98		
$4p^2$	^1S	0	174 113.91		94		
$4s4d$	^1D	2	178 140.35		65	30	$4p^2\ ^1D$

Ge III – Continued

Configuration	Term	J	Level (cm^{-1})	g	*Leading percentages*		
$4s5p$	$^3\mathrm{P}^\circ$	0	*181 859.17*		100		
		1	*182 027.84*	1.48	98		
		2	*182 487.04*	1.49	100		
$4s5p$	$^1\mathrm{P}^\circ$	1	*184 298.06*		95	3	$4p5s$ $^1\mathrm{P}^\circ$
$4s4f$	$^3\mathrm{F}^\circ$	2	*210 445.99*		96	4	$4p4d$ $^3\mathrm{F}^\circ$
		3	*210 461.50*		72	24	$4s4f$ $^1\mathrm{F}^\circ$
		4	*210 523.91*		96	4	$4p4d$ $^3\mathrm{F}^\circ$
$4s4f$	$^1\mathrm{F}^\circ$	3	*210 536.58*		73	24	$4s4f$ $^3\mathrm{F}^\circ$
$4s6s$	$^3\mathrm{S}$	1	211 140.07	1.94	100		
$4s6s$	$^1\mathrm{S}$	0	212 662.0		99		
$4s5d$	$^3\mathrm{D}$	*1*	*213 123.16*	*0.50*	100		
		2	213 152.45	1.16	100		
		3	213 197.64	1.32	100		
$4s5d$	$^1\mathrm{D}$	2	215 576.96		95	3	$4p^2$ $^1\mathrm{D}$
$4s7s$	$^3\mathrm{S}$	1	234 432.3		100		
$4s5g$	$^3\mathrm{G}$	3	234 916.12		100		
		4	234 916.38		51	48	$4s5g$ $^1\mathrm{G}$
		5	234 920.10		100		
$4s5g$	$^1\mathrm{G}$	4	234 920.04		51	48	$4s5g$ $^3\mathrm{G}$
$4s7s$	$^1\mathrm{S}$	0	235 099.8		100		
$4s6d$	$^3\mathrm{D}$	1	235 436.5		100		
		2	235 452.2		100		
		3	235 479.5		100		
$4s6d$	$^1\mathrm{D}$	2	236 248.5		98		
$4p4d$	$^1\mathrm{D}^\circ$	2	*237 851.3*		56	21	$4p4d$ $^3\mathrm{F}^\circ$
$4s8s$	$^3\mathrm{S}$	1	246 875.0		100		
$4s6g$	$^3\mathrm{G}$	3	247 083.70		100		
		4	247 084.01		72	28	$4s6g$ $^1\mathrm{G}$
		5	247 087.25		100		
$4s6g$	$^1\mathrm{G}$	4	247 087.28		72	28	$4s6g$ $^3\mathrm{G}$
$4p4d$	$^1\mathrm{P}^\circ$	1	*262 715.2*		94	3	$3p5s$ $^1\mathrm{P}^\circ$
....	....	....	....	....			
Ge IV ($^2\mathrm{S}_{1/2}$)	***Limit***		**274 693**				

Ge IV

$Z=32$

Cu I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^{10}4s$ $^2S_{1/2}$

Ionization energy 368 720 ± 10 cm^{-1} (45.7155 ± 0.0010 eV)

The spectrum was first observed by Carroll [1925] who classifed nine lines, from which he derived the $4s$, $4p$, $4d$, and $5s$ term values. Improved wavelengths were given by Lang [1929] who extended the term system by locating $3d^{10}6p$, $3d^{10}5g$, and $3d^94s^2$ terms. He identified lines in the range of 440 – 3676 Å.

The spectrum was reobserved by Ryabtsev and Wyart [1987]. They classified 56 additional lines in the range of 301 – 1229 Å with a wavelength uncertainty that we estimate to be ±0.005 Å for most lines. Several lines originating from autoionizing levels of $3d^94p^2$ are very broad and probably have an uncertainty of ±0.05 Å. With these new data they found 16 new levels, extending the *nl* series to $9s$, $8p$, $6d$, and $6f$. They also replaced the $6s$ and $6p$ levels of Lang, which they found to be incorrect, and redetermined values for all the levels except $4f\,^2F^o$, $5g\,^2G$, and $3d^94s^2$ ^2D. With the *ns* series they determined the value for the ionization energy.

In addition Ryabtsev and Wyart identified the $3d^{10}4p-3d^94p^2$ array in the range of 301 – 338 Å. Sixteen levels of $3d^94p^2$ were found, all of which are above the first ionization threshold. The percentage compositions for these levels are given, derived with configuration interaction with $3d^94s4d$.

The transitions $3d^{10}4s-3d^94s4p$ were identified by Wyart *et al.* [1984] in the range of 314 – 354 Å. They classified eight lines from $3d^94s4p$ levels with $J={}^1\!/_2$ and $^3\!/_2$, and gave the first component of the percentage composition for these levels. Ryabtsev and Wyart corrected the transition $3d^{10}4s$ $^2S_{1/2}-3d^9(^2D)4s4p(^3P^o)$ $^4P^o_{3/2}$ to 354.968 Å and added the transition $3d^{10}4s$ $^2S_{1/2}-3d^9(^2D)4s4p(^3P^o)$ $^4P^o_{1/2}$ at 352.102 Å.

We quote the results of Ryabtsev and Wyart for all the $3d^{10}nl$ levels, with the exception of $4f\,^2F^o$ and $5g\,^2G$ taken from Lang's work, and those of $3d^94p^2$. The $3d^94s4p$ levels are from Wyart *et al.* with the additions from Ryabtsev and Wyart. The $3d^94s^2$ ^2D levels are taken from Lang's paper.

The *g*-values were derived by Moore [1952] from the Zeeman patterns observed by van den Bosch and Klinkenberg [1941].

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Ge IV

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^{10}4s$	^2S	$^1\!/_2$	0		
$3d^{10}4p$	$^2P^o$	$^1\!/_2$	*81 311.4*		
		$^3\!/_2$	*84 102.3*		
$3d^{10}4d$	^2D	$^3\!/_2$	190 601.5	0.82	
		$^5\!/_2$	190 852.5	1.26	
$3d^{10}5s$	^2S	$^1\!/_2$	199 263.7	2.04	
$3d^{10}5p$	$^2P^o$	$^1\!/_2$	*226 456.7*	0.68	
		$^3\!/_2$	*227 393.9*	1.34	
$3d^{10}4f$	$^2F^o$	$^7\!/_2$	*257 492*		
		$^5\!/_2$	*257 496*		

Ge IV — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^{9}(^{2}\mathrm{D})4s^{2}$	$^{2}\mathrm{D}$	5/2	259 938		
		3/2	264 444		
$3d^{10}5d$	$^{2}\mathrm{D}$	3/2	267 455.5	0.80	
		5/2	267 575.6	1.19	
$3d^{10}6s$	$^{2}\mathrm{S}$	1/2	270 603.4		
$3d^{9}(^{2}\mathrm{D})4s4p(^{3}\mathrm{P}^{\circ})$	$^{4}\mathrm{P}^{\circ}$	3/2	*281 715*		94
		1/2	*284 009*		97
$3d^{10}6p$	$^{2}\mathrm{P}^{\circ}$	1/2	*283 027.8*		
		3/2	*283 461.4*		
$3d^{9}(^{2}\mathrm{D})4s4p(^{3}\mathrm{P}^{\circ})$	$^{4}\mathrm{D}^{\circ}$	3/2	*291 652*		43
		1/2	*293 876*		75
$3d^{9}(^{2}\mathrm{D})4s4p(^{3}\mathrm{P}^{\circ})$	$^{2}\mathrm{P}^{\circ}$	1/2	*292 755*		73
		3/2	*293 306*		83
$3d^{9}(^{2}\mathrm{D})4s4p(^{3}\mathrm{P}^{\circ})$	$^{2}\mathrm{D}^{\circ}$	3/2	*295 255*		58
$3d^{10}5f$	$^{2}\mathrm{F}^{\circ}$	5/2	*297 563.6*		
		7/2	*297 564.2*		
$3d^{10}5g$	$^{2}\mathrm{G}$	7/2,9/2	298 373		
$3d^{10}6d$	$^{2}\mathrm{D}$	3/2	303 105.8		
		5/2	303 168.5		
$3d^{10}7s$	$^{2}\mathrm{S}$	1/2	304 667.6		
$3d^{10}7p$	$^{2}\mathrm{P}^{\circ}$	1/2	*311 342*		
		3/2	*311 482*		
$3d^{9}(^{2}\mathrm{D})4s4p(^{1}\mathrm{P}^{\circ})$	$^{2}\mathrm{P}^{\circ}$	3/2	*318 124*		97
		1/2	*322 139*		99
$3d^{10}6f$	$^{2}\mathrm{F}^{\circ}$	7/2	*319 277.1*		
		5/2	*319 277.9*		
$3d^{10}8s$	$^{2}\mathrm{S}$	1/2	323 605.5		
$3d^{10}9s$	$^{2}\mathrm{S}$	1/2	*335 228*		
Ge V ($^{1}\mathrm{S}_{0}$)	***Limit***		***368 720***		
$3d^{9}(^{2}\mathrm{D})4p^{2}(^{1}\mathrm{D})$	$^{2}\mathrm{S}$	1/2	379 514		58
$3d^{9}(^{2}\mathrm{D})4p^{2}(^{1}\mathrm{D})$	$^{2}\mathrm{P}$	3/2	380 814		59
		1/2	384 514		41
$3d^{9}(^{2}\mathrm{D})4p^{2}(^{3}\mathrm{P})$	$^{4}\mathrm{D}$	3/2	381 702		82
		1/2	383 260		75
$3d^{9}(^{2}\mathrm{D})4p^{2}(^{1}\mathrm{D})$	$^{2}\mathrm{D}$	3/2	387 565		39

Ge IV — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9(^2D)4p^2(^3P)$	^4P	$^5/_2$	390 374		86
		$^3/_2$	393 376		81
		$^1/_2$	394 870		76
$3d^9(^2D)4p^2(^3P)$	^2D	$^3/_2$	392 040		64
		$^5/_2$	394 170		58
$3d^9(^2D)4p^2(^3P)$		$^5/_2$	393 460		
$3d^9(^2D)4p^2(^3P)$	^2P	$^1/_2$	396 620		76
		$^3/_2$	397 366		83
$3d^9(^2D)4p^2(^1S)$	^2D	$^5/_2$	415 660?		92

Ge V

$Z=32$

Ni I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^{10}$ ^{1}S$_0$

Ionization energy 729 930 ± 150 cm^{-1} (94.500 ± 0.02 eV)

Sixteen levels comprising all of $3d^94s$ and $3d^94p$ were determined by Mack *et al.* [1928] from observations by Carroll [1925]. Their values relative to the ground state were found by Kruger and Shoupp [1934] who identified three resonance lines. The wavelengths in the range of 942 – 1222 Å were measured with improved accuracy by Joshi and van Kleef [1974]. They redetermined all the energy level values and added the $3d^94p$ ^{3}P$^\circ_1$ level.

The spectrum was reobserved by Ryabtsev [1975] and Ryabtsev and Churilov [1991] in the range of 178 – 1222 Å with an uncertainty of ±0.005 Å. They found all the levels of $3d^94d$, $4f$, $5s$ to $7s$, $5p$ and $6p$, and part of $5d$ and $6d$, as well as improved values for the previously known levels. Their results are quoted here along with their value for the ionization energy.

We have calculated the percentage composition of all the levels and designated them accordingly.

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Ge V

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^{10}$	^{1}S	0	0			
$3d^94s$	^{3}D	3	234 219.3	100		
		2	235 967.0	83	17	$3d^94s$ ^{1}D
		1	238 764.9	100		
$3d^94s$	^{1}D	2	241 935.2	83	17	$3d^94s$ ^{3}D
$3d^94p$	^{3}P°	2	*323 748.9*	96	4	$3d^94p$ ^{3}D°
		1	*327 753.0*	96	3	"
		0	*330 332.5*	100		
$3d^94p$	^{3}F°	3	*327 891.0*	68	27	$3d^94p$ ^{1}F°
		4	*329 847.8*	100		
		2	*330 790.6*	95	4	$3d^94p$ ^{3}D°
$3d^94p$	^{1}F°	3	*335 161.3*	60	27	$3d^94p$ ^{3}D°
$3d^94p$	^{1}D°	2	*335 560.3*	64	32	$3d^94p$ ^{3}D°
$3d^94p$	^{3}D°	3	*337 168.1*	68	19	$3d^94p$ ^{3}F°
		1	*339 540.2*	72	24	$3d^94p$ ^{1}P°
		2	*340 295.7*	60	36	$3d^94p$ ^{1}D°
$3d^94p$	^{1}P°	1	*338 273.5*	75	25	$3d^94p$ ^{3}D°
$3d^94d$	^{3}S	1	456 051.8	93	5	$3d^94d$ ^{3}P
$3d^94d$	^{3}G	5	461 417.5	100		
		4	461 642.6	64	36	$3d^94d$ ^{1}G
		3	464 077.0	68	19	$3d^94d$ ^{1}F

Ge v – Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^{9}4d$	$^{1}\mathrm{P}$	1	461 814.9	52		28	$3d^{9}4d\ ^{3}\mathrm{P}$
$3d^{9}4d$	$^{3}\mathrm{P}$	2	461 828.5	76		24	$3d^{9}4d\ ^{3}\mathrm{D}$
		0	463 957.9	94		6	$3d^{9}4d\ ^{1}\mathrm{S}$
		1	464 852.7	57		36	$3d^{9}4d\ ^{1}\mathrm{P}$
$3d^{9}4d$	$^{3}\mathrm{D}$	3	463 361.6	89		9	$3d^{9}4d\ ^{3}\mathrm{F}$
		2	464 652.2	50		24	$3d^{9}4d\ ^{1}\mathrm{D}$
		1	467 029.1	80		10	$3d^{9}4d\ ^{1}\mathrm{P}$
$3d^{9}4d$		4	464 705.7	45	$3d^{9}4d\ ^{3}\mathrm{F}$	39	$3d^{9}4d\ ^{1}\mathrm{G}$
$3d^{9}4d$	$^{1}\mathrm{F}$	3	466 780.2	42		31	$3d^{9}4d\ ^{3}\mathrm{G}$
$3d^{9}4d$	$^{3}\mathrm{F}$	4	467 386.7	54		25	$3d^{9}4d\ ^{1}\mathrm{G}$
		3	469 686.4	53		38	$3d^{9}4d\ ^{1}\mathrm{F}$
		2	469 889.6	64		35	$3d^{9}4d\ ^{1}\mathrm{D}$
$3d^{9}4d$	$^{1}\mathrm{D}$	2	468 695.8	41		27	$3d^{9}4d\ ^{3}\mathrm{D}$
$3d^{9}5s$	$(^{5}/_{2},^{1}/_{2})$	3	490 741.7	100	or	100	$3d^{9}5s\ ^{3}\mathrm{D}$
		2	491 443.3	98	or	55	″
$3d^{9}4d$	$^{1}\mathrm{S}$	0	493 765.5?	94		6	$3d^{9}4d\ ^{3}\mathrm{P}$
$3d^{9}5s$	$(^{3}/_{2},^{1}/_{2})$	1	495 288.4	100	or	100	$3d^{9}5s\ ^{3}\mathrm{D}$
		2	495 907.7	98	or	55	$3d^{9}5s\ ^{1}\mathrm{D}$
$3d^{9}5p$	$^{3}\mathrm{P}^{\circ}$	2	*522 959*	93		7	$3d^{9}5p\ ^{3}\mathrm{D}^{\circ}$
		1	*525 343*	72		22	$3d^{9}5p\ ^{1}\mathrm{P}^{\circ}$
		0	*528 156*	100			
$3d^{9}5p$	$^{3}\mathrm{F}^{\circ}$	3	*524 232*	57		36	$3d^{9}5p\ ^{1}\mathrm{F}^{\circ}$
		4	*524 950*	100			
		2	*528 625*	71		26	$3d^{9}5p\ ^{1}\mathrm{D}^{\circ}$
$3d^{9}5p$	$^{1}\mathrm{D}^{\circ}$	2	*526 373*	42		29	$3d^{9}5p\ ^{3}\mathrm{D}^{\circ}$
$3d^{9}5p$	$^{3}\mathrm{D}^{\circ}$	3	*526 902*	80		20	$3d^{9}5p\ ^{1}\mathrm{F}^{\circ}$
		1	*530 928*	94		5	$3d^{9}5p\ ^{3}\mathrm{P}^{\circ}$
		2	*531 321*	61		32	$3d^{9}5p\ ^{1}\mathrm{D}^{\circ}$
$3d^{9}5p$	$^{1}\mathrm{P}^{\circ}$	1	*529 476*	77		22	$3d^{9}5p\ ^{3}\mathrm{P}^{\circ}$
$3d^{9}5p$	$^{1}\mathrm{F}^{\circ}$	3	*530 113*	44		42	$3d^{9}5p\ ^{3}\mathrm{F}^{\circ}$
$3d^{9}4f$	$(^{5}/_{2},^{5}/_{2})^{\circ}$	0	*[553 660]*	100			
		1	*553 910.9*	75		24	$3d^{9}4f\ (^{5}/_{2},^{7}/_{2})^{\circ}$
		5	*554 690.2*	95		5	″
		2	*555 298.8*	77		23	″
		4	*555 860.0*	86		12	″
		3	*555 912.7*	72		28	″
$3d^{9}4f$	$(^{5}/_{2},^{7}/_{2})^{\circ}$	2	*554 370.9*	75		22	$3d^{9}4f\ (^{5}/_{2},^{5}/_{2})^{\circ}$
		6	*554 658.0*	100			
		3	*555 337.1*	72		28	″
		1	*555 730.2*	72		25	″
		4	*555 798.4*	87		13	″
		5	*555 852.3*	93		5	″

Ge v – Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^94f$	$(^3/_2,^7/_2)^\circ$	2	*558 877.1*	89	8	$3d^94f\ (^3/_2,^5/_2)^\circ$
		5	*559 467.6*	98	2	$3d^94f\ (^5/_2,^7/_2)^\circ$
		3	*560 096.6*	96	4	$3d^94f\ (^3/_2,^5/_2)^\circ$
		4	*560 547.2*	95	5	"
$3d^94f$	$(^3/_2,^5/_2)^\circ$	4	*559 463.1*	93	5	$3d^94f\ (^3/_2,^7/_2)^\circ$
		2	*560 034.6*	91	8	"
		1	*560 149.3*	96	4	$3d^94f\ (^5/_2,^7/_2)^\circ$
		3	*560 587.7*	96	4	$3d^94f\ (^3/_2,^7/_2)^\circ$
$3d^95d$	^{3}S	1	574 389	79	15	$3d^95d\ ^3$P
$3d^95d$	^{3}G	5	576 067	100		
		4	576 226	55	44	$3d^95d\ ^1$G
		3	580 695	78	14	$3d^95d\ ^1$F
$3d^95d$	^{3}D	3	576 963	84	13	$3d^95d\ ^3$F
$3d^95d$	^{1}F	3	577 459	48	29	$3d^95d\ ^3$F
$3d^95d$	^{3}F	4	577 553	80	14	$3d^95d\ ^1$G
		3	582 225	50	36	$3d^95d\ ^1$F
		2	582 308	68	30	$3d^95d\ ^1$D
$3d^95d$	^{1}G	4	581 114	41	40	$3d^95d\ ^3$G
$3d^96s$	$(^5/_2,^1/_2)$	3	588 094			
		2	588 403			
$3d^96s$	$(^3/_2,^1/_2)$	1	592 644			
		2	592 872			
$3d^96p$	$(^5/_2,^1/_2)^\circ$	2	*603 388*	73	26	$3d^96p\ (^5/_2,^3/_2)^\circ$
		3	*603 921*	95	5	"
$3d^96p$	$(^5/_2,^3/_2)^\circ$	4	*604 256*	100		
		1	*604 656*	97	3	$3d^96p\ (^3/_2,^3/_2)^\circ$
		2	*604 965*	73	26	$3d^96p\ (^5/_2,^1/_2)^\circ$
		3	*605 176*	95	4	"
$3d^96p$	$(^3/_2,^3/_2)^\circ$	0	*608 172*	100		
		3	*609 029*	100		
		1	*609 384*	57	42	$3d^96p\ (^3/_2,^1/_2)^\circ$
		2	*609 581*	93	7	$3d^96p\ (^1/_2,^1/_2)^\circ$
$3d^96p$	$(^3/_2,^1/_2)^\circ$	2	*608 262*	93	7	$3d^96p\ (^3/_2,^3/_2)^\circ$
		1	*608 530*	56	40	"
$3d^97s$	$(^5/_2,^1/_2)$	3	635 973			
		2	636 143			
		1	640 509			
$3d^97s$	$(^3/_2,^1/_2)$	2	640 625			
Ge VI (^{2}D$_{5/2}$)	***Limit***		**729 930**			

Ge VI

$Z=32$

Co I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^9\ ^2D_{5/2}$

Ionization energy 934 800 ± 1 000 cm^{-1} (115.9 ± 0.1 eV)

The $3d^9-3d^84p$ array was observed in the range of 222−242 Å by Kononov [1967], who measured the spectrum with a wavelength uncertainty of ±0.03 Å. The ground state ^{2}D splitting and 21 levels of $3d^84p$ were determined. Aksenov and Ryabtsev [1975] extended the range of observation to include 200−1100 Å and classified 110 lines in the arrays $3d^9-3d^84p$ and $3d^84s-3d^84p$. Their measurement uncertainty is ±0.005 Å. An improved value for the ^{2}D ground state splitting and all levels of $3d^84s$ and $3d^84p$ were found except for those based on the $3d^8\ ^1$S parent. Ramonas and Ryabtsev [1979] classified an additional 20 lines and found the missing levels of the above configurations. They also calculated the percentage composition of the levels. All energy level values were redetermined. Their results are quoted here.

New observations in the range of 128−148 Å by Ryabtsev *et al.* [1985] with an uncertainty of ±0.005 Å were interpreted as the transitions $3d^9-3d^84f$ and $3p^63d^9-3p^53d^{10}$. Percentage compositions were calculated for the mixed configurations $3d^84f$ + $3p^53d^{10}$. We quote these results.

We determined the value for the ionization energy from the center of gravity of the $3d^84f$ configuration and an interpolated value for its term energy, and the center of gravity of the $3d^8$ configuration calculated with the Cowan [1981] HFR program.

References

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Ge VI

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3p^63d^9$	^{2}D	5/2	0			
		3/2	4 560			
$3p^63d^8(^3F)4s$	^{4}F	9/2	303 696.2	100		
		7/2	306 243.4	92	7	$3p^63d^8(^3F)4s\ ^2F$
		5/2	308 657.2	98		
		3/2	310 199.1	98		
$3p^63d^8(^3F)4s$	^{2}F	7/2	313 024.6	92	7	$3p^63d^8(^3F)4s\ ^4F$
		5/2	316 936.8	94	4	$3p^63d^8(^1D)4s\ ^2D$
$3p^63d^8(^3P)4s$	^{4}P	5/2	327 537.9	55	42	$3p^63d^8(^1D)4s\ ^2D$
		3/2	332 376.6	79	19	"
		1/2	332 497.0	100		
$3p^63d^8(^1D)4s$	^{2}D	3/2	329 073.6	70	19	$3p^63d^8(^3P)4s\ ^4P$
		5/2	333 034.6	53	45	"
$3p^63d^8(^3P)4s$	^{2}P	3/2	339 335.3	92	7	$3p^63d^8(^1D)4s\ ^2D$
		1/2	340 525.3	100		
$3p^63d^8(^1G)4s$	^{2}G	9/2	343 624.4	100		
		7/2	343 674.0	100		
$3p^63d^8(^1S)4s$	^{2}S	1/2	391 183.2	100		

Ge VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3p^63d^8(^3F)4p$	$^4D^\circ$	7/2	404 892.3	88	6	$3p^63d^8(^3F)4p$ $^4F^\circ$
		5/2	408 981.1	86	7	"
		3/2	412 037.7	86	8	$3p^63d^8(^3P)4p$ $^4D^\circ$
		1/2	413 872.6	88	9	"
$3p^63d^8(^3F)4p$	$^4G^\circ$	9/2	409 188.4	53	27	$3p^63d^8(^3F)4p$ $^2G^\circ$
		11/2	411 591.6	100		
		7/2	411 885.9	74	14	$3p^63d^8(^3F)4p$ $^4F^\circ$
		5/2	413 728.0	86	8	"
$3p^63d^8(^3F)4p$	$^4F^\circ$	9/2	415 142.7	77	16	$3p^63d^8(^3F)4p$ $^2G^\circ$
		7/2	416 709.7	56	10	$3p^63d^8(^3F)4p$ $^2F^\circ$
		3/2	417 792.2	62	21	$3p^63d^8(^3F)4p$ $^2D^\circ$
		5/2	417 941.9	61	20	"
$3p^63d^8(^3F)4p$	$^2G^\circ$	9/2	417 421.2	56	40	$3p^63d^8(^3F)4p$ $^4G^\circ$
		7/2	421 310.0	62	14	$3p^63d^8(^3F)4p$ $^2F^\circ$
$3p^63d^8(^3F)4p$	$^2D^\circ$	5/2	420 117.8	58	15	$3p^63d^8(^3F)4p$ $^2F^\circ$
		3/2	423 030.0	53	31	$3p^63d^8(^3F)4p$ $^4F^\circ$
$3p^63d^8(^3F)4p$	$^2F^\circ$	7/2	420 542.0	55	24	$3p^63d^8(^3F)4p$ $^2G^\circ$
		5/2	424 506.4	72	12	$3p^63d^8(^3F)4p$ $^2D^\circ$
$3p^63d^8(^3P)4p$	$^4P^\circ$	3/2	429 997.3	72	9	$3p^63d^8(^1D)4p$ $^2P^\circ$
		5/2	430 736.0	66	12	$3p^63d^8(^1D)4p$ $^2D^\circ$
		1/2	431 041.9	90	5	$3p^63d^8(^1D)4p$ $^2P^\circ$
$3p^63d^8(^1D)4p$	$^2F^\circ$	5/2	433 507.0	69	19	$3p^63d^8(^3P)4p$ $^4P^\circ$
		7/2	436 173.3	70	14	$3p^63d^8(^1G)4p$ $^2F^\circ$
$3p^63d^8(^1D)4p$	$^2D^\circ$	3/2	436 023.6	40	19	$3p^63d^8(^3P)4p$ $^4P^\circ$
		5/2	437 801.0	74	8	"
$3p^63d^8(^1D)4p$	$^2P^\circ$	1/2	436 727.0	58	29	$3p^63d^8(^3P)4p$ $^2P^\circ$
		3/2	438 871.4	46	34	$3p^63d^8(^1D)4p$ $^2D^\circ$
$3p^63d^8(^3P)4p$	$^4D^\circ$	1/2	441 221.0	86	8	$3p^63d^8(^3F)4p$ $^4D^\circ$
		3/2	441 278.0	74	7	$3p^63d^8(^1D)4p$ $^2P^\circ$
		5/2	441 386.0	59	19	$3p^63d^8(^3P)4p$ $^2D^\circ$
		7/2	442 790.4	76	17	$3p^63d^8(^1G)4p$ $^2F^\circ$
$3p^63d^8(^1G)4p$	$^2H^\circ$	9/2	444 442.2	98		
		11/2	448 258.9	100		
$3p^63d^8(^3P)4p$	$^2P^\circ$	3/2	445 439.0	72	13	$3p^63d^8(^1D)4p$ $^2P^\circ$
		1/2	449 093.0	58	22	"
$3p^63d^8(^3P)4p$	$^2D^\circ$	5/2	445 670.0	66	27	$3p^63d^8(^3P)4p$ $^4D^\circ$
		3/2	447 373.0	83	10	"
$3p^63d^8(^1G)4p$	$^2F^\circ$	7/2	447 780.0	64	22	$3p^63d^8(^1D)4p$ $^2D^\circ$
		5/2	450 153.0	85	8	$3p^63d^8(^1D)4p$ $^2F^\circ$
$3p^63d^8(^3P)4p$	$^2S^\circ$	1/2	451 362.0	83	9	$3p^63d^8(^1D)4p$ $^2P^\circ$
$3p^63d^8(^3P)4p$	$^4S^\circ$	3/2	451 501.0	96		

Ge VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3p^63d^8(^1G)4p$	$^2G^\circ$	$7/2$	*458 378.0*	96			
		$9/2$	*459 014.5*	98			
$3p^63d^8(^1S)4p$	$^2P^\circ$	$1/2$	*496 179.5*	98			
		$3/2$	*500 575.3*	98			
$3p^63d^8(^3F)4f$	$^2S^\circ$	$1/2$	*682 720*	45		23	$3p^63d^8(^3F)4f\ ^2P^\circ$
$3p^63d^8(^3F)4f$	$^4D^\circ$	$7/2$	*682 980*	61		35	$3p^63d^8(^3F)4f\ ^4F^\circ$
$3p^63d^8(^3F)4f$	$^2P^\circ$	$3/2$	*683 460*	45		20	$3p^63d^8(^3F)4f\ ^4D^\circ$
		$1/2$	*689 590*	48		22	$3p^63d^8(^3F)4f\ ^2S^\circ$
$3p^63d^84f$		$7/2$	*684 530*	34	$3p^63d^8(^3F)4f\ ^2F^\circ$	21	$3p^63d^8(^3F)4f\ ^4G^\circ$
$3p^63d^84f$		$5/2$	*684 730*	30	$3p^63d^8(^3F)4f\ ^4F^\circ$	26	$3p^63d^8(^3F)4f\ ^2D^\circ$
$3p^63d^8(^3F)4f$	$^4P^\circ$	$1/2$	*686 810*	58		27	$3p^63d^8(^3F)4f\ ^2P^\circ$
$3p^63d^84f$		$3/2$	*687 320*	30	$3p^63d^8(^3F)4f\ ^2P^\circ$	26	$3p^63d^8(^3F)4f\ ^4D^\circ$
$3p^63d^84f$		$5/2$	*687 690*	34	$3p^63d^8(^3F)4f\ ^4D^\circ$	27	$3p^63d^8(^3F)4f\ ^4P^\circ$
$3p^63d^84f$		$3/2$	*687 750*	32	$3p^63d^8(^3F)4f\ ^4S^\circ$	30	$3p^63d^8(^3F)4f\ ^4F^\circ$
$3p^63d^84f$		$7/2$	*688 330*	33	$3p^63d^8(^3F)4f\ ^4G^\circ$	32	$3p^63d^8(^3F)4f\ ^2F^\circ$
$3p^63d^8(^3F)4f$	$^2D^\circ$	$5/2$	*688 460*	41		31	$3p^63d^8(^3F)4f\ ^4F^\circ$
		$3/2$	*691 020*	67		14	$3p^63d^8(^3F)4f\ ^2P^\circ$
$3p^63d^8(^3F)4f$	$^2G^\circ$	$7/2$	*690 680*	45		31	$3p^63d^8(^3F)4f\ ^2F^\circ$
$3p^63d^8(^3F)4f$	$^2F^\circ$	$5/2$	*691 420*	53		31	$3p^63d^8(^3F)4f\ ^2D^\circ$
$3p^63d^8(^1D)4f$	$^2F^\circ$	$5/2$	*705 420*	57		16	$3p^63d^8(^3P)4f\ ^2F^\circ$
		$7/2$	*706 410*	45		28	$3p^63d^8(^1D)4f\ ^2G^\circ$
$3p^63d^8(^1D)4f$	$^2D^\circ$	$3/2$	*706 300*	50		23	$3p^63d^8(^3P)4f\ ^4F^\circ$
		$5/2$	*706 650*	64		15	″
$3p^63d^8(^1D)4f$	$^2P^\circ$	$1/2$	*706 490*	73		24	$3p^63d^8(^3P)4f\ ^4D^\circ$
		$3/2$	*706 850*	63		17	″
$3p^63d^8(^3P)4f$	$^4F^\circ$	$5/2$	*710 830*	67		17	$3p^63d^8(^1D)4f\ ^2D^\circ$
		$3/2$	*710 940*	72		21	″
$3p^63d^8(^3P)4f$	$^2F^\circ$	$7/2$	*711 920*	67		19	$3p^63d^8(^1D)4f\ ^2G^\circ$
$3p^63d^8(^3P)4f$	$^4G^\circ$	$7/2$	*712 940*	81		12	$3p^63d^8(^3P)4f\ ^2G^\circ$
$3p^63d^84f$		$5/2$	*713 230*	32	$3p^63d^8(^3P)4f\ ^2F^\circ$	25	$3p^63d^8(^3P)4f\ ^4D^\circ$
$3p^63d^8(^3P)4f$	$^4D^\circ$	$3/2$	*713 250*	66		14	$3p^63d^8(^1D)4f\ ^2P^\circ$
		$5/2$	*713 650*	47		27	$3p^63d^8(^3P)4f\ ^2F^\circ$
		$7/2$	*714 030*	71		12	$3p^63d^8(^3P)4f\ ^2G^\circ$
$3p^63d^8(^3P)4f$	$^2G^\circ$	$7/2$	*713 518*	67		20	$3p^63d^8(^3P)4f\ ^4D^\circ$

Ge VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3p^63d^8(^3P)4f$	$^2D^\circ$	$^3/_2$	*714 100*	67	16	$3p^63d^8(^1D)4f\ ^2D^\circ$
		$^5/_2$	*714 210*	79	14	$3p^63d^8(^3P)4f\ ^4D^\circ$
$3p^63d^8(^1G)4f$	$^2P^\circ$	$^3/_2$	*715 650*	79	8	$3p^53d^{10}\ ^2P^\circ$
		$^1/_2$	*717 595*	95	3	"
$3p^63d^8(^1G)4f$	$^2D^\circ$	$^5/_2$	*720 370*	98		
		$^3/_2$	*720 550*	98		
$3p^63d^8(^1G)4f$	$^2F^\circ$	$^7/_2$	*721 400*	99		
		$^5/_2$	*721 470*	98		
$3p^53d^{10}$	$^2P^\circ$	$^3/_2$	*753 930*	87	11	$3p^63d^8(^1G)4f\ ^2P^\circ$
		$^1/_2$	*783 600*	95	3	"
$3p^63d^8(^1S)4f$	$^2F^\circ$	$^7/_2$	*768 990*	99		
Ge VII ($^3F_4$)	***Limit***		**934 800**			

Ge VII

$Z=32$

Fe I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^8\ ^3F_4$

Ionization energy 1 169 000 ± 12 000 cm^{-1} (144.9 ± 1.5 eV)

The spectrum was obtained with a spark discharge and recorded in the range of 160 – 210 Å with an uncertainty of ±0.004 Å by Podobedova *et al.* [1980]. They classified 220 lines in the array $3d^8-3d^74p$. All the levels of the ground configuration and most of $3d^74p$ were determined with an uncertainty of ±10 cm^{-1}.

New observations obtained by Podobedova and Ryabtsev [1986] enabled them to classify lines of the $3p^63d^8-3p^53d^9$ array in the range of 123 to 142 Å and the $3d^74s-3d^74p$ in the range of 739 – 987 Å as well as improving the earlier work by Podobedova *et al.* [1980]. They also give the percentage composition of all the levels.

We obtained the levels and percentages for the $3d^8$ configuration from the earlier Podobedova *et al.* [1980] paper and the remaining levels from the later Podobedova and Ryabtsev [1986] paper.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

References

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Podobedova, L. I., Ramonas, A. A., and Ryabtsev, A. N., [1980] Opt. Spectrosc. (USSR) **49**, 247.

Podobedova, L. I., and Ryabtsev, A. N., [1986] Opt. Spectrosc. (USSR) **60**, 694.

Ge VII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3p^63d^8$	^{3}F	4	0	100		
		3	4 055	100		
		2	6 468	96		
$3p^63d^8$	^{1}D	2	22 658	67	30	$3p^63d^8\ ^3$P
$3p^63d^8$	^{3}P	2	28 827	70	29	$3p^63d^8\ ^1$D
		1	29 212	100		
		0	29 769	100		
$3p^63d^8$	^{1}G	4	37 923	100		
$3p^63d^8$	^{1}S	0	86 203	100		
$3p^63d^7(^4F)4s$	^{5}F	5	393 964	99		
		4	396 659	98		
		3	398 813	98		
		2	400 338	99		
		1	401 310	99		
$3p^63d^7(^4F)4s$	^{3}F	4	405 833	97		
		3	409 481	98		
		2	411 818	98		
$3p^63d^7(^4P)4s$	^{5}P	3	421 833	99		
		2	422 209	88	12	$3p^63d^7(^2P)4s\ ^3$P
		1	423 790	98		

Ge VII – Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3p^63d^7(^2G)4s$	^3G	5	427 035	94			
		4	428 431	86			
		3	430 455	99			
$3p^63d^7(^4P)4s$	^3P	2	432 065	47		38	$3p^63d^7(^2P)4s$ ^3P
		1	432 097	44		24	$3p^63d^7(^2P)4s$ ^1P
		0	438 647?	55		45	$3p^63d^7(^2P)4s$ ^3P
$3p^63d^7(^2P)4s$	^3P	0	433 275?	55		45	$3p^63d^7(^4P)4s$ ^3P
		2	434 645	51		35	$3p^63d^7(^2P)4s$ ^3P
		1	435 977	52		35	"
$3p^63d^7(^2G)4s$	^1G	4	434 261	80		11	$3p^63d^7(^2G)4s$ ^3G
$3p^63d^7(^2H)4s$	^3H	6	437 438	100			
		5	438 931	90			
		4	441 167	87		11	$3p^63d^7(^2G)4s$ ^1G
$3p^63d^7(^2D2)4s$	^3D	3	438 698	76		23	$3p^63d^7(^2D1)4s$ ^3D
		2	440 920	57		15	"
		1	445 585	43		37	$3p^63d^7(^2P)4s$ ^1P
$3p^63d^74s$		1	439 551	38	$3p^63d^7(^2P)4s$ ^1P	26	$3p^63d^7(^2D1)4s$ ^3D
$3p^63d^7(^2H)4s$	^1H	5	444 819	91			
$3p^63d^7(^2D2)4s$	^1D	2	447 235	61		15	$3p^63d^7(^2D1)4s$ ^1D
$3p^63d^7(^2F)4s$	^3F	2	462 416	99			
		3	462 884	98			
		4	463 729	99			
$3p^63d^7(^2F)4s$	^1F	3	469 133	98			
$3p^63d^7(^2D1)4s$	^3D	1	498 640	81		18	$3p^63d^7(^2D2)4s$ ^3D
		2	499 206	78		19	"
		3	500 364	76		23	"
$3p^63d^7(^2D1)4s$	^1D	2	505 648	76		21	$3p^63d^7(^2D2)4s$ ^1D
$3p^63d^7(^4F)4p$	$^5D^\circ$	4	*506 743*	47		41	$3p^63d^7(^4F)4p$ $^5F^\circ$
		3	*514 478*	42		34	$3p^63d^7(^4F)4p$ $^5G^\circ$
		1	*517 882*	75		16	$3p^63d^7(^4P)4p$ $^5D^\circ$
		0	*518 296?*	81		18	"
$3p^63d^7(^4F)4p$	$^5F^\circ$	5	*507 521*	80		13	$3p^63d^7(^4F)4p$ $^5G^\circ$
		3	*509 684*	60		30	$3p^63d^7(^4F)4p$ $^5D^\circ$
		2	*511 950*	74		17	"
		1	*513 576*	87			
$3p^63d^74p$		4	*511 843*	35	$3p^63d^7(^4F)4p$ $^5D^\circ$	33	$3p^63d^7(^4F)4p$ $^5F^\circ$
$3p^63d^7(^4F)4p$	$^5G^\circ$	6	*514 281*	99			
		5	*514 626*	56		23	$3p^63d^7(^4F)4p$ $^3G^\circ$
		4	*516 182*	56		21	$3p^63d^7(^4F)4p$ $^5F^\circ$
		2	*516 277*	56		32	$3p^63d^7(^4F)4p$ $^5D^\circ$
		3	*517 123*	51		23	$3p^63d^7(^4F)4p$ $^5F^\circ$
$3p^63d^74p$		2	*517 526*	35	$3p^63d^7(^4F)4p$ $^5D^\circ$	33	$3p^63d^7(^4F)4p$ $^5G^\circ$

Ge VII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3p^63d^7(^4F)4p$	$^3G^\circ$	5	*520 237*	69		30	$3p^63d^7(^4F)4p\ ^5G^\circ$
		4	*524 060*	83		14	″
		3	*526 696*	90			
$3p^63d^7(^4F)4p$	$^3F^\circ$	4	*520 617*	81			
		3	*523 344*	63		21	$3p^63d^7(^4F)4p\ ^3D^\circ$
		2	*525 786*	60		23	$3p^63d^7(^4P)4p\ ^5S^\circ$
$3p^63d^7(^4F)4p$	^3D	3	525 123?	72		16	$3p^63d^7(^4F)4p\ ^3F$
		2	527 177	73			
		1	528 653	83			
$3p^63d^7(^4P)4p$	$^5S^\circ$	2	*525 200*	67		20	$3p^63d^7(^4F)4p\ ^3F^\circ$
$3p^63d^74p$		1	*537 900*	33	$3p^63d^7(^2P)4p\ ^3P^\circ$	20	$3p^63d^7(^4P)4p\ ^3S^\circ$
$3p^63d^7(^4P)4p$	$^5D^\circ$	2	*539 685*	50		11	$3p^63d^7(^4F)4p\ ^5D^\circ$
		3	*540 316*	63		13	$3p^63d^7(^2P)4p\ ^3P^\circ$
		1	*541 541*	58		13	$3p^63d^7(^4P)4p\ ^3S^\circ$
		4	*542 862*	86			
$3p^63d^7(^2G)4p$	$^3H^\circ$	5	*540 170*	56		20	$3p^63d^7(^2G)4p\ ^1H^\circ$
		4	*542 376*	79			
		6	*544 249*	89			
$3p^63d^7(^2G)4p$	$^3F^\circ$	4	*540 217*	53		13	$3p^63d^7(^2G)4p\ ^3G^\circ$
		3	*544 670*	53		28	″
		2	*549 137*	90			
$3p^63d^74p$		0	*540 556?*	36	$3p^63d^7(^4P)4p\ ^5D^\circ$	16	$3p^63d^7(^4F)4p\ ^5D^\circ$
$3p^63d^7(^2P)4p$	$^3P^\circ$	0	*543 430?*	47		27	$3p^63d^7(^4P)4p\ ^5D^\circ$
		2	*543 913*	50		10	″
$3p^63d^74p$		1	*544 951*	31	$3p^63d^7(^2P)4p\ ^3P^\circ$	24	$3p^63d^7(^4P)4p\ ^5P^\circ$
$3p^63d^74p$		2	*545 592*	26	$3p^63d^7(^4P)4p\ ^5P^\circ$	21	$3p^63d^7(^2P)4p\ ^1D^\circ$
$3p^63d^74p$		4	*546 178*	39	$3p^63d^7(^2G)4p\ ^1G^\circ$	29	$3p^63d^7(^2G)4p\ ^3F^\circ$
$3p^63d^7(^4P)4p$	$^5P^\circ$	3	*546 636*	42		18	$3p^63d^7(^4P)4p\ ^3D^\circ$
		2	*547 728*	44		13	″
$3p^63d^7(^2G)4p$	$^3G^\circ$	5	*547 345*	76		13	$3p^63d^7(^2G)4p\ ^1H^\circ$
		4	*549 426*	68		14	$3p^63d^7(^2G)4p\ ^3H^\circ$
		3	*549 742*	44		18	$3p^63d^7(^2G)4p\ ^3F^\circ$
$3p^63d^74p$		1	*548 195*	24	$3p^63d^7(^4P)4p\ ^5P^\circ$	23	$3p^63d^7(^4P)4p\ ^3S^\circ$
$3p^63d^7(^2H)4p$	$^3G^\circ$	5	*548 225*	84			
		4	*551 889*	81			
		3	*554 987*	63			
$3p^63d^7(^4P)4p$	$^3D^\circ$	3	*548 808*	44		21	$3p^63d^7(^4P)4p\ ^5P^\circ$
$3p^63d^74p$		1	*549 121*	33	$3p^63d^7(^4P)4p\ ^5P^\circ$	24	$3p^63d^7(^2P^\circ)4p\ ^3D^\circ$
$3p^63d^7(^2P)4p$	$^1S^\circ$	0	*549 503?*	65		23	$3p^63d^7(^4P)4p\ ^3P^\circ$

Ge VII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3p^63d^7(^2H)4p$	$^3I^\circ$	6	*549 592*	58		35	$3p^63d^7(^2H)4p$ $^1I^\circ$
		5	*552 176*	83		10	$3p^63d^7(^2G)4p$ $^1H^\circ$
		7	*553 185*	100			
$3p^63d^7(^2G)4p$	$^1H^\circ$	5	*549 675*	50		37	$3p^63d^7(^2G)4p$ $^3H^\circ$
$3p^63d^74p$		2	*551 188*	36	$3p^63d^7(^4P)4p$ $^3P^\circ$	25	$3p^63d^7(^4P)4p$ $^3D^\circ$
$3p^63d^7(^2D2)4p$	$^3D^\circ$	3	*551 831*	47		15	$3p^63d^7(^2D1)4p$ $^3D^\circ$
$3p^63d^74p$		1	*552 495*	35	$3p^63d^7(^4P)4p$ $^3D^\circ$	23	$3p^63d^7(^4P)4p$ $^3P^\circ$
$3p^63d^74p$		3	*552 823*	35	$3p^63d^7(^2P)4p$ $^3D^\circ$	27	$3p^63d^7(^2D2)4p$ $^3F^\circ$
$3p^63d^74p$		2	*553 030*	32	$3p^63d^7(^4P)4p$ $^3P^\circ$	16	$3p^63d^7(^2D2)4p$ $^3F^\circ$
$3p^63d^74p$		2	*553 730*	29	$3p^63d^7(^2D2)4p$ $^3D^\circ$	19	$3p^63d^7(^4P)4p$ $^3D^\circ$
$3p^63d^74p$		1	*553 741*	37	$3p^63d^7(^2D2)4p$ $^3D^\circ$	23	$3p^63d^7(^2P)4p$ $^1P^\circ$
$3p^63d^7(^4P)4p$	$^3P^\circ$	1	*555 075*	47		16	$3p^63d^7(^4P)4p$ $^3D^\circ$
		0	*558 187*	69		30	$3p^63d^7(^2P)4p$ $^1S^\circ$
$3p^63d^7(^2P)4p$	$^3D^\circ$	2	*555 549*	44		18	$3p^63d^7(^2P)4p$ $^1D^\circ$
$3p^63d^7(^2D2)4p$	$^3F^\circ$	4	*557 572*	76		19	$3p^63d^7(^2D1)4p$ $^3F^\circ$
$3p^63d^7(^2H)4p$	$^1I^\circ$	6	*557 878*	60		33	$3p^63d^7(^2H)4p$ $^3I^\circ$
$3p^63d^74p$		3	*558 778*	34	$3p^63d^7(^2D2)4p$ $^3F^\circ$	15	$3p^63d^7(^2G)4p$ $^1F^\circ$
$3p^63d^74p$		2	*559 843*	37	$3p^63d^7(^2D2)4p$ $^3F^\circ$	16	$3p^63d^7(^2D2)4p$ $^1D^\circ$
$3p^63d^7(^2P)4p$	$^3S^\circ$	1	*559 953*	60		11	$3p^63d^7(^2P)4p$ $^3P^\circ$
$3p^63d^74p$		2	*560 486*	30	$3p^63d^7(^2D2)4p$ $^1D^\circ$	21	$3p^63d^7(^2D2)4p$ $^3P^\circ$
$3p^63d^74p$		1	*560 894*	39	$3p^63d^7(^2P)4p$ $^1P^\circ$	11	$3p^63d^7(^2D2)4p$ $^3D^\circ$
$3p^63d^7(^2H)4p$	$^3H^\circ$	6	*561 279*	94			
		5	*562 236*	88			
		4	*563 599*	92			
$3p^63d^74p$		2	*564 446*	32	$3p^63d^7(^2D2)4p$ $^3P^\circ$	19	$3p^63d^7(^2D2)4p$ $^1D^\circ$
$3p^63d^7(^2H)4p$	$^1G^\circ$	4	*564 577*	61		35	$3p^63d^7(^2G)4p$ $^1G^\circ$
$3p^63d^7(^2D2)4p$	$^1F^\circ$	3	*566 263*	52		14	$3p^63d^7(^2G)4p$ $^1F^\circ$
$3p^63d^7(^2D2)4p$	$^1P^\circ$	1	*567 391*	40		20	$3p^63d^7(^2D2)4p$ $^3P^\circ$
$3p^63d^74p$		1	*568 575*	36	$3p^63d^7(^2D2)4p$ $^1P^\circ$	30	$3p^63d^7(^2D2)4p$ $^3P^\circ$
$3p^63d^7(^2D2)4p$	$^3P^\circ$	0	*568 862*	68		14	$3p^63d^7(^2P)4p$ $^3P^\circ$
$3p^63d^7(^2H)4p$	$^1H^\circ$	5	*570 244*	90			
$3p^63d^7(^2F)4p$	$^1D^\circ$	2	*577 022*	47		38	$3p^63d^7(^2F)4p$ $^3F^\circ$

Ge VII – Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3p^63d^7(^2\mathrm{F})4p$	$^3\mathrm{G}^\circ$	3	*578 696*	63		19	$3p^63d^7(^2\mathrm{F})4p$ $^3\mathrm{F}^\circ$
		4	*579 547*	45		26	"
		5	*584 341*	92			
$3p^63d^7(^2\mathrm{F})4p$	$^3\mathrm{D}^\circ$	3	*580 763*	56		21	$3p^63d^7(^2\mathrm{F})4p$ $^3\mathrm{F}^\circ$
		2	*583 647*	68		19	$3p^63d^7(^2\mathrm{F})4p$ $^1\mathrm{D}^\circ$
		1	*583 788*	87			
$3p^63d^7(^2\mathrm{F})4p$	$^3\mathrm{F}^\circ$	2	*582 542*	52		27	$3p^63d^7(^2\mathrm{F})4p$ $^1\mathrm{D}^\circ$
		3	*582 977*	51		24	$3p^63d^7(^2\mathrm{F})4p$ $^3\mathrm{D}^\circ$
		4	*584 123*	42		34	$3p^63d^7(^2\mathrm{F})4p$ $^1\mathrm{G}^\circ$
$3p^63d^7(^2\mathrm{F})4p$	$^1\mathrm{G}^\circ$	4	*584 712*	45		48	$3p^63d^7(^2\mathrm{F})4p$ $^3\mathrm{F}^\circ$
$3p^63d^7(^2\mathrm{F})4p$	$^1\mathrm{F}^\circ$	3	*592 619*	92			
$3p^63d^7(^2\mathrm{D}1)4p$	$^3\mathrm{P}^\circ$	2	*609 898*	75		20	$3p^63d^7(^2\mathrm{D}2)4p$ $^3\mathrm{P}^\circ$
		1	*610 851*	76		15	"
		0	*612 085*	83		15	"
$3p^63d^7(^2\mathrm{D}1)4p$	$^3\mathrm{F}^\circ$	2	*612 681*	74		20	$3p^63d^7(^2\mathrm{D}2)4p$ $^3\mathrm{F}^\circ$
		3	*614 904*	69		18	"
		4	*618 502*	73		22	"
$3p^63d^7(^2\mathrm{D}1)4p$	$^1\mathrm{P}^\circ$	1	*620 557*	70		10	$3p^63d^7(^2\mathrm{D}2)4p$ $^1\mathrm{P}^\circ$
$3p^63d^7(^2\mathrm{D}1)4p$	$^1\mathrm{F}^\circ$	3	*621 422*	69		18	$3p^63d^7(^2\mathrm{D}2)4p$ $^1\mathrm{F}^\circ$
$3p^63d^7(^2\mathrm{D}1)4p$	$^3\mathrm{D}^\circ$	1	*625 836*	65		19	$3p^63d^7(^2\mathrm{D}2)4p$ $^3\mathrm{D}^\circ$
		2	*626 496*	64		20	"
		3	*629 033*	66		24	"
$3p^53d^9$	$^3\mathrm{F}^\circ$	4	*728 432*	100			
		3	*742 467*	91			
		2	*759 175*	53		22	$3p^53d^9$ $^3\mathrm{D}^\circ$
$3p^53d^9$	$^1\mathrm{D}^\circ$	2	*733 491*	77		18	$3p^53d^9$ $^3\mathrm{F}^\circ$
$3p^53d^9$	$^3\mathrm{P}^\circ$	1	*769 022*	81		19	$3p^53d^9$ $^3\mathrm{D}^\circ$
		0	*769 854?*	100			
		2	*794 440*	53		43	"
$3p^53d^9$	$^3\mathrm{D}^\circ$	3	*772 711*	90			
		1	*784 470*	75		16	$3p^53d^9$ $^3\mathrm{P}^\circ$
$3p^53d^9$		2	*775 405*	34	$3p^53d^9$ $^3\mathrm{D}^\circ$	28	$3p^53d^9$ $^3\mathrm{F}^\circ$
$3p^53d^9$	$^1\mathrm{F}^\circ$	3	*845 547*	97			
$3p^53d^9$	$^1\mathrm{P}^\circ$	1	*848 346?*	91			
Ge VIII ($^4\mathrm{F}_{9/2}$)	***Limit***		**1 169 000**				

Ge VIII

$Z=32$

Mn I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^7\ ^4F_{9/2}$

Ionization energy 1 423 000 ± 14 000 cm^{-1} (176.4 ± 1.7 eV)

No classified lines have been reported for this spectrum. The energy levels of the $3d^7$ configuration have been predicted by Wyart *et al.* [1985] in a parametric study of the isoelectronic sequence with an uncertainty of a few hundred cm^{-1}.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

References

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Wyart, J. -F., Raassen, A. J. J., and Uylings, P. H. M. [1985], Phys. Scr. **32**, 169.

Ge IX

$Z=32$

Cr I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^6\ ^5D_4$

Ionization energy 1 714 000 ± 17 000 cm^{-1} (212.7 ± 2.1 eV)

No classified lines have been reported for this spectrum. We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

Reference

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Ge X

$Z=32$

V I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d^5\ ^6S_{5/2}$

Ionization energy 2 030 000 ± 20 000 cm^{-1} (251.7 ± 2.5 eV)

No classified lines have been reported for this spectrum. We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

Reference

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Ge XI

$Z = 32$

Ti I isoelectronic sequence

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

Ionization energy 2 304 000 ± 23 000 cm^{-1} (285.7 ± 2.8 eV)

No classified lines have been reported for this spectrum. We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

Reference

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. Califorania Press, Berkeley, CA).

Ge XII

$Z = 32$

Sc I isoelectronic sequence

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

Ionization energy 2 634 000 ± 26 000 cm^{-1} (326.6 ± 3.2 eV)

No lines have been classified in this spectrum. Wyart *et al.* [1985] have predicted the values for the energy levels of the $3d^3$ ground configuration and their percentage composition in a study of the isoelectronic sequence with an uncertainty of a few hundred cm^{-1}.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

References

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).
Wyart, J. -F., Raassen, A. J. J., and Uylings, P. H. M. [1985], Phys. Scr. **32**, 169.

Ge XIII

$Z = 32$

Ca I isoelectronic sequence

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

Ionization energy 2 960 000 ± 30 000 cm^{-1} (368 ± 4 eV)

No observations have been reported for this spectrum. Energy levels values for the $3d^2$ ground configuration were predicted by Wyart *et al*. [1985] with an uncertainty of a few hundred cm^{-1} in an isoelectronic study.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

References

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).
Wyart, J. F., Raassen, A. J. J., and Uylings, P. H. M. [1985], Phys. Scr. **32**, 169.

Ge XIV

$Z=32$

K I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^63d\ ^2D_{3/2}$

Ionization energy 3 300 000 ± 16 000 cm^{-1} (409 ± 2 eV)

Three transitions of the array $3p^63d-3p^53d^2$ were observed by Fawcett and Hayes [1975] with an uncertainty of ±0.03 Å in a laser-produced plasma. Kaufman *et al.* [1989] observed this spectrum in a tokamak plasma with an uncertainty of ±0.005 Å and classified three additional lines of this array. They derived the energy levels from the observed transitions and obtained an interpolated value for the ^2D ground term splitting of 7714±5 cm^{-1}. The $3p^5(^2P^\circ)3d^2(^3P)\ ^2P^\circ_{1/2}$ level value was predicted from an isoelectronic interpolation.

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion.

References

Fawcett, B. C., and Hayes, R. W. [1975], J. Opt. Soc. Am. **65**, 623.

Finkelnburg, W., and Humbach, W. [1955], Naturwiss. **42**, 35.

Kaufman, V., Sugar, J., and Rowan, W. L. [1989], J. Opt. Soc. Am. B **6**, 142.

Ge XIV

Configuration	Term	J	Level (cm^{-1})
$3s^23p^63d$	^2D	$^3/_2$	0
		$^5/_2$	7 714
$3s^23p^5(^2P^\circ)3d^2(^3F)$	$^2F^\circ$	$^5/_2$	*800 830*
$3s^23p^5(^2P^\circ)3d^2(^1G)$	$^2F^\circ$	$^7/_2$	*822 250*
$3s^23p^5(^2P^\circ)3d^2(^3P)$	$^2P^\circ$	$^1/_2$	[*877 550*]
		$^3/_2$	*887 740*
$3s^23p^5(^2P^\circ)3d^2(^3F)$	$^2D^\circ$	$^3/_2$	*885 420*
		$^5/_2$	*885 710*
Ge XV ($^1S_0$)	***Limit***		***3 300 000***

Ge XV

$Z = 32$

Ar I isoelectronic sequence

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

Ionization energy 4 290 000 ± 8000 cm^{-1} (532 ± 1 eV)

The resonance transition $3p^6\ {}^1S_0 - 3p^53d\ {}^1P^\circ_1$ was first observed by Fawcett and Hayes [1975] at 117.25 ± 0.03 Å by means of a laser-produced plasma. It was later measured by Sugar *et al.* [1987] in the spectrum of a tokamak plasma at 117.222 ± 0.01Å. They also reported a value of 145.829 ± 0.01Å for the transition $3p^6\ {}^1S_0 - 3p^53d\ {}^3D^\circ_1$.

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion.

References

Fawcett, B. C., and Hayes, R. W. [1975], J. Opt. Soc. Am. **65**, 623.

Finkelnburg, W., and Humbach, W. [1955], Naturwiss. **42**, 35.

Sugar, J., Kaufman, V., and Rowan, W. L. [1987], J. Opt. Soc. Am. B **4**, 1927.

Ge XV

Configuration	Term	J	Level (cm^{-1})
$3s^23p^6$	^1S	0	0
$3s^23p^53d$	$^3D^\circ$	1	*685 735*
$3s^23p^53d$	$^1P^\circ$	1	*853 082*
....	....	....	....
Ge XVI ($^2P^\circ_{3/2}$)	***Limit***		***4 290 000***

Ge XVI

$Z=32$

Cl I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^5\,^2P^{\circ}_{3/2}$

Ionization energy 4 570 000 ± 16 000 cm^{-1} (567 ± 2 eV)

The interval of the $3p^5\,^2P^{\circ}$ ground term is determined by the $^2P^{\circ}_{1/2}-^2P^{\circ}_{3/2}$ M1 transition observed by Denne *et al.* [1983] with a tokamak plasma at 2085.1 ± 0.1 Å.

Kaufman *et al.* [1989] observed five lines of the $3s^23p^5-3s^23p^43d$ array with a tokamak plasma. They fall in the range of 114 – 126 Å and have a measurement uncertainty of ± 0.005 Å. Corrected values for the sequence $3s^23p^5\,^2P^{\circ}_{1/2}-3s^23p^4(^3P)3d\,^2P_{1/2}$ were given by Kaufman *et al.* [1990]. We quote the energy levels from the two papers of Kaufman *et al.* The level value 838 414 is given in brackets because it was obtained by isoelectronic interpolation of the corresponding wavelength. We estimate the wavelength uncertainty to be ± 0.010 Å

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion. This was given in their paper as 367 eV but it is a misprint, as shown by our calculation with the Cowan HFR code giving a value of 568 eV.

Ge XVI

Configuration	Term	J	Level (cm^{-1})
$3s^23p^5$	$^2P^{\circ}$	3/2	*0*
		1/2	*47 944*
$3s^23p^4(^1D)3d$	^2S	1/2	790 233
$3s^23p^4(^3P)3d$	^2P	3/2	820 499
		1/2	[838 414]
$3s^23p^4(^3P)3d$	^2D	5/2	827 801
		3/2	869 839
....	....	....	....
Ge XVII ($^3P_2$)	***Limit***		**4 570 000**

References

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Denne, B., Hinnov, E., Suckewer, S., and Cohen, S. [1983], Phys. Rev. A **28**, 206.

Finkelnburg, W., and Humbach, W. [1955], Naturwiss. **42**, 35.

Kaufman, V., Sugar, J., and Rowan, W. L. [1989], J. Opt. Soc. Am. B **6**, 1444.

Kaufman, V., Sugar, J., and Rowan, W. L. [1990], J. Opt. Soc. Am. B **7**, 1169.

Ge XVII

$Z = 32$

S I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^4\ ^3\mathrm{P}_2$

Ionization energy 4 920 000 ± 8000 cm^{-1} (610 ± 1 eV)

Denne [1983] observed three M1 lines in a tokamak plasma due to transitions among the $3s^23p^4$ levels. Their measurement uncertainty is ±0.3 Å. These lines determine all levels of $3s^23p^4$ except for $^3\mathrm{P}_0$, which was derived by Kaufman *et al.* [1990] by isoelectronic fitting at 33 290±30 cm^{-1}. Level values were derived from these lines with an uncertainty of ±5 to ±30 cm^{-1} for the $^1\mathrm{S}_0$ level.

Kaufman *et al.* [1990] observed ten lines of the transition array $3s^23p^4-3s^23p^33d$ in the range of 125−143 Å and three lines of $3s^23p^4-3s3p^5$ at 218−231 Å. Their measurement uncertainty was ±0.007 Å. Their calculated percentage compositions of the levels of $3s^23p^4$ are given here. We calculated the compositions of the mixed $3s3p^5$ and $3s^23p^33d$ configurations.

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion.

References

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Ge XVII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^4$	^{3}P	2	0	88	12	$3s^23p^4\ ^1$D
		0	[33 290]	78	22	$3s^23p^4\ ^1$S
		1	41 535	100		
$3s^23p^4$	^{1}D	2	73 461	88	12	$3s^23p^4\ ^3$P
$3s^23p^4$	^{1}S	0	146 478	78	22	$3s^23p^4\ ^3$P
$3s3p^5$	^{3}P°	2	*431 810*	82	12	$3s^23p^3(^2$D°$)3d\ ^3$P°
		1	*457 340*	76	12	"
$3s^23p^3(^2$P°$)3d$	^{3}P°	2	*743 200*	71	9	$3s^23p^3(^2$P°$)3d\ ^1$D°
$3s^23p^3(^2$D°$)3d$	^{3}P°	2	*773 690*	78	12	$3s3p^5\ ^3$P°
$3s^23p^3(^2$P°$)3d$	^{1}F°	3	*782 600*	46	31	$3s^23p^3(^2$D°$)3d\ ^1$F°
$3s^23p^3(^4$S°$)3d$	^{3}D°	3	*799 240*	45	20	$3s^23p^3(^2$D°$)3d\ ^1$F°
		2	*817 680*	28	22	$3s^23p^3(^2$P°$)3d\ ^3$D°
$3s^23p^3(^2$D°$)3d$	^{1}D°	2	*851 540*	50	17	$3s^23p^3(^2$P°$)3d\ ^1$D°
$3s^23p^3(^2$D°$)3d$	^{1}F°	3	*867 340*	58	32	$3s^23p^3(^2$P°$)3d\ ^1$F°
$3s^23p^3(^2$P°$)3d$	^{1}P°	1	*915 030*	80	7	$3s^23p^3(^4$S°$)3d\ ^3$D°
Ge XVIII (^{4}S$^\circ_{3/2}$)	***Limit***		***4 920 000***			

Ge XVIII

$Z = 32$

P I isoelectronic sequence

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

Ionization energy 5 390 000 ± 32 000 cm^{-1} (668 ± 4 eV)

All levels of the ground configuration are determined with the M1 transitions observed by Denne *et al.* [1984] in a tokamak discharge. Except for the ${}^4S^\circ_{3/2}-{}^2P^\circ_{3/2}$ line at 703.6 Å, all the M1 lines are tentatively assigned. Their measurement uncertainty is ±0.2 Å, giving a level uncertainty of ±40 cm^{-1}.

The transition array $3p^3-3p^23d$ was observed in a tokamak plasma by Sugar *et al.* [1991], who classified seven lines in the range of 131 – 137 Å measured with an uncertainty of ±0.005 Å. We quote their levels. They also calculated the percentage composition of the $3s^23p^3$ levels. We have calculated the percentages for the interacting $3s3p^4$ and $3s^23p^23d$ configurations. The two level values given in parentheses were obtained by Sugar *et al.* by interpolation of observed minus calculated energies with an uncertainty of ±0.01 Å.

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion.

References

Denne, B., Hinnov, E., Suckewer, S., and Timberlake, J. [1984], J. Opt. Soc. Am. B **1**, 296.

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Sugar, J., Kaufman, V., and Rowan, W. L. [1991], J. Opt. Soc. Am. B **8**, 22.

Ge XVIII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^3$	${}^4S^\circ$	3/2	*0*	86	11	$3s^23p^3\ {}^2P^\circ$
$3s^23p^3$	${}^2D^\circ$	3/2	*56 117*	75	16	$3s^23p^3\ {}^2P^\circ$
		5/2	*73 646*	100		
$3s^23p^3$	${}^2P^\circ$	1/2	*112 334*	100		
		3/2	*142 132*	73	22	$3s^23p^3\ {}^2D^\circ$
$3s^23p^2({}^3P)3d$	${}^4P$	5/2	731 502	80	7	$3s3p^4\ {}^4P$
		3/2	740 598	56	15	$3s^23p^2({}^1D)3d\ {}^2P$
$3s^23p^2({}^1S)3d$	${}^2D$	5/2	805 800	51	8	$3s^23p^2({}^1D)3d\ {}^2F$
$3s^23p^2({}^3P)3d$	${}^2F$	7/2	834 392	40	34	$3s^23p^2({}^1D)3d\ {}^2F$
$3s^23p^2({}^1D)3d$	${}^2P$	3/2	[840 300]	46	27	$3s^23p^2({}^3P)3d\ {}^2P$
$3s^23p^2({}^3P)3d$	${}^2D$	5/2	876 810	39	23	$3s^23p^2({}^1S)3d\ {}^2D$
Ge XIX (${}^3P_0$)	***Limit***		**5 390 000**			

Ge XIX

$Z=32$

Si I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^2\ {}^3\mathrm{P}_0$

Ionization energy 5 700 000 ± 8000 cm^{-1} (707 ± 1 eV)

Measurements of M1 radiation in tokamak discharges provided sufficient information with which to determine all the energy levels of the $3p^2$ configuration. The interval ${}^3\mathrm{P}_0-{}^3\mathrm{P}_1$ and ${}^3\mathrm{P}_1-{}^3\mathrm{P}_2$ were observed by Denne *et al.* [1983] at 2933.7 ± 0.2 Å and 5170.3 ± 0.3 Å, respectively. Datla *et al.* [1989] have given the ${}^3\mathrm{P}_1-{}^1\mathrm{D}_2$ and ${}^3\mathrm{P}_2-{}^1\mathrm{D}_2$ M1 transitions at 1341.2 ± 0.5 Å and 1809.9 ± 0.5 Å. Hinnov [1985] reported the ${}^3\mathrm{P}_1-{}^1\mathrm{S}_0$ line at 746.9 ± 0.3 Å.

The transition $3p^2\ {}^3\mathrm{P}_2-3p3d\ {}^3\mathrm{D}^\circ_3$ was reported by Fawcett and Hayes [1975]. With spectra of a laser-produced plasma and a tokamak discharge, Sugar *et al.* [1990] classified nine additional lines of this array and three lines of $3s^2 3p^2-3s3p^3$. Their wavelength uncertainty was ±0.005 Å. They also included the percentage composition of the levels.

New observations of this spectrum with a high energy laser-produced plasma by Ekberg *et al.* [1992] confirm all but the $3s3p^3\ {}^3\mathrm{P}^\circ_2$ level in the results of Sugar *et al.* They report three additional levels: the $3s3p^3\ {}^3\mathrm{P}^\circ_1$, ${}^3\mathrm{D}^\circ_2$, and ${}^3\mathrm{D}^\circ_1$. We include their values for these levels and their calculated percentage compositions.

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion.

References

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Fawcett, B. C., and Hayes, R. W. [1975], J. Opt. Soc. Am. **65**, 623.

Finkelnburg, W., and Humbach, W. [1955], Naturwiss. **42**, 35.

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Sugar, J., Kaufman, V., and Rowan, W. L. [1990], J. Opt. Soc. Am. B **7**, 152.

Ge XIX

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^2$	^{3}P	0	0	90	10	$3s^23p^2$ ^{1}S
		1	34 076.7	100		
		2	53 412.5	71	29	$3s^23p^2$ ^{1}D
$3s^23p^2$	^{1}D	2	108 650	71	29	$3s^23p^2$ ^{3}P
$3s^23p^2$	^{1}S	0	167 970	90	10	$3s^23p^2$ ^{3}P
$3s3p^3$	^{3}D°	1	*444 690*	77	11	$3s^23p3d$ ^{3}D°
		2	*446 159*	75	10	"
$3s3p^3$	^{3}P°	1	*515 931*	78	10	$3s^23p3d$ ^{3}P°
		2	*521 554*	59	14	$3s3p^3$ ^{3}D°
$3s3p^3$	^{3}S°	1	*617 645*	67	28	$3s3p^3$ ^{1}P°
$3s3p^3$	^{1}P°	1	*674 263*	55	29	$3s3p^3$ ^{3}S°
$3s^23p3d$	^{3}P°	2	*704 381*	50	16	$3s^23p3d$ ^{1}D°
		1	*752 767*	60	30	$3s^23p3d$ ^{3}D°
$3s^23p3d$	^{3}D°	1	*716 266*	57	29	$3s^23p3d$ ^{3}P°
		3	*752 792*	86	8	"
		2	*759 430*	43	37	"
$3s^23p3d$	^{1}D°	2	*741 021*	38	31	$3s^23p3d$ ^{3}D°
$3s^23p3d$	^{1}F°	3	*817 036*	95	4	$3s^23p3d$ ^{3}D°
$3s^23p3d$	^{1}P°	1	*839 250*	82	12	$3s3p^3$ ^{1}P°
Ge XX (^{2}P$_{1/2}$)	***Limit***		**5 700 000**			

Ge XX

$Z = 32$

Al I isoelectronic sequence

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

Ionization energy 6 030 000 ± 24 000 cm^{-1} (748 ± 3 eV)

The first observations were reported by Fawcett and Hayes [1975] who identified the $3s^23p-3s^23d$ $^2\mathrm{P}^\circ_{1/2}-{}^2\mathrm{D}_{3/2}$ and $^2\mathrm{P}^\circ_{3/2}-{}^2\mathrm{D}_{5/2}$ lines as well as the transition $3s^23p\ ^2\mathrm{P}^\circ_{3/2}-3s3p^2\ ^2\mathrm{P}_{3/2}$ with a laser-produced plasma.

The spectrum was observed in a tokamak discharge by Hinnov *et al.* [1986]. They classified nine lines in the $3s^23p-3s3p^2$ and $3s^23p-3s^23d$ arrays and gave wavelengths with an uncertainty of ±0.05 Å. The spectrum was reobserved by Sugar *et al.* [1988] who also used a tokamak discharge but obtained a wavelength uncertainty of ±0.01 Å by means of photographic detection and an improved distribution of wavelength standards.

With spectra emitted by a laser-produced plasma in the range of 130 – 235 Å Ekberg *et al.* [1991] observed transitions from the $3p^3$ and $3s3p3d$ configurations and determined the positions of 16 of these levels. Their wavelength uncertainty is reported as ±0.01 Å, giving an average level uncertainty of ±40 cm^{-1}. They also derived the percentage composition of all the levels. The $3s^23p$ $^2\mathrm{P}^\circ$ splitting is from the M1 line of Hinnov *et al.* Levels of $3s3p^2$ and $3s^23d$ are those derived by Sugar *et al.*

The value for the ionization energy was calculated by Finkelnburg and Humbach [1955] by extrapolation of the effective charge on the residual ion.

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Ge XX

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p$	^{2}P°	1/2	*0*	97		
		3/2	*54 564*	97		
$3s3p^2$	^{2}D	3/2	453 869	83	12	$3s^23d$ ^{2}D
		5/2	466 407	76	11	"
$3s3p^2$	^{2}P	1/2	530 521	48	47	$3s3p^2$ ^{2}S
		3/2	597 020	93		
$3s3p^2$	^{2}S	1/2	585 257	48	49	$3s3p^2$ ^{2}P
$3s^23d$	^{2}D	3/2	682 246	84	13	$3s3p^2$ ^{2}D
		5/2	689 533	86	12	"
$3p^3$	^{4}S°	3/2	*875 850*	75	13	$3p^3$ ^{2}D°
$3s3p(^3$P°$)3d$	^{4}P°	5/2	*996 200*	60	28	$3s3p(^3$P°$)3d$ ^{4}D°
		1/2	*1 035 630*	90	10	"
$3s3p(^3$P°$)3d$	^{4}D°	3/2	*1 000 790*	62	32	$3s3p(^3$P°$)3d$ ^{4}P°
		1/2	*1 002 640*	88	10	"
		7/2	*1 033 390*	95		
$3s3p(^3$P°$)3d$	^{2}D°	3/2	*1 050 590*	46	23	$3s3p(^1$P°$)3d$ ^{2}D°
$3s3p(^3$P°$)3d$	^{2}F°	7/2	*1 114 490*	69	30	$3s3p(^1$P°$)3d$ ^{2}F°
$3s3p(^3$P°$)3d$	^{2}P°	3/2	*1 157 630*	63	18	$3s3p(^1$P°$)3d$ ^{2}P°
		1/2	*1 184 750*	86	10	$3p^3$ ^{2}P°
$3s3p(^1$P°$)3d$	^{2}F°	7/2	*1 184 190*	66	30	$3s3p(^3$P°$)3d$ ^{2}F°
		5/2	*1 190 040*	66	28	"
$3s3p(^1$P°$)3d$	^{2}P°	1/2	*1 211 960*	88	6	$3p^3$ ^{2}P°
		3/2	*1 223 700*	73	9	$3s3p(^1$P°$)3d$ ^{2}D°
$3s3p(^1$P°$)3d$	^{2}D°	3/2	*1 217 450*	44	18	$3s3p(^3$P°$)3d$ ^{2}P°
		5/2	*1 222 780*	64	16	$3s3p(^3$P°$)3d$ ^{2}D°
…………	…………	…………	…………			
Ge XXI (^{1}S$_0$)	***Limit***		**6 030 000**			

Ge XXI

$Z = 32$

Mg I isoelectronic sequence

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

Ionization energy 6 730 000 ± 67 000 cm^{-1} (834 ± 8 eV)

The first observations of this spectrum were reported by Fawcett and Hayes [1975] who identified the transitions $3s^2\ {}^1S_0 - 3s3p\ {}^1P^\circ_1$, $3s3p\ {}^3P^\circ_2 - 3s3d\ {}^3D_3$, and $3s3p\ {}^1P^\circ_1 - 3s3d\ {}^1D_2$ with a laser-produced plasma. The spin-forbidden resonance line $3s^2\ {}^1S_0 - 3s3p\ {}^3P^\circ_1$ and the M1 transition $3s3p\ {}^3P^\circ_1 - {}^3P^\circ_2$ were both identified in spectra of tokamak discharges by Finkenthal *et al.* [1982] and by Denne *et al.* [1983], respectively. With a laser-generated plasma, Litzén and Redfors [1987] identified the $3s3d - 3p3d$ transitions ${}^3D - {}^3F^\circ$ and ${}^1D - {}^1F^\circ$.

The spectrum was observed more completely by Sugar *et al.* [1989] with both laser and tokamak excitations. They identified 38 lines in the range of 152 – 266 Å measured with an uncertainty of ±0.005 Å. Their values for the $3s^2 - 3s3p$ resonance lines are 196.573 Å and 293.362 Å. Lines of the arrays $3s3p - 3p^2$, $3s3p - 3s3d$, $3s3d - 3p3d$, $3p^2 - 3p3d$, and $3p3d - 3d^2$ were classified.

With a line-focused high-powered laser plasma Ekberg *et al.* [1989] produced a more complete excitation and improved and extended the analysis. We report their values for the levels obtained with wavelength measurements having an uncertainty of ±0.01 Å. They also gave the percentage compositions of the levels with configuration interaction among all the even configurations $3s^2$, $3p^2$, $3d^2$, and $3s3d$ and between the odd configurations $3s3p$ and $3p3d$.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

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Ge XXI

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2$	^{1}S	0	0	98	2	$3p^2$ ^{1}S
$3s3p$	^{3}P°	0	*326 384*	100		
		1	*340 862*	97	2	$3s3p$ ^{1}P°
		2	*383 421*	100		
$3s3p$	^{1}P°	1	*508 690*	95	3	$3s3p$ ^{3}P°
$3p^2$	^{3}P	0	777 547	91	8	$3p^2$ ^{1}S
		1	813 275	100		
		2	864 401	76	16	$3p^2$ ^{1}D
$3p^2$	^{1}D	2	808 162	62	23	$3p^2$ ^{3}P
$3p^2$	^{1}S	0	963 328	88	9	$3p^2$ ^{3}P
$3s3d$	^{3}D	1	965 838	100		
		2	969 563	100		
		3	975 540	100		
$3s3d$	^{1}D	2	1 080 920	78	21	$3p^2$ ^{1}D
$3p3d$	^{3}F°	2	*1 315 892*	82	17	$3p3d$ ^{1}D°
		3	*1 344 446*	95	4	$3p3d$ ^{3}D°
		4	*1 380 973*	100		
$3p3d$	^{1}D°	2	*1 361 297*	65	15	$3p3d$ ^{3}P°
$3p3d$	^{3}D°	1	*1 392 766*	75	21	$3p3d$ ^{3}P°
		2	*1 406 809*	46	32	"
		3	*1 431 589*	94	4	$3p3d$ ^{3}F°
$3p3d$	^{3}P°	0	*1 435 471*	100		
		1	*1 435 827*	77	23	$3p3d$ ^{3}D°
		2	*1 437 695*	52	45	"
$3p3d$	^{1}F°	3	*1 521 245*	97	2	$3p3d$ ^{3}D°
$3p3d$	^{1}P°	1	*1 538 477*	94	3	$3p3d$ ^{3}D°
$3d^2$	^{3}F	2	1 952 219	99	1	$3d^2$ ^{1}D
		3	1 958 840	100		
		4	1 966 176	99	1	$3d^2$ ^{1}G
$3d^2$	^{1}D	2	2 000 311	58	40	$3d^2$ ^{3}P
$3d^2$	^{3}P	1	2 005 861	100		
		2	2 013 067	59	40	$3d^2$ ^{1}D
$3d^2$	^{1}G	4	2 011 823	99	1	$3d^2$ ^{3}F
Ge XXII (^{2}S$_{1/2}$)	***Limit***		**6 730 000**			

Ge XXII

$Z=32$

Na I isoelectronic sequence

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

Ionization energy 7 101 700 ± 500 cm^{-1} (880.50 ± 0.06 eV)

The $3s-3p$ and $3p-3d$ doublets were first observed in a laser-induced plasma by Fawcett and Hayes [1975] with a wavelength uncertainty of 0.03 Å. Using a similar light source Kononov *et al.* [1979] considerably extended the observed lines to include $3s-np$ $(n=3-5)$, $3p-nd$ $(n=3-6)$, $3p-4s$, $3d-nf$ $(n=4-6)$, $3d-4p$, $4p-5d$, $4d-5f$, and $4f-5g$. The $3s\ {}^2S_{1/2}-3p\ {}^2P^\circ_{1/2}$ line was not observed. The wavelength uncertainties are within ±0.01 Å for all lines except for $3d-6d$ and $3d-7f$. Improved values are derived by Reader *et al.* [1987] for the $3s-3p$, $3p-3d$, and $3d-4f$ transitions with uncertainties of ±0.007 Å, including the $3s\ {}^2S_{1/2}-3p\ {}^2P^\circ_{1/2}$ line. Their values agree with Kononov *et al.* to within ±0.005 Å, except for the $3p\ {}^2P^\circ_{1/2}-3d\ {}^2D_{3/2}$ line, which deviates by 0.011 Å.

We have derived the values for the energy levels combining the data of Reader *et al.* with those of Kononov *et al.* We derived the value for the ionization energy from the nf series $(n=4-6)$, assuming a linear quantum defect dependence on the term value.

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Ge XXII

Configuration	Term	J	Level (cm^{-1})
$3s$	${}^2S$	$1/2$	0
$3p$	${}^2P^\circ$	$1/2$	*382 403*
		$3/2$	*441 501*
$3d$	${}^2D$	$3/2$	955 830
		$5/2$	966 130
$4s$	${}^2S$	$1/2$	3 305 400
$4p$	${}^2P^\circ$	$1/2$	*3 460 300*
		$3/2$	*3 483 200*
$4d$	${}^2D$	$3/2$	3 674 900
		$5/2$	3 679 300
$4f$	${}^2F^\circ$	$5/2$	*3 770 000*
		$7/2$	*3 771 800*
$5p$	${}^2P^\circ$	$1/2$	*4 816 000*
		$3/2$	*4 826 700*
$5d$	${}^2D$	$5/2$	4 921 000
		$7/2$	4 923 400
$5f$	${}^2F^\circ$	$5/2$	4 968 800
		$7/2$	4 969 500
$5g$	${}^2G$	$7/2$	4 975 200
		$9/2$	4 975 800
$6d$	${}^2D$	$5/2$	5 593 000
$6f$	${}^2F^\circ$	$5/2$	*5 620 400*
		$7/2$	*5 621 400*
$7f$	${}^2F^\circ$	$7/2$	*6 019 000*
Ge XXIII (${}^1S_0$)	***Limit***		**7 101 700**

Ge XXIII

$Z=32$

Ne I isoelectronic sequence

Ground state $1s^22s^22p^6\ ^1\mathrm{S}_0$

Ionization energy 17 558 000 ± 18 000 cm^{-1} (2176.9 ± 2.2 eV)

Resonance lines in the range of 7 – 10 Å originating from $2p^5nl$ configurations where $nl = 3s, 3d, 4s$, and $4d$ as well as $2s2p^63p$ were observed by Burkhalter *et al.* [1975] with a laser-generated plasma and a measurement uncertainty of ±0.01 Å. Gordon *et al.* [1980] extended the observations to $nl=5d$ and $6d$, added $2s2p^64p$, and improved the wavelength uncertainty to ±0.005 Å. We quote the results of Gordon *et al.*

By observing axially along a line-focused laser plasma, Lee *et al.* [1987] identified three lines of the array $2p^53s-2p^53p$ from which we derive the $2p^53p$ levels.

The value for the ionization energy was derived by Hutcheon [1980] from the $2p^5nd$ series.

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Ge XXIII

Configuration	Term	J	Level (cm^{-1})
$2s^22p^6$	$^1\mathrm{S}$	0	0
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})3s$	$(\frac{3}{2},\frac{1}{2})^\circ$	1	*9 990 000*
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})3s$	$(\frac{1}{2},\frac{1}{2})^\circ$	1	*10 244 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})3p$	$(\frac{3}{2},\frac{3}{2})$	2	10 421 000
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})3p$	$(\frac{1}{2},\frac{3}{2})$	2	10 667 000
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})3p$	$(\frac{1}{2},\frac{1}{2})$	0	10 754 000
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})3d$	$(\frac{3}{2},\frac{3}{2})^\circ$	1	*10 846 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})3d$	$(\frac{3}{2},\frac{5}{2})^\circ$	1	*10 976 000*
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})3d$	$(\frac{1}{2},\frac{3}{2})^\circ$	1	*11 197 000*
$2s2p^63p$	$(\frac{1}{2},\frac{1}{2})^\circ$	1	*11 867 000*
$2s2p^63p$	$(\frac{1}{2},\frac{3}{2})^\circ$	1	*11 943 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})4s$	$(\frac{3}{2},\frac{1}{2})^\circ$	1	*13 490 000*
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})4s$	$(\frac{1}{2},\frac{1}{2})^\circ$	1	*13 749 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})4d$	$(\frac{3}{2},\frac{5}{2})^\circ$	1	*13 879 000*
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})4d$	$(\frac{1}{2},\frac{3}{2})^\circ$	1	*14 122 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})5d$	$(\frac{3}{2},\frac{3}{2})^\circ$	1	*15 188 000*
$2s2p^64p$	$(\frac{1}{2},\frac{1}{2})^\circ$	1	*15 188 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})5d$	$(\frac{3}{2},\frac{5}{2})^\circ$	1	*15 218 000*
$2s2p^64p$	$(\frac{1}{2},\frac{3}{2})^\circ$	1	*15 218 000*
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})5d$	$(\frac{1}{2},\frac{3}{2})^\circ$	1	*15 468 000*
$2s^22p^5(^2\mathrm{P}^\circ_{3/2})6d$	$(\frac{3}{2},\frac{5}{2})^\circ$	1	*15 944 000*
$2s^22p^5(^2\mathrm{P}^\circ_{1/2})6d$	$(\frac{1}{2},\frac{3}{2})^\circ$	1	*16 202 000*
Ge XXIV $(^2\mathrm{P}^\circ_{3/2})$	***Limit***		***17 558 000***

Ge XXIV

$Z=32$

F I isoelectronic sequence

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

Ionization energy 18 580 000 ± 180 000 cm^{-1} (2303 ± 22 eV)

The ground state $^2\mathrm{P}^\circ$ term interval was determined with the magnetic dipole transition observed at 379.5 ± 0.1 Å in a tokamak plasma by Denne and Hinnov [1987]. The $2s2p^6\ ^2\mathrm{S}_{1/2}$ level was derived from the identification of the two resonance lines to the ground $^2\mathrm{P}^\circ$ term in a laser plasma by Behring *et al.* [1976] and by Kononov *et al.* [1977]. Improved wavelengths with an uncertainty of ±0.01 Å were obtained by Feldman *et al.* [1989] by observing along the axis of a line-focused laser plasma.

Burkhalter *et al.* [1977] classified lines in the range of 8.5 – 9.5 Å observed with a laser plasma. These are identified as transitions from $2p^43s$ and $2p^43d$ to the $2p^5$ ground term. Their wavelength uncertainty is given as ±0.003 Å. The same transition arrays were observed by Boiko *et al.* [1979] including nine additional classified lines with the same wavelength uncertainty of Burkhalter *et al.* Gordon *et al.* [1980] repeated the observations with an estimated uncertainty of ±0.005 Å but extended the wavelength range to 6.7 Å to include the upper configurations $2s2p^53p$, $2p^44s$, and $2p^44d$. We give the results of Gordon *et al.* and their calculated percentage compositions for the levels. No levels could be derived for the $2p^44d$ configuration because of insufficient resolution of the spectrum.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

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Ge XXIV

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2s^22p^5$	$^2\mathrm{P}^\circ$	3/2	*0*				
		1/2	*263 500*				
$2s2p^6$	$^2\mathrm{S}$	1/2	1 517 440				
$2s^22p^4(^3\mathrm{P})3s$	$^4\mathrm{P}$	5/2	10 468 000	83		17	$2s^22p^4(^1\mathrm{D})3s\ ^2\mathrm{D}$
		1/2	10 594 000	51		38	$2s^22p^4(^1\mathrm{S})3s\ ^2\mathrm{S}$
		3/2	10 707 000	80		19	$2s^22p^4(^3\mathrm{P})3s\ ^2\mathrm{P}$
$2s^22p^4(^3\mathrm{P})3s$	$^2\mathrm{P}$	3/2	10 498 000	60		21	$2s^22p^4(^1\mathrm{D})3s\ ^2\mathrm{D}$
		1/2	10 732 000	73		25	$2s^22p^4(^3\mathrm{P})3s\ ^4\mathrm{P}$
$2s^22p^4(^1\mathrm{D})3s$	$^2\mathrm{D}$	5/2	10 803 000	83		17	$2s^22p^4(^3\mathrm{P})3s\ ^4\mathrm{P}$
		3/2	10 811 000	78		21	$2s^22p^4(^3\mathrm{P})3s\ ^2\mathrm{P}$
$2s^22p^4(^1\mathrm{S})3s$	$^2\mathrm{S}$	1/2	11 133 000	60		24	$2s^22p^4(^3\mathrm{P})3s\ ^4\mathrm{P}$
$2s^22p^4(^3\mathrm{P})3d$	$^4\mathrm{P}$	1/2	11 357 000	47		29	$2s^22p^4(^3\mathrm{P})3d\ ^2\mathrm{P}$
$2s^22p^43d$		3/2	11 379 000	37	$2s^22p^4(^3\mathrm{P})3d\ ^4\mathrm{P}$	29	$2s^22p^4(^3\mathrm{P})3d\ ^2\mathrm{D}$
$2s^22p^43d$		5/2	11 406 000	28	$2s^22p^4(^3\mathrm{P})3d\ ^2\mathrm{D}$	24	$2s^22p^4(^3\mathrm{P})3d\ ^2\mathrm{F}$

Ge XXIV – Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2s^22p^4(^3P)3d$	^4D	$1/2$	11 526 000	71		15	$2s^22p^4(^3P)3d\ ^2P$
$2s^22p^43d$		$3/2$	11 557 000	38	$2s^22p^4(^3P)3d\ ^4D$	17	$2s^22p^4(^3P)3d\ ^4P$
$2s^22p^4(^3P)3d$	^2F	$5/2$	11 570 000	45		24	$2s^22p^4(^3P)3d\ ^2D$
$2s^22p^4(^3P)3d$	^2P	$3/2$	11 594 000	41		17	$2s^22p^4(^1D)3d\ ^2P$
$2s^22p^4(^1D)3d$	^2S	$1/2$	11 660 000	72		18	$2s^22p^4(^3P)3d\ ^4P$
$2s^22p^4(^1D)3d$	^2P	$3/2$	11 680 000	62		13	$2s^22p^4(^3P)3d\ ^2P$
		$1/2$	11 746 000	56		35	″
$2s^22p^43d$		$5/2$	11 682 000	38	$2s^22p^4(^1D)3d\ ^2F$	27	$2s^22p^4(^1D)3d\ ^2D$
$2s^22p^4(^1D)3d$	^2D	$3/2$	11 727 000	60		28	$2s^22p^4(^1D)3d\ ^2D$
$2s2p^5(^3P^\circ)3p$	^4D	$5/2$	12 177 000	48		32	$2s2p^5(^3P^\circ)3p\ ^2D$
		$3/2$	12 347 000	42		25	$2s2p^5(^3P^\circ)3p\ ^4P$
$2s2p^5(^3P^\circ)3p$	^4P	$5/2$	12 231 000	52		47	$2s2p^5(^3P^\circ)3p\ ^2D$
$2s2p^5(^3P^\circ)3p$	^2P	$3/2$	12 291 000	47		37	$2s2p^5(^3P^\circ)3p\ ^4D$
$2s2p^53p$		$1/2$	12 330 000	38	$2s2p^5(^3P^\circ)3p\ ^2S$	35	$2s2p^5(^3P^\circ)3p\ ^2P$
$2s2p^53p$		$1/2$	12 483 000	38	$2s2p^5(^3P^\circ)3p\ ^2S$	35	$2s2p^5(^3P^\circ)3p\ ^2P$
$2s2p^5(^1P^\circ)3p$	^2D	$3/2$	12 658 000	74		12	$2s2p^5(^1P^\circ)3p\ ^2P$
		$5/2$	12 724 000	85		8	$2s2p^5(^3P^\circ)3p\ ^4D$
$2s2p^5(^1P^\circ)3p$	^2P	$1/2$	12 721 000	78		10	$2s2p^5(^3P^\circ)3p\ ^2S$
		$3/2$	12 745 000	76		11	$2s2p^5(^1P^\circ)3p\ ^2D$
$2s^22p^4(^3P)4s$	^2P	$3/2$	14 198 000	66		19	$2s^22p^4(^1D)4s\ ^2D$
$2s^22p^4(^1D)4s$	^2D	$5/2$	14 522 000	82		18	$2s^22p^4(^3P)4s\ ^4P$
		$3/2$	14 529 000	80		17	$2s^22p^4(^3P)4s\ ^2P$
....	....	......	....				
Ge XXV ($^3P_2$)	***Limit***		**18 580 000**				

Ge XXV

$Z = 32$

O I isoelectronic sequence

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

Ionization energy 19 700 000 ± 200 000 cm^{-1} (2442 ± 25 eV)

Two magnetic dipole lines were identified by Denne and Hinnov [1987] in a tokamak plasma: the $3p^4\ {}^3P_2 - {}^3P_1$ and ${}^3P_1 - {}^1D_2$ at 410.7 ± 0.3 Å and 297.5 ± 0.3 Å, respectively.

Behring *et al.* [1976] gave classifications for six lines of the $2s^22p^4 - 2s2p^5$ array observed in a laser plasma. This was extended to 14 lines by Feldman *et al.* [1989], who also identified two transitions from the $2p^6\ {}^1S_0$ level. These authors improved the wavelength uncertainty to ± 0.01 Å by observing axially along a line-focused laser plasma. Their level values are given, rounded off to correspond with their measurement uncertainty. Gordon *et al.* [1980] have given classifications for transitions in the arrays $2p^4 - 2p^33d$ and $2p^4 - 2p^33s$, but most are unresolved.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

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Ge XXV

Configuration	Term	J	Level (cm^{-1})
$2s^22p^4$	${}^3P$	2	0
		0	127 240
		1	243 540
$2s^22p^4$	${}^1D$	2	336 200
$2s^22p^4$	${}^1S$	0	646 650
$2s2p^5$	${}^3P^\circ$	2	*1 324 130*
		1	*1 457 310*
		0	*1 596 720*
$2s2p^5$	${}^1P^\circ$	1	*1 842 920*
$2p^6$	${}^1S$	0	3 021 850
Ge XXVI (${}^4S_{3/2}$)	***Limit***		**19 700 000**

Ge XXVI

$Z=32$

N I isoelectronic sequence

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

Ionization energy 21 500 000 ± 220 000 cm^{-1} (2666 ± 27 eV)

Two magnetic dipole transitions were identified by Denne and Hinnov [1987] in a tokamak plasma: the $2p^3$ $^4S^\circ_{3/2}-{}^2D^\circ_{3/2}$ and $2p^3$ $^4S^\circ_{3/2}-{}^2D_{5/2}$ lines at 427.9 ± 0.3 Å and 319.1 ± 0.3 Å, respectively.

Behring *et al.* [1985] observed nine lines of the arrays $2s^22p^3-2s2p^4$ and $2s2p^4-2p^5$. Their results were extended by Feldman *et al.* [1989] to 22 lines with a wavelength uncertainty of ±0.01 Å by observing a line-focused laser plasma axially. We give the energy level values of Feldman *et al.* rounded off to correspond with their measurement uncertainty.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

References

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Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Denne, B., and Hinnov, E. [1987], Phys. Scr. **35**, 811.

Feldman, U., Ekberg, J. O., Brown, C. M., and Seely, J. F. [1989], J. Opt. Soc. Am. B **6**, 1652.

Ge XXVI

Configuration	Term	J	Level (cm^{-1})
$2s^22p^3$	$^4S^\circ$	3/2	*0*
$2s^22p^3$	$^2D^\circ$	3/2	*233 740*
		5/2	*313 520*
$2s^22p^3$	$^2P^\circ$	1/2	*426 510*
		3/2	*629 730*
$2s2p^4$	^4P	5/2	1 081 480
		3/2	1 248 820
		1/2	1 272 280
$2s2p^4$	^2D	3/2	1 504 340
		5/2	1 569 240
$2s2p^4$	^2S	1/2	1 716 690
$2s2p^4$	^2P	3/2	1 787 650
		1/2	2 038 470
$2p^5$	$^2P^\circ$	3/2	*2 743 260*
		1/2	*3 016 700*
Ge XXVII ($^3P_0$)	*Limit*		*21 500 000*

Ge XXVII

$Z = 32$

C I isoelectronic sequence

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

Ionization energy 22 130 000 ± 220 000 cm^{-1} (2744 ± 27 eV)

Two magnetic dipole lines were reported by Denne and Hinnov [1987] from tokamak plasma observations: the $2p^2\ ^3P_0 - ^3P_1$ and $2p^2\ ^3P_1 - ^3P_2$ at 454.8 ± 0.3 Å and 1473.7 ± 0.1 Å, respectively.

Behring *et al.* [1985] identified two lines of the array $2s^22p^2 - 2s2p^3$ in a laser plasma. Their measurement uncertainty is ±0.005 Å. We derive level values from their wavelength measurements.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

Ge XXVII

Configuration	Term	J	Level (cm^{-1})
$2s^22p^2$	^3P	0 1 2	0 219 880 287 736
$2s2p^3$	$^3P°$	2	*1 516 690*
$2s2p^3$	$^3S°$	1	*1 633 620*
Ge XXVIII ($^2P°_{1/2}$)	***Limit***		***22 130 000***

References

Behring, W. E., Seely, J. F., Goldsmith, S., Cohen, L., Richardson, M., and Feldman, U. [1985], J. Opt. Soc. Am. B 2, 886.

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Denne, B., and Hinnov, E. [1987], Phys. Scr. 35, 811.

Ge XXVIII

$Z = 32$

B I isoelectronic sequence

Ground state $1s^22s^22p\ ^2P°_{1/2}$

Ionization energy 23 280 000 ± 230 000 cm^{-1} (2886 ± 29 eV)

The $^2P°$ ground term splitting is determined by the magnetic dipole line at 339.5 ± 0.3 Å given by Denne and Hinnov [1987]. We derive the $^2P°_{3/2}$ level from their wavelength measurement.

The transition array $2s2p^2 - 2s2p3d$ was reported by Burkhalter *et al.* [1989] at 7.3 – 7.8 Å. No transitions from the $2s2p^2$ levels to the ground term are known.

We calculated the value for the ionization energy with the Cowan [1981] HFR code and estimate the uncertainty to be 1%.

Ge XXVIII

Configuration	Term	J	Level (cm^{-1})
$2s^22p$	$^2P°$	$^1/_2$ $^3/_2$	*0* *294 550*
Ge XXIX ($^1S_0$)	***Limit***		***23 280 000***

References

Burkhalter, P. G., Newman, D. A., and Knauer, J. P. [1989], J. Opt. Soc. Am. B 6, 1964.

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra,* (Univ. California Press, Berkeley, CA).

Denne, B., and Hinnov, E. [1987], Phys. Scr. 35, 811.

Ge XXIX

$Z=32$

Be I isoelectronic sequence

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

Ionization energy 24 750 000 ± 250 000 cm^{-1} (3069 ± 31 eV)

Denne and Hinnov measured the M1 transition $2s2p\ ^3P_1^\circ - ^3P_2^\circ$ at 408.7 ± 0.3 Å. In addition they reported the $2s^2\ ^1S_0 - 2s2p\ ^3P_1^\circ$ and $^1P_1^\circ$ lines at 199.36 ± 0.03 Å and 92.90 ± 0.03 Å, respectively. The levels are derived from these identifications.

Seven lines of the $2s2p-2s3d$ and $2p^2-2p3d$ arrays are reported by Burkhalter *et al.* [1989]. Four of these lines are also classified in the next lower ionization stage and two lines are multiply classified in B-like germanium. We omit these results.

Boiko *et al.* [1977] have given classifications for transitions in the $2p^2-2p3d$ array, but these are mostly unresolved.

The value for the ionization energy was calculated with the Cowan [1981] HFR code.

Ge XXIX

Configuration	Term	J	Level (cm^{-1})
$2s^2$	^1S	0	0
$2s2p$	$^3P^\circ$	0	
		1	*501 600*
		2	*746 280*
$2s2p$	$^1P^\circ$	1	*1 076 400*
Ge XXX ($^2S_{1/2}$)	***Limit***		***24 750 000***

References

Boiko, V. A., Pikuz, S. A., Safronova, U. I., and Faenov, A. Ya. [1977], J. Phys. B 7, 1253.

Burkhalter, P. G., Newman, D. A., and Knauer, J. P. [1989], J. Opt. Soc. Am. B 6, 1964.

Cowan, R. D. [1981], *The Theory of Atomic Structure and Spectra*, (Univ. California Press, Berkeley, CA).

Denne, B., and Hinnov, E. [1987], Phys. Scr. 35, 811.

Ge xxx

$Z = 32$

Li I isoelectronic sequence

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

Ionization energy 25 766 000 ± 30 000 cm^{-1} (3194.6 ± 3.7 eV)

Hinnov *et al.* [1989] report wavelengths for the $2s-2p$ doublet at 200.290±0.01 Å and 122.705±0.02 Å from a tokamak discharge. Behring *et al.* [1989], using a laser-produced plasma, measured the $2s\ ^2S_{1/2}-2p\ ^2P^\circ_{3/2}$ transition at 122.738±0.015 Å, and the $2s-3p$, $2p-3s$, $2p-3d$, $3p-4d$ and $3d-4f$ transitions from 6−20 Å with a wavelength uncertainty of ±0.015 Å. We use the measurements of Hinnov *et al.* for the $2s-2p$ transitions. The uncertainties of the $2p\ ^2P^\circ_{1/2}$ and $2p\ ^2P^\circ_{3/2}$ levels are ±25 cm^{-1} and ±140 cm^{-1}, respectively. Using the same laser as Behring *et al.*, Burkhalter *et al.* [1989] identified the transitions $2s-3p$, $2p-3d$, $2p-3s$, and one line of the $2p-4d$ doublet.

We derive the levels of $3s$, $3p$, $3d$, $4d$, and $4f$ from the measurements of Behring *et al.* with an uncertainty of ±30 000 cm^{-1}.

The value for the ionization energy was determined by Behring *et al.* from a Dirac-Fock calculation of the $4d$ and $4f$ binding energies and their measured excitation energies.

Ge xxx

Configuration	Term	J	Level (cm^{-1})
$1s^2 2s$	^2S	$^1/_2$	0
$1s^2 2p$	$^2P^\circ$	$^1/_2$	*499 276*
		$^3/_2$	*814 963*
$1s^2 3s$	^2S	$^1/_2$	14 455 000
$1s^2 3p$	$^2P^\circ$	$^1/_2$	*14 594 000*
		$^3/_2$	*14 686 000*
$1s^2 3d$	^2D	$^3/_2$	14 756 000
		$^5/_2$	14 781 000
$1s^2 4d$	^2D	$^3/_2$	19 560 000
		$^5/_2$	19 570 000
$1s^2 4f$	$^2F^\circ$	$^5/_2$	*19 594 000*
		$^7/_2$	*19 595 000*
Ge XXXI ($^1S_0$)	***Limit***		**25 766 000**

References

Behring, W. E., Seely, J. F., Brown, C. M., Feldman, U., and Knauer, J. P. [1989], J. Opt. Soc. Am. B **6**, 531.

Burkhalter, P. G., Newman, D. A., and Knauer, J. P. [1989], J. Opt. Soc. Am. B **6**, 1964.

Hinnov, E., TFTR Operating Team, Denne, B., and JET Operating Team [1989], Phys. Rev. A **40**, 4357.

Ge XXXI

$Z = 32$

He I isoelectronic sequence

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

Ionization energy 109 347 260 ± 5000 cm^{-1} (13 557.34 ± 0.62 eV)

MacLaren *et al.* [1992] have measured the $1s^2 - 1s2p$ resonance lines with an EBIT device and obtained the following values:

Transition	Wavelength (Å)
$1s^2\ {}^1S_0 - 1s2p\ {}^1P^\circ_1$	1.205 99 ± 0.000 03
$1s^2\ {}^1S_0 - 1s2p\ {}^3P^\circ_1$	1.212 94 ± 0.000 04
$1s^2\ {}^1S_0 - 1s2p\ {}^3P^\circ_2$	1.208 48 ± 0.000 04
$1s^2\ {}^1S_0 - 1s2s\ {}^3S_1$	1.217 76 ± 0.000 06

The ${}^1S - {}^1P^\circ$ transition energy is 53 ppm above the value calculated by Drake [1988]. We give Drake's separations for the $1s2s$ and $1s2p$ levels and the experimental values for the $1s2s\ {}^3S_1$ and $1s2p\ {}^3P^\circ_1$ levels. Drake's estimated uncertainty is ±130 cm^{-1}. We adopt an uncertainty of 5 parts in 10^5 representing the average difference between his values and the best observations in this region of the sequence (see e.g., Beiersdorfer *et al.* [1989] and Drake [1988] for a summary of the measurements). Drake's $n = 2$ levels are $130 \pm 20\ \mathrm{cm}^{-1}$ lower than those circulated privately by him in 1985, which included levels of the $n = 3$ shell. We give the latter reduced by 130 cm^{-1}.

The ionization energy is the value calculated by Drake [1988].

References

Beiersdorfer, P., Bitter, M., von Goeler, S., and Hill, K. W. [1989],Phys. Rev. A **40**, 150.

Drake, G. W. F. [1985], unpublished calculations.

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

MacLaren, S., Beiersdorfer, P., Vogel, D. A., Knapp, D., Marrs, R.E., Wong, K., and Zasadzinski, R. [1992], Phys. Rev. A **45**, 329.

Ge XXXI

Configuration	Term	J	Level (cm^{-1})
$1s^2$	${}^1S$	0	0
$1s2s$	${}^3S$	1	82 118 000
$1s2p$	${}^3P^\circ$	0	[*82 422 810*]
		1	*82 444 310*
		2	[*82 751 280*]
$1s2s$	${}^1S$	0	[82 445 630]
$1s2p$	${}^1P^\circ$	1	[*82 923 470*]
$1s3s$	${}^3S$	1	[97 353 380]
$1s3p$	${}^3P^\circ$	0	[*97 437 160*]
		1	[*97 443 200*]
		2	[*97 534 920*]
$1s3s$	${}^1S$	0	[97 440 830]
$1s3d$	${}^3D$	2	[97 577 460]
		1	[97 579 170]
		3	[97 610 380]
$1s3p$	${}^1P^\circ$	1	[*97 581 770*]
$1s3d$	${}^1D$	2	[97 613 790]
Ge XXXII (${}^2S_{1/2}$)	***Limit***		**[109 347 260]**

Ge XXXII

$Z=32$

H I isoelectronic sequence

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

Ionization energy 113 880 880 ± 50 cm^{-1} (14 119.4348 ± 0.0060 eV)

No spectral line measurements are available for this ion. We give the theoretical value for the binding energy of the 1*s* ground level and the energies of the 2*s* and 2*p* levels relative to this value published by Johnson and Soff [1985]. They estimate the absolute uncertainties to be ±50 cm^{-1}, the uncertainty in the 2*p* $^2P^\circ$ fine structure as ±3 cm^{-1}, and the uncertainty in the 2*s* − 2*p* interval as ±9 cm^{-1}.

The energies of the levels with $n=3-5$ were obtained by subtracting the binding energies calculated by Erickson [1977] from that of the ground state given by Johnson and Soff. Assuming that the Lamb-shift scales as $({}^{1}/_{n})^{3}$, we estimate the error in Erickson's calculations for the *ns* levels as $({}^{8}/_{n})^{3}$ times the uncertainty of ±472 cm^{-1} for 2*s*. The results for 3*s*, 4*s*, and 5*s* are ±140 cm^{-1}, ±60 cm^{-1}, and ±30 cm^{-1}. For the remaining levels with $n \geqslant 3$ we estimate the uncertainties to be ±30 cm^{-1}.

References

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

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

Ge XXXII

Configuration	Term	*J*	Level (cm^{-1})
1*s*	^2S	1/2	0
2*p*	$^2P^\circ$	1/2	[*85 295 210*]
		3/2	[*85 692 518*]
2*s*	^2S	1/2	[85 304 498]
3*p*	$^2P^\circ$	1/2	[*101 220 487*]
		3/2	[*101 338 318*]
3*s*	^2S	1/2	[101 223 426]
3*d*	^2D	3/2	[101 338 105]
		5/2	[101 376 377]
4*p*	$^2P^\circ$	1/2	[*106 778 029*]
		3/2	[*106 827 682*]
4*s*	^2S	1/2	[106 779 278]
4*d*	^2D	3/2	[106 827 591]
		5/2	[106 843 756]
4*f*	$^2F^\circ$	5/2	[*106 843 727*]
		7/2	[*106 851 758*]
5*p*	$^2P^\circ$	1/2	[*109 343 447*]
		3/2	[*109 368 837*]
5*s*	^2S	1/2	[109 344 085]
5*d*	^2D	3/2	[109 368 789]
		5/2	[109 377 067]
5*f*	$^2F^\circ$	5/2	[*109 377 052*]
		7/2	[*109 381 167*]
5*g*	^2G	7/2	[109 381 159]
		9/2	[109 383 622]
	Limit		**113 880 880**