Energy Levels of Copper, Cu I through Cu XXIX

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The energy levels of the copper atom, in all stages of ionization for which experimental data are available, have been compiled. Ionization energies, either experimental or theoretical, and experimental g-factors are given. Leading components of calculated eigenvectors are listed.

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

Contents

1. Introduction

In 1952 Moore published a compilation of energy levels of copper containing the results of extensive analyses of Cu I through Cu III along with six levels of Cu XIX (Na-like). Today, we have energy levels for most stages of ionization of Cu and very accurate calculated levels for Li-, He-, and H-like ions. The new experimental data were obtained with light sources such as the sliding spark, low inductance triggered spark, laser, tokamak, and beam-foil, most of which were unheard of in 1952.

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

A companion work containing all published wavelengths of Cu X through Cu XXIX is in preparation in collaboration with the Japanese Atomic Energy Research Institute at Tokai-Mura. Similar works for titanium by Mori *et al.* (1986) and iron, nickel, and molybdenum by Shirai *et al.* (1987a, 1987b, 1990) have been published. The strong lines of Cu I to Cu V are contained in the *CRC Handbook of Chemistry and Physics*, "Line Spectra of the Elements," edited by Reader and Corliss (1989). A compilation published by Kelly (1987) gives classifications and all wavelengths of copper ions below 2000 Å.

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 usually given with each ion. This is reflected in the number of significant figures given for the levels. Ionization energies are also given in eV with the conversion factor 8065.5410(24) cm^{-1}/eV published by Cohen and Taylor [1987]. These values are usually derived from Rydberg series by the authors or by us from their data. Where series data are not available we have used ionization-energy values obtained by Lotz [1967] by isoelectronic extrapolation. These have an accuracy of about 1.0%, as estimated from comparisons with experimental values.

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. When the first and second resultant terms are the same but have different parentages, and their share of the eigenvector composition sums to 40% or more, the level is named as the higher percentage term. In cases where these percentages differ by one or two percent (an insignificant difference), either term may be selected for the level name, and the lower percentage may appear first. 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 can 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.

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, tables of the allowed terms for equivalent electrons, etc.

The text for each ion 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.

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3. Tables of Energy Levels

Cu I

$Z = 29$

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

Ionization energy 62 317.44 ± 0.10 cm^{-1} (7.726 380±0.000 012 eV)

Shenstone's [1948] analysis of this spectrum, with wavelengths in the range of 1504 to 18 229 Å, provides the energy levels $3d^{10}4s$ to $9s$, $4p$ to $11p$, $4d$ to $11d$, $4f$ and $5f$, as well as $3d^94s^2$, $4s4p$, $4s5p$, $4s5s$ to $4s8s$, and $4s4d$ to $4s6d$. All levels built on the $3d^9$ core are above the first ionization limit except $4s^2$ and $4s4p$. Shenstone recognized the coupling of $3d^94s4p$ as $3d^9(^2D)+4s4p(^{1,3}P^\circ)$, a scheme that is found to apply in general to $3d^n4s4p$ configurations. Shenstone fit the very regular ^2S and ^2D series to extended Ritz formulas. However he found that the $^2P^\circ$ series is strongly perturbed by the $3d^9(^2D)4s4p(^1P^\circ)\ ^2P^\circ$ term, causing considerable displacement of the $3d^{10}np$ series and inverted $^2P^\circ$ terms. The percentage compositions of the $3d^94s4p$ levels are given by Martin and Sugar [1969], who included configuration interaction with $3d^84s^24p$. They also provided unpublished percentages for $3d^94s5s$.

Absorption spectra in the range of 1146–1633 Å were observed by Tondello [1973] using flash-pyrolysis supplemented by observations with an inductively heated furnace. He extended the $3d^{10}np$ series to $n=31$ and reported several series of the type $3d^94snp$ and nf. The series $3d^94snp\ ^4P^\circ_{3/2}$, $^4P^\circ_{1/2}$, and $^2P^\circ_{1/2}$ show strong autoionization effects (broad Fano profiles) due to mixing with the $3d^{10}\epsilon p\ ^2P^\circ$ continuum. The broadest line of the spectrum is assigned to $3d^{10}4s\ ^2S_{1/2}-3d^94s5p\ ^2P^\circ_{3/2}$ but no other member of this series is identified. A series tentatively identified as $3d^{10}4s(^1D_2)np\ ^2P^\circ_{1/2,3/2}$ is sharp but would be expected to mix strongly with the continuum. We have assigned J_1j-coupling terms where possible because they are more clearly associated with the limits given by Tondello. His LS names for the series are also included. The $(^3D_2)nf$ and $(^3D_3)nf$ series have no unique term designations. This is also true of the $(^3D_1)np$ series in J_1j-coupling, although Tondello has given LS-designations. For $(^3D_3)4f$ and $(^3D_1)5f$ the author gave two lines each because he was unable to select between them.

The $3d^94s(^1D)np\ ^2P^\circ$ series is tentatively identified. Tondello notes that this series is sharp and that there is no doubt about the limit.

Longmire *et al.* [1980] obtained high resolution absorption data using a King furnace and a 6.6-m vacuum spectrograph in second and third orders of the grating. They observed the forbidden series $3d^{10}4s-3d^{10}ns$ for $n=20-41$ and the electric quadrupole series $4s-nd$ for $n=4-8$. The $3d^{10}np$ series was extended to $n=57$. We use their results where they improve the accuracy of previous measurements, as well as their value for the ionization energy. Most of the measurements of Longmire *et al.* have an uncertainty of ±0.10 cm^{-1} while those of Tondello are ±0.7 cm^{-1}. Each long term series observed in absorption has been grouped by series rather than interspersed by level value in numerical order.

The g-values given to three and four places are from Blachman *et al.* [1969], and the remaining ones are from Sommer [1926], Shenstone [1926], and Beals [1926].

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Cu I

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$3d^{10}(^1S)4s$	^2S	1/2	0.000	2.00			
$3d^9\ 4s^2$	^2D	5/2	11 202.565	1.23			
		3/2	13 245.423	0.80			
$3d^{10}(^1S)4p$	$^2P^\circ$	1/2	*30 535.302*	0.68	96	4	$3d^9(^2D)4s4p(^1P^\circ)\ ^2P^\circ$
		3/2	*30 783.686*	1.33	96	4	

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$3d^9(^2D)4s4p(^3P^\circ)$	$^4P^\circ$	5/2	*39 018.652*	1.600	98			
		3/2	*40 113.99*	1.75	96			
		1/2	*40 943.73*	2.62	97			
$3d^9(^2D)4s4p(^3P^\circ)$	$^4F^\circ$	9/2	*40 909.138*	1.3340	100			
		7/2	*41 153.433*	1.26	89		8	$^2F^\circ$
		5/2	*41 562.895*		81		16	$^2F^\circ$
		3/2	*42 302.47*	0.44	95			
$3d^{10}(^1S)5s$	^2S	1/2	43 137.209					
$3d^9(^2D)4s4p(^3P^\circ)$	$^4D^\circ$	7/2	*43 513.95*	1.45	87		11	$^2F^\circ$
		5/2	*44 406.268*	1.43	43		33	$^2F^\circ$
		3/2	*44 544.153*	1.09	65		26	$^2D^\circ$
		1/2	*44 915.61*	0.00	64		33	$^2P^\circ$
$3d^9(^2D)4s4p(^3P^\circ)$	$^2F^\circ$	5/2	*43 726.191*		51		38	$^4D^\circ$
		7/2	*44 963.223*	1.22	78		11	$^4F^\circ$
$3d^9(^2D)4s4p(^3P^\circ)$	$^2P^\circ$	1/2	*45 821.00*		65		33	$^4D^\circ$
		3/2	*45 879.311*	1.22	55		35	$^2D^\circ$
$3d^9(^2D)4s4p(^3P^\circ)$		3/2	*46 172.842*	0.69	40	$^2P^\circ$	36	$^2D^\circ$
$3d^9(^2D)4s4p(^3P^\circ)$	$^2D^\circ$	5/2	*46 598.34*	1.22	83		15	$^4D^\circ$
$3d^{10}(^1S)5p$	$^2P^\circ$	3/2	*49 382.95*					
		1/2	*49 383.26*					
$3d^{10}(^1S)4d$	^2D	3/2	49 935.200	0.82				
		5/2	49 942.057	1.19				
$3d^{10}(^1S)6s$	^2S	1/2	52 848.749	1.99				
$3d^{10}(^1S)6p$	$^2P^\circ$	3/2	*54 784.06*					
		1/2	*55 027.74*					
$3d^{10}(^1S)5d$	^2D	3/2	55 387.668	0.77				
		5/2	55 391.292	1.22				
$3d^{10}(^1S)4f$	$^2F^\circ$	7/2	*55 426.3*					
		5/2	*55 429.8*					
$3d^9(^2D)4s4p(^1P^\circ)$	$^2F^\circ$	7/2	*56 029.95*		94		2	$3d^8(^3F)4s^24p\ ^2F^\circ$
		5/2	*58 119.28*		80		14	$3d^9(^2D)4s4p(^1P^\circ)\ ^2D^\circ$
$3d^9(^2D)4s4p(^1P^\circ)$	$^2P^\circ$	3/2	*56 343.74*		92		4	$3d^8(^3P)4s^24p\ ^2P^\circ$
		1/2	*58 364.73*		96		4	
$3d^9(^2D)4s4p(^1P^\circ)$	$^2D^\circ$	5/2	*56 651.48*	1.17	75		15	$3d^9(^2D)4s4p(^1P^\circ)\ ^2F^\circ$
		3/2	*58 690.86*		87		6	$3d^8(^3F)4s^24p\ ^2D^\circ$
$3d^{10}(^1S)7s$	^2S	1/2	56 671.387					
$3d^{10}(^1S)7p$	$^2P^\circ$	1/2	*57 419.26*					
		3/2	*57 948.57*					
$3d^{10}(^1S)6d$	^2D	3/2	57 893.05					
		5/2	57 895.10					

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^{10}(^1S)5f$	$^2F^\circ$	5/2	*57 905.23*		
		7/2	*57 908.7*		
$3d^{10}(^1S)8s$	^2S	1/2	58 568.92		
$3d^{10}(^1S)7d$	^2D	3/2	59 249.46		
		5/2	59 250.72		
$3d^{10}(^1S)8p$	$^2P^\circ$	3/2	*59 274.97*		
		1/2	*59 322.71*		
$3d^{10}(^1S)9s$	^2S	1/2	59 647.88		
$3d^{10}(^1S)8d$	^2D	3/2	60 065.51		
		5/2	60 066.33		
$3d^{10}(^1S)9p$	$^2P^\circ$	3/2	*60 070.18*		
		1/2	*60 084.84*		
$3d^{10}(^1S)8f$	$^2F^\circ$	5/2	*60 593.72*		
$3d^{10}(^1S)9d$	^2D	3/2	60 594.53		
		5/2	60 595.05		
$3d^{10}(^1S)10p$	$^2P^\circ$	3/2	*60 595.07*		
		1/2	*60 601.18*		
$3d^{10}(^1S)11p$	$^2P^\circ$	3/2	*60 956.35*		
		1/2	*60 959.42*		
$3d^{10}(^1S)10d$	^2D	3/2	60 956.92		
		5/2	60 957.35		
$3d^{10}(^1S)12p$	$^2P^\circ$	3/2	*61 215.13*		
		1/2	*61 216.84*		
$3d^{10}(^1S)11d$	^2D	5/2	61 215.59		
$3d^{10}(^1S)13p$	$^2P^\circ$	3/2	*61 406.75*		
		1/2	*61 407.50*		
$3d^{10}(^1S)14p$	$^2P^\circ$	1/2,3/2	*61 552.67*		
$3d^{10}(^1S)15p$	$^2P^\circ$	1/2,3/2	*61 665.89*		
$3d^{10}(^1S)16p$	$^2P^\circ$	1/2,3/2	*61 755.75*		
$3d^{10}(^1S)17p$	$^2P^\circ$	1/2,3/2	*61 828.24*		
$3d^{10}(^1S)18p$	$^2P^\circ$	1/2,3/2	*61 887.55*		
$3d^{10}(^1S)19p$	$^2P^\circ$	1/2,3/2	*61 936.69*		
$3d^{10}(^1S)20p$	$^2P^\circ$	1/2,3/2	*61 977.86*		
$3d^{10}(^1S)21p$	$^2P^\circ$	1/2,3/2	*62 012.71*		
$3d^{10}(^1S)22p$	$^2P^\circ$	1/2,3/2	*62 042.45*		
$3d^{10}(^1S)23p$	$^2P^\circ$	1/2,3/2	*62 068.02*		
$3d^{10}(^1S)24p$	$^2P^\circ$	1/2,3/2	*62 090.18*		
$3d^{10}(^1S)25p$	$^2P^\circ$	1/2,3/2	*62 109.53*		
$3d^{10}(^1S)26p$	$^2P^\circ$	1/2,3/2	*62 126.52*		
$3d^{10}(^1S)27p$	$^2P^\circ$	1/2,3/2	*62 141.46*		
$3d^{10}(^1S)28p$	$^2P^\circ$	1/2,3/2	*62 154.75*		
$3d^{10}(^1S)29p$	$^2P^\circ$	1/2,3/2	*62 166.62*		
$3d^{10}(^1S)30p$	$^2P^\circ$	1/2,3/2	*62 177.23*		
$3d^{10}(^1S)31p$	$^2P^\circ$	1/2,3/2	*62 186.74*		

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$3d^{10}(^1S)32p$	$^2P^\circ$	1/2,3/2	*62 195.37*				
$3d^{10}(^1S)33p$	$^2P^\circ$	1/2,3/2	*62 203.12*				
$3d^{10}(^1S)34p$	$^2P^\circ$	1/2,3/2	*62 210.17*				
$3d^{10}(^1S)35p$	$^2P^\circ$	1/2,3/2	*62 216.54*				
$3d^{10}(^1S)36p$	$^2P^\circ$	1/2,3/2	*62 222.35*				
$3d^{10}(^1S)37p$	$^2P^\circ$	1/2,3/2	*62 227.72*				
$3d^{10}(^1S)38p$	$^2P^\circ$	1/2,3/2	*62 232.66*				
$3d^{10}(^1S)39p$	$^2P^\circ$	1/2,3/2	*62 237.20*				
$3d^{10}(^1S)40p$	$^2P^\circ$	1/2,3/2	*62 241.36*				
$3d^{10}(^1S)41p$	$^2P^\circ$	1/2,3/2	*62 245.23*				
$3d^{10}(^1S)42p$	$^2P^\circ$	1/2,3/2	*62 248.80*				
$3d^{10}(^1S)43p$	$^2P^\circ$	1/2,3/2	*62 252.07*				
$3d^{10}(^1S)44p$	$^2P^\circ$	1/2,3/2	*62 255.13*				
$3d^{10}(^1S)45p$	$^2P^\circ$	1/2,3/2	*62 258.05*				
$3d^{10}(^1S)46p$	$^2P^\circ$	1/2,3/2	*62 260.72*				
$3d^{10}(^1S)47p$	$^2P^\circ$	1/2,3/2	*62 263.19*				
$3d^{10}(^1S)48p$	$^2P^\circ$	1/2,3/2	*62 265.57*				
$3d^{10}(^1S)49p$	$^2P^\circ$	1/2,3/2	*62 267.71*				
$3d^{10}(^1S)50p$	$^2P^\circ$	1/2,3/2	*62 269.80*				
$3d^{10}(^1S)51p$	$^2P^\circ$	1/2,3/2	*62 271.78*				
$3d^{10}(^1S)52p$	$^2P^\circ$	1/2,3/2	*62 273.48*				
$3d^{10}(^1S)53p$	$^2P^\circ$	1/2,3/2	*62 275.18*				
$3d^{10}(^1S)54p$	$^2P^\circ$	1/2,3/2	*62 276.72*				
$3d^{10}(^1S)55p$	$^2P^\circ$	1/2,3/2	*62 278.36*				
$3d^{10}(^1S)56p$	$^2P^\circ$	1/2,3/2	*62 279.78*				
$3d^{10}(^1S)57p$	$^2P^\circ$	1/2,3/2	*62 281.11*				
$3d^{10}(^1S)20s$	^2S	1/2	61 955.72				
$3d^{10}(^1S)21s$	^2S	1/2	61 993.80				
$3d^{10}(^1S)22s$	^2S	1/2	62 026.08				
$3d^{10}(^1S)23s$	^2S	1/2	62 054.02				
$3d^{10}(^1S)24s$	^2S	1/2	62 077.95				
$3d^{10}(^1S)25s$	^2S	1/2	62 098.90				
$3d^{10}(^1S)26s$	^2S	1/2	62 117.34				
$3d^{10}(^1S)27s$	^2S	1/2	62 133.05				
$3d^{10}(^1S)28s$	^2S	1/2	62 147.42				
$3d^{10}(^1S)29s$	^2S	1/2	62 159.95				
$3d^{10}(^1S)30s$	^2S	1/2	61 271.39				
$3d^{10}(^1S)31s$	^2S	1/2	62 181.48				
$3d^{10}(^1S)32s$	^2S	1/2	62 190.56				
$3d^{10}(^1S)33s$	^2S	1/2	62 198.73				
$3d^{10}(^1S)34s$	^2S	1/2	62 206.26				
$3d^{10}(^1S)35s$	^2S	1/2	62 212.87				
$3d^{10}(^1S)36s$	^2S	1/2	62 219.16				
$3d^{10}(^1S)37s$	^2S	1/2	62 224.53				
$3d^{10}(^1S)38s$	^2S	1/2	62 229.76				
$3d^{10}(^1S)39s$	^2S	1/2	62 234.52				
$3d^{10}(^1S)40s$	^2S	1/2	62 238.70				
$3d^{10}(^1S)41s$	^2S	1/2	62 242.81				
Cu II ($^1S_0$)	***Limit***		**62 317.44**				
$3d^94s(^3D)5s$	^4D	7/2	62 403.320	1.42	100		
		5/2	62 948.29		82	12	$(^1D)\ ^2D$
		3/2	63 584.57		73	15	$(^3D)\ ^2D$
		1/2	64 472.300	0.00	100		
$3d^94s(^3D)5s$	^2D	5/2	64 657.8		87	13	^4D
		3/2	65 260.1		55	26	

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9 4s(^1D)5s$	^2D	5/2	67 142.7	0.69	95 5 $(^3D)\ ^4D$
		3/2	67 971.94		69 30 $(^3D)\ ^2D$
$3d^9 4s(^3D)5p$	$^4P^\circ$	3/2	*70 280.5*		
		1/2	*71 001.5*		
$3d^9 4s(^3D)5p$	$^4F^\circ$	7/2	*70 336.94*		
		5/2	*70 414.50*		
$3d^9 4s(^3D)5p$	$^4D^\circ$	7/2	*70 441.57*	1.43	
		5/2	*70 561.2*		
		3/2	*71 029.76*		
$3d^9 4s(^3D)4d$	^2P	3/2	70 853.39		
		1/2	72 151.49?		
$3d^9 4s(^3D)4d$	^2S	1/2	70 853.9?		
$3d^9 4s(^3D)4d$	^2G	9/2	70 859.53		
		7/2	72 016.76		
$3d^9 4s5p$	$^2F^\circ$	5/2	*70 959.80*		
		7/2	*71 613.91*		
$3d^9 4s(^3D)4d$	^4S	3/2	70 998.12		
$3d^9 4s(^3D)4d$	^2D	5/2	71 098.17		
		3/2	72 104.8		
$3d^9 4s(^3D)4d$	^2F	7/2	71 127.81		
		5/2	72 151.18	1.10	
$3d^9 4s(^3D)4d$	^4G	11/2	71 130.69		
		9/2	71 978.70		
		7/2	73 102.74		
		5/2	73 198.71		
$3d^9 4s(^3D)4d$	^4P	5/2	71 178.19		
		1/2	71 882.96		
		3/2	71 927.22		
$3d^9 4s(^3D)4d$	^4D	7/2	71 268.21	1.48	
		5/2	72 066.97	1.43	
		3/2	73 104.88		
$3d^9 4s(^3D)4d$	^4F	9/2	71 290.54		
		7/2	72 093.08		
		5/2	73 304.67		
		3/2	73 316.46		
$3d^9 4s5p$	$^2D^\circ$	5/2	*71 745.56*		
		3/2	*72 024.32*		
$3d^9 4s5p$	$^2P^\circ$	3/2	*71 917*		
$3d^9 4s(^3D)5p$	$^4D^\circ$	3/2	*71 948.7*		
		1/2	*72 601.6*		
$3d^9 4s(^3D)5p$	$^2P^\circ$	1/2	*72 737.8*		

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9 4s(^3D)6s$	^4D	7/2	73 995.15		
		5/2	74 312.91		
		3/2	75 043.61		
		1/2	76 064.37		
$3d^9 4s(^1D)5p$	$^2P^\circ$	3/2	*74 259.42*		
		1/2	*75 091.24*		
$3d^9 4s(^3D)5p$	$^2F^\circ$	7/2	*74 341.99*		
		5/2	*74 924.48*		
$3d^9 4s 5p$	$^2D^\circ$		*74 507.77*		
$3d^9 4s(^1D)4d$	^2P	1/2	75 109.46		
		3/2	75 263.45		
$3d^9 4s(^3D)6s$	^2D	5/2	75 170.25		
		3/2	76 332.3		
[illegible]	^2G	7/2	75 206.4		
		9/2	75 346.1?		
$3d^9 4s(^1D)$[illegible]	^2S	[illegible]	75 386.7		
$3d^9 4s(^1D)4d$	^2D	3/2	75 440.1		
		5/2	75 446.5		
$3d^9 4s(^1D)4d$	^2F	5/2	75 536.2		
		7/2	75 572.85		
$3d^9 4s(^3D)5d$	^2G	9/2	76 824.3		
		7/2	77 898.9		
$3d^9 4s(^3D)5d$	^2P	[illegible]	76 831.31		
$3d^9 4s(^3D)6p$	$^4P^\circ$	3/2	*76 911.8*		
$3d^9 4s(^3D)5d$	^2D	5/2	[illegible] 949.2		
		3/2	[illegible].3		
$3d^9 4s(^3D)5d$	^4S	3/2	76 959.[illegible]		
$3d^9 4s(^3D)5d$	^2F	7/2	76 960.2		
		5/2	77 959.3		
$3d^9 4s(^3D)5d$	^4G	11/2	77 014.1		
		9/2	77 854.0		
		7/2	78 988.3		
		5/2	79 053.4		
$3d^9 4s(^3D)5d$	^4P	5/2	77 030.59		
		1/2	77 814.5		
		3/2	77 840.9		
$3d^9 4s(^3D)5d$	[illegible]	7/2	77 068.2		
		[illegible]	77 905.5		
		3/2	[illegible]		

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^94s(^3D)5d$	^4F	9/2	77 080.5		
		7/2	77 919.4		
		5/2	79 116.5		
		3/2	79 119.3		
$3d^94s(^3D_3)4f$		1/2,3/2	*77 286.9?*		
$3d^94s(^3D_3)4f$		1/2,3/2	*77 297.1?*		
$3d^94s(^3D_3)5f$		1/2,3/2	*79 798.6*		
$3d^94s(^3D_3)6f$		1/2,3/2	*81 163.0*		
$3d^94s(^3D_3)7f$		1/2,3/2	*82 084.1*		
$3d^94s(^3D_3)8f$		1/2,3/2	*82 515.7*		
$3d^94s(^3D_3)9f$		1/2,3/2	*82 878.9*		
$3d^94s(^3D_3)10f$		1/2,3/2			
$3d^94s(^3D_3)11f$		1/2,3/2	*83 333.3*		
$3d^94s(^3D_3)12f$		1/2,3/2	*83 478.0*		
$3d^94s(^3D_3)13f$		1/2,3/2	*83 590.4*		
$3d^94s(^3D_3)14f$		1/2,3/2	*83 680.6*		
$3d^94s(^3D_2)4f$		1/2,3/2	*77 622.9*		
$3d^94s(^3D_2)5f$		1/2,3/2	*80 424.6*		
$3d^94s(^3D_2)6f$		1/2,3/2	*82 124.7*		
$3d^94s(^3D_2)7f$		1/2,3/2	*82 903.1*		
$3d^94s(^3D_2)8f$		1/2,3/2	*83 434.8*		
$3d^94s(^3D_2)9f$		1/2,3/2	*83 817.4*		
$3d^94s(^3D_2)10f$		1/2,3/2	*84 054.7*		
$3d^94s(^3D_2)11f$		1/2,3/2	*84 249.5*		
$3d^94s(^3D_2)12f$		1/2,3/2	*84 394.6*		
$3d^94s(^3D_2)13f$		1/2,3/2	*84 509.4*		
$3d^94s(^3D)6p$	$^4P^\circ$	1/2	*77 683.2*		
$3d^94s(^3D)7s$	^4D	7/2	78 261.2		
		5/2	78 486.5		
		3/2	79 257.8		
		1/2	80 330.4		
$3d^94s(^1D)6s$	^2D	5/2	78 349.6		
		3/2	78 578.0		
$3d^94s(^3D)6p$	$^4D^\circ$	1/2	*78 892.3*		
$3d^94s(^3D)6p$	$^2P^\circ$	1/2	*78 920.4*		
$3d^94s(^3D)7s$	^2D	5/2	79 268.0		
		3/2	80 456.4?		
$3d^94s(^3D_1)4f_{5/2}$	$(1,5/2)^\circ$	3/2	*79 357.5*		
$3d^94s(^3D_1)5f_{5/2}$	$(1,5/2)^\circ$	3/2	*81 873.9?*		
$3d^94s(^3D_1)5f_{5/2}$	$(1,5/2)^\circ$	3/2	*81 880.6?*		

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9 4s(^3D_1)6f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*83 236.2*		
$3d^9 4s(^3D_1)7f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*84 038.5*		
$3d^9 4s(^3D_1)8f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*84 587.3*		
$3d^9 4s(^3D_1)9f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*84 950.2*		
$3d^9 4s(^3D_1)10f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*85 209.4*		
$3d^9 4s(^3D_1)11f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*85 400.7*		
$3d^9 4s(^3D_1)12f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*85 546.8*		
$3d^9 4s(^3D_1)13f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*85 661.2*		
$3d^9 4s(^3D_1)14f_{5/2}$	$(1,{}^5/_2)^\circ$	$^3/_2$	*85 750.1*		
$3d^9 4s(^3D)6d$	^4S	$^3/_2$	79 641.4		
$3d^9 4s(^3D)7p$	$^4P^\circ$	$^3/_2$	*79 647.6*		
$3d^9 4s(^3D)6d$	^4G	$^{11}/_2$	79 667.9		
		$^9/_2$	80 505.5		
$3d^9 4s(^3D)6d$	^4P	$^5/_2$	79 675.1		
$3d^9 4s(^3D)6d$	^4D	$^7/_2$	79 694.5		
		$^5/_2$	80 542.2		
$3d^9 4s(^3D)6d$	^4F	$^9/_2$	79 700.5		
		$^7/_2$	80 560.0		
$3d^9 4s(^3D)8s$	^4D	$^7/_2$	80 318.4		
$3d^9 4s(^3D)7p$	$^4P^\circ$	$^1/_2$	*80 478.3*		
$3d^9 4s(^3D)6d$	^2G	$^7/_2$	80 553.8		
$3d^9 4s(^3D)6d$	^2F	$^5/_2$	80 574		
$3d^9 4s(^3D)6d$	^2D	$^3/_2$	80 586.7?		
$3d^9 4s(^1D)6p$?	$^2P^\circ$	$^3/_2$	*80 944.3*		
		$^1/_2$	*81 613.3*		
$3d^9 4s(^3D)8p$	$^4P^\circ$	$^3/_2$	*81 084.6*		
$3d^9 4s(^1D)5d$	^2D	$^5/_2$	81 292.5		
		$^3/_2$	81 313.7		
$3d^9 4s(^1D)5d$	^2F	$^5/_2$	81 362.7		
		$^7/_2$	81 376.2		
$3d^9 4s(^3D)7p$	$^4D^\circ$	$^1/_2$	*81 613.3*		
$3d^9 4s(^3D)7p$	$^2P^\circ$	$^1/_2$	*81 642.4*		
$3d^9 4s(^3D)9p$	$^4P^\circ$	$^3/_2$	*81 970.6*		
$3d^9 4s(^3D)8p$	$^4P^\circ$	$^1/_2$	*81 986.0*		

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^94s(^3D_3)10p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*82 482.4*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)11p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*82 865.7*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)12p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 110.3*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)13p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 316.7*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)14p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 470.4*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)15p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 584.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)16p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 674.3*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)17p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 719.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)18p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 800.5*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)19p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 860.9*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)20p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 901.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_3)21p_{3/2}$	$(3,^3/_2)^\circ$	$^3/_2$	*83 937.7*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D)9p$	$^4P^\circ$	$^1/_2$	*82 813.7*		
$3d^94s(^3D_2)10p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*83 382.0*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)11p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*83 756.3*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)12p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 025.1*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)13p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 228.2*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)14p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 376.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)15p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 495.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)16p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 604.5*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)17p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 666.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)18p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 727.8*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)19p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 774.5*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)20p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 817.6*		or $(^3D)\ ^4P^\circ$
$3d^94s(^3D_2)21p_{3/2}$	$(2,^3/_2)^\circ$	$^1/_2$	*84 854.3*		or $(^3D)\ ^4P^\circ$
$3d^94s(^1D)7p$?	$^2P^\circ$	$^3/_2$	*83 817.4*		
		$^1/_2$	*84 131.2*		
$3d^94s(^3D)9p$	$^2P^\circ$	$^1/_2$	*83 975.7*		
Cu II $(^3D_3)$	*Limit*		84 246.19		
$3d^94s(^3D_1)10p$		$^1/_2$	*84 533.0*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)11p$		$^1/_2$	*84 911.3*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)12p$		$^1/_2$	*85 179.6*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)13p$		$^1/_2$	*85 386.9*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)14p$		$^1/_2$	*85 535.1*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)15p$		$^1/_2$	*85 650.9*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)16p$		$^1/_2$	*85 742.0*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)17p$		$^1/_2$	*85 819.2*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)18p$		$^1/_2$	*85 879.7*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)19p$		$^1/_2$	*85 926.2*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)20p$		$^1/_2$	*85 971.9*		or $(^3D)\ ^2P^\circ$
$3d^94s(^3D_1)21p$		$^1/_2$	*86 005.9*		or $(^3D)\ ^2P^\circ$
Cu II $(^3D_2)$	*Limit*		85 164.57		
$3d^94s(^1D)8p$?	$^2P^\circ$	$^3/_2$	*85 319.1*		
		$^1/_2$	*85 496.4*		
$3d^94s(^1D)9p$?	$^2P^\circ$	$^3/_2$	*86 212.0*		
		$^1/_2$	*86 317.0*		
Cu II $(^3D_1)$	*Limit*		86 315.82		

Cu I — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^94s(^1D)10p$?	$^2P°$	$^3/_2$	*86 780.7*		
		$^1/_2$	*86 848.5*		
$3d^94s(^1D)11p$?	$^2P°$	$^3/_2$	*87 164.9*		
		$^1/_2$	*87 213.6*		
Cu II ($^1D_2$)	*Limit*		88 582.01		

Cu II

Z = 29

Ni I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}\ ^1S_0$

Ionization energy 163 669.2±0.5 cm^{-1} (20.292 40 ± 0.000 06 eV)

Shenstone [1936] carried out the major analysis of this spectrum with observations of 1350 lines from 600 to 10 200 Å. A review of the earlier work is given in this reference. Shenstone gave *LS*-coupling names to almost all the levels. However, many of the $3d^9nl$ configurations are clearly in *jl*-coupling and we have used that notation for $3d^9nf$ and $3d^9ng$. The $3d^9ns$ levels ($n=5-10$) are given *jj*-coupling designations.

The odd configurations $3d^94p$ and ($3d^95p+3d^96p+3d^84s4p$) were calculated by Roth [1969] in *LS*-coupling, the latter with configuration interaction. We have given the theoretical designations for these levels and Roth's *jl*-coupling assignments for the configurations $3d^94f$ and $5f$.

Reader, Meissner, and Andrew [1960] reported interferometric measurements of 61 Cu II lines in the region 1979 to 2885 Å with an uncertainty of ±0.001 Å. With these data, relative level values for $3d^94p$, $3d^94s$, and $3d^95s$ were established. From infrared grating observations by Carter [1948] accurate values were extended to levels of $3d^95p$ and $3d^96s$. With these level values (38 in all) 66 wavelengths between 983 and 1663 Å were calculated with an accuracy of ±0.0005 Å

Kaufman and Ward [1966] measured three resonance transitions (at 1358 Å, 1367 Å, and 1472 Å) from the three $J=1$ levels of the $3d^94p$ configuration. Using as reference standards the calculated Cu II wavelengths of Reader *et al.* in the second order they obtained a level uncertainty of ±0.03 cm^{-1}.

A more extensive set of interferometric and grating measurements of Cu II was reported by Ross [1969]. He extended the analysis with about 90 new levels and resolved close levels of the $3d^95g$ configuration. The new determinations for all the levels have uncertainties of ±0.03 cm^{-1}. We have rounded his four-place level values to three places. Two levels from Shenstone established with one line each were not confirmed. They are given here to one decimal place.

The Zeeman effect for Cu II was observed by Shenstone [1927] and by Lott, Roos, and Ginter [1966]. The *g*-values from Shenstone's observations were calculated by Moore [1952].

The ionization energy was obtained by Ross [1969] from the *ns*, *nd*, and *nf* series. We quote his average for 12 series.

References

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Cu II

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^{10}$	^1S	0	0.00		
$3d^9(^2D)4s$	^3D	3	21 928.754	1.32	
		2	22 847.131	1.16	
		1	23 998.381	0.48	
$3d^9(^2D)4s$	^1D	2	26 264.568	1.00	
$3d^9(^2D)4p$	$^3P°$	2	*66 418.687*	1.49	98
		1	*67 916.555*	1.49	97
		0	*68 850.260*		100

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$3d^9(^2D)4p$	$^3F^\circ$	3	*68 447.741*	1.06	69	29	$^1F^\circ$
		4	*68 730.893*	1.23	100		
		2	*69 867.983*	0.67	94	4	$^3D^\circ$
$3d^84s^2$	^3F	4	69 704.699				
		3	71 531.539				
		2	72 723.817				
$3d^9(^2D)4p$	$^1F^\circ$	3	*70 841.470*		62	19	$^3D^\circ$
$3d^9(^2D)4p$	$^1D^\circ$	2	*71 493.853*	1.08	61	33	$^3D^\circ$
$3d^9(^2D)4p$	$^3D^\circ$	3	*71 920.102*		78	12	$^3F^\circ$
		1	*73 102.038*	0.47	98		
		2	*73 353.292*	0.99	61	37	$^1D^\circ$
$3d^9(^2D)4p$	$^1P^\circ$	1	*73 595.813*	1.04	98		
$3d^84s^2$	^1D	2	85 388.770				
$3d^84s^2$	^3P	2	88 361.997				
		1	88 605.090				
		0	88 925.995				
$3d^84s^2$	^1G	4	95 565.631	0.98			
$3d^8(^3F)4s4p(^3P^\circ)$	$^5D^\circ$	4	*107 942.787*		94		
		3	*109 276.015*		91		
		2	*110 363.719*		92		
		1	*111 124.6*		93		
$3d^9(^2D)5s$	$(^5/_2,^1/_2)$	3	108 014.836				
		2	108 335.601				
$3d^9(^2D)5s$	$(^3/_2,^1/_2)$	1	110 084.468				
		2	110 366.152				
$3d^8(^3F)4s4p(^3P^\circ)$	$^5G^\circ$	5	*110 631.186*		83	13	$^5F^\circ$
		4	*111 218.697*		84	10	$^5F^\circ$
		3	*111 876.407*		89	7	$^5F^\circ$
		2	*112 424.677*		96		
$3d^8(^3F)4s4p(^3P^\circ)$	$^5F^\circ$	5	*112 401.619*		86	11	$^5G^\circ$
		4	*113 302.813*		84	9	$^5G^\circ$
		3	*114 000.439*		86	7	$^5G^\circ$
		2	*114 481.669*		92		
		1	*114 755.971*		98		
$3d^9(^2D)4d$	^3S	1	114 511.228				
$3d^8(^3F)4s4p(^3P^\circ)$	$^3G^\circ$	4	*115 359.524*		80	20	$^1G^\circ$
		5	*115 546.096*		94		
		3	*116 643.944*		74	22	$^3D^\circ$
$3d^9(^2D)4d$	^3G	5	115 568.985				
		4	115 662.550				
		3	117 747.337				

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$3d^9(^2D)4d$	^3P	2	115 638.795					
		1	115 665.146					
		0	116 576.567					
$3d^9(^2D)4d$	^3D	3	116 080.213					
		2	116 387.778					
		1	117 928.209					
$3d^9(^2D)4d$	^3F	3	116 325.904					
		4	116 371.171					
		2	118 531.895					
$3d^8(^3F)4s4p(^3P^\circ)$	$^3D^\circ$	3	*116 375.402*		60		19	$(^3F)(^3P^\circ)\ ^3G^\circ$
		2	*117 130.332*		76		10	$(^3F)(^3P^\circ)\ ^3F^\circ$
		1	*118 071.300*		88		6	$(^1D)(^3P^\circ)\ ^3D^\circ$
$3d^9(^2D)4d$	^1P	1	117 231.391					
$3d^8(^3F)4s4p(^3P^\circ)$	$^3F^\circ$	4	*117 666.619*		89			
		3	*118 142.946*		63		16	$(^3F)(^3P^\circ)\ ^1F^\circ$
		2	*119 039.630*		83		9	$(^3F)(^3P^\circ)\ ^3D^\circ$
$3d^9(^2D)4d$	^1G	4	117 883.089					
$3d^9(^2D)4d$	^1D	2	118 163.257					
$3d^9(^2D)4d$	^1F	3	118 483.804					
$3d^8(^3F)4s4p(^3P^\circ)$	$^5G^\circ$	4	*118 991.325*		74		21	$^3G^\circ$
$3d^9(^2D)5p$	$^3P^\circ$	2	*120 092.374*		94			
		1	*120 919.562*		66		28	$^1P^\circ$
		0	*122 224.011*		99			
$3d^9(^2D)5p$	$^1F^\circ$	3	*120 684.711*		47		39	$^3F^\circ$
$3d^9(^2D)5p$	$^3F^\circ$	4	*120 789.807*		97			
		2	*122 745.938*		69		16	$^3D^\circ$
$3d^9(^2D)5p$	$^1D^\circ$	2	*120 876.009*		43		33	$3d^8(^3F)4s4p(^3P^\circ)\ ^1D^\circ$
$3d^8(^3F)4s4p(^3P^\circ)$	$^1F^\circ$	3	*121 079.149*		42		35	$3d^9(^2D)5p\ ^3D^\circ$
$3d^9(^2D)5p$	$^3D^\circ$	3	*121 524.856*		53		30	$3d^8(^3F)4s4p(^3P^\circ)\ ^1F^\circ$
		1	*123 304.814*		85		12	$3d^9(^2D)5p\ ^1P^\circ$
$3d^8(^3F)4s4p(^3P^\circ)$	$^1D^\circ$	2	*121 981.844*		40		28	$3d^9(^2D)5p\ ^3D^\circ$
$3d^9(^2D)4d$	^1S	0	122 415.951					
$3d^9(^2D)5p$	$^1P^\circ$	1	*122 867.732*		60		33	$^3P^\circ$
$3d^9(^2D)5p$		3	*123 016.816*		45	$^1F^\circ$	40	$^3F^\circ$
$3d^9(^2D)5p$		2	*123 556.816*		45	$^1D^\circ$	36	$^3D^\circ$
$3d^8(^3P)4s4p(^3P^\circ)$	$^5P^\circ$	3	*125 230.092*		89		8	$(^1D)(^3P^\circ)\ ^3D^\circ$
		2	*125 248.109*		89			
		1	*125 569.318*		95			

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages		
$3d^8(^1D)4s4p(^3P^\circ)$	$^3F^\circ$	2	*128 365.720*		70	14	$(^1D)(^3P^\circ)\ ^3D^\circ$
		3	*128 559.308*		69	12	$(^3P)(^3P^\circ)\ ^5D^\circ$
		4	*128 778.034*		63	30	$(^3P)(^3P^\circ)\ ^5D^\circ$
$3d^8(^1D)4s4p(^3P^\circ)$	$^3D^\circ$	1	*128 569.138*		62	10	$^3P^\circ$
		2	*128 854.034*		59	18	$^3F^\circ$
		3	*129 116.934*		65	9	$^3F^\circ$
$3d^8(^1D)4s4p(^3P^\circ)$	$^3P^\circ$	0	*129 105.765*		63	33	$(^3P)(^3P^\circ)\ ^3P^\circ$
		1	*129 759.738*		54	21	$(^1D)(^3P^\circ)\ ^3D^\circ$
		2	*130 386.389*		73	14	$(^3P)(^3P^\circ)\ ^3P^\circ$
$3d^8(^3P)4s4p(^3P^\circ)$	$^5D^\circ$	1	*130 940.476*		91		
		2	*130 943.649*		88		
		3	*131 044.304*		80	12	$(^1D)(^3P^\circ)\ ^3F^\circ$
		4	*131 312.416*		65	27	$(^1D)(^3P^\circ)\ ^3F^\circ$
$3d^9(^2D)6s$	$(^5/_2,^1/_2)$	3	133 594.222				
		2	133 728.031				
$3d^8(^3P)4s4p(^3P^\circ)$	$^3P^\circ$	2	*133 825.916*		50	26	$(^3P)(^3P^\circ)\ ^3D^\circ$
		1	*135 135.157*		52	18	$(^1D)(^3P^\circ)\ ^3P^\circ$
		0	*135 484.064*		63	33	$(^1D)(^3P^\circ)\ ^3P^\circ$
$3d^8(^3P)4s4p(^3P^\circ)$	$^3D^\circ$	3	*133 984.320*		56	27	$(^3F)(^1P^\circ)\ ^3D^\circ$
		1	*134 359.840*		59	18	$(^3P)(^3P^\circ)\ ^3P^\circ$
		2	*134 675.515*		42	28	$(^3P)(^3P^\circ)\ ^3P^\circ$
$3d^8(^3F)4s4p(^1P^\circ)$	$^3G^\circ$	5	*134 110.862*		100		
		4	*135 834.661*		67	22	$(^3F)(^3P^\circ)\ ^3F^\circ$
		3	*137 078.181*		68	15	$(^1G)(^3P^\circ)\ ^3F^\circ$
$3d^9(^2D)6p$	$^3F^\circ$	4	*134 742.853*		49	39	$3d^8(^1G)4s4p(^3P^\circ)\ ^3F^\circ$
		3	*138 401.946*		43	34	$3d^9(^2D)6p\ ^1F^\circ$
$3d^9(^2D)6s$	$(^3/_2,^1/_2)$	1	135 664.510				
		2	135 760.151				
$3d^8(^3F)4s4p(^1P^\circ)$	$^3D^\circ$	3	*135 733.422*		43	36	$3d^8(^3P)4s4p(^3P^\circ)\ ^3D^\circ$
		2	*136 800.128*		44	21	$3d^8(^3P)4s4p(^3P^\circ)\ ^1D^\circ$
		1	*137 913.441*		52	21	$3d^9(^2D)6p\ ^3D^\circ$
$3d^9(^2D_{5/2})4f$	$^2[^3/_2]^\circ$	1	*135 863.674*				
		2	*135 910.713*				
$3d^9(^2D_{5/2})4f$	$^2[^1/_2]^\circ$	0	*135 902.127*				
		1	*135 958.178*				
$3d^9(^2D_{5/2})4f$	$^2[^{11}/_2]^\circ$	6	*135 931.001*				
		5	*135 933.884*				
$3d^8(^3P)4s4p(^3P^\circ)$	$^5S^\circ$	2	*135 952.261*		92		
$3d^9(^2D_{5/2})4f$	$^2[^5/_2]^\circ$	3	*135 989.904*				
		2	*136 013.956*				
$3d^9(^2D_{5/2})4f$	$^2[^7/_2]^\circ$	3	*136 035.321*				
		4	*136 269.987*				

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$3d^9(^2D_{5/2})4f$	$^2[^9/_2]^\circ$	4	*136 132.765*					
		5	*136 160.606*					
$3d^9(^2D)5d$	^3S	1	136 336.884					
$3d^8(^3F)4s4p(^1P^\circ)$		3	*136 441.806*		27	$^3F^\circ$	26	$(^1G)(^3P^\circ)\ ^3F^\circ$
$3d^8(^1G)4s4p(^3P^\circ)$	$^3H^\circ$	4	*136 693.937*		99			
		5	*137 082.156*		100			
$3d^9(^2D)5d$	^3G	5	136 725.846					
		4	136 765.350					
		3	138 819.066					
$3d^9(^2D)5d$	^3P	2	136 754.099					
		1	136 773.162					
		0	137 614.143					
$3d^9(^2D)5d$	^3D	3	136 919.342					
		2	137 073.638					
		1	138 898.326					
$3d^9(^2D)5d$	^3F	3	137 034.770					
		4	137 044.458					
		2	139 142.035					
$3d^8(^3P)4s4p(^3P^\circ)$	$^1P^\circ$	1	*137 212.765*		86		7	$^3P^\circ$
$3d^8(^1G)4s4p(^3P^\circ)$	$^3F^\circ$	2	*137 648.790*		44		34	$(^3F)(^1P^\circ)\ ^3F^\circ$
$3d^8(^3F)4s4p(^1P^\circ)$	$^3F^\circ$	4	*137 938.898*		53		31	$^3G^\circ$
		3	*139 741.095*		40		28	
$3d^9(^2D_{3/2})4f$	$^2[^3/_2]^\circ$	2	*138 002.871*					
		1	*138 028.377*					
$3d^9(^2D_{3/2})4f$	$^2[^9/_2]^\circ$	5	*138 064.291*					
		4	*138 073.577*					
$3d^9(^2D_{3/2})4f$	$^2[^5/_2]^\circ$	3	*138 130.522*					
		2	*138 176.869*					
$3d^9(^2D_{3/2})4f$	$^2[^7/_2]^\circ$	4	*138 219.849*					
		3	*138 261.570*					
$3d^9(^2D)5d$	^1P	1	138 593.030					
$3d^9(^2D)6p$	$^3P^\circ$	2	*138 745.813*		76		19	$^1D^\circ$
		1	*140 981.503*		54		44	$^1P^\circ$
		0	*141 154.164*		97			
$3d^9(^2D)5d$	^1G	4	138 882.898					
$3d^9(^2D)5d$	^1D	2	138 981.229					
$3d^9(^2D)6p$		2	*139 028.698*		36	$^1D^\circ$	14	$^3P^\circ$
$3d^9(^2D)5d$	^1F	3	139 119.420					
$3d^9(^2D)6p$	$^1P^\circ$	1	*139 241.123*		47		39	$^3P^\circ$

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages			
$3d^9(^2D)6p$	$^3D^\circ$	3	*139 331.146*		56		24	$3d^9(^2D)6p$ $^1F^\circ$
		1	*141 244.576*		78		14	$3d^8(^3F)4s4p(^1P^\circ)$ $^3D^\circ$
		2	*141 541.998*		53		23	$3d^8(^1D)4s4p(^1P^\circ)$ $^1D^\circ$
$3d^9(^2D)6p$	$^3F^\circ$	4	*139 395.786*		49		30	$3d^8(^1G)4s4p(^3P^\circ)$ $^3F^\circ$
		3	*141 202.630*		55		23	$3d^9(^2D)6p$ $^1F^\circ$
		2	*141 734.167*		58		19	$3d^8(^3F)4s4p(^1P^\circ)$ $^3F^\circ$
$3d^8(^3F)4s4p(^1P^\circ)$		2	*139 710.488*		31	$^3F^\circ$	22	$3d^9(^2D)6p$ $^3F^\circ$
$3d^9(^2D)5d$	^1S	0	140 589.334					
		1	*144 240.6*					
$3d^9(^2D_{5/2})7s$	$(^5/_2,^1/_2)$	3	144 814.906					
		2	144 882.979					
$3d^9(^2D_{5/2})5f$	$^2[^1/_2]^\circ$	0	*145 889.324*					
		1	*145 900.894*					
$3d^9(^2D_{5/2})5f$	$^2[^5/_2]^\circ$	2	*145 927.222*					
		3	*145 978.134*					
$3d^9(^2D_{5/2})5f$	$^2[^{11}/_2]^\circ$	5	*145 945.583*					
		6	*145 951.516*					
$3d^9(^2D_{5/2})5f$	$^2[^3/_2]^\circ$	1	*145 955.437*					
		2	*145 985.191*					
$3d^9(^2D_{5/2})5f$	$^2[^7/_2]^\circ$	3	*146 021.267*					
		4	*146 029.337*					
$3d^9(^2D_{5/2})5f$	$^2[^9/_2]^\circ$	4	*146 023.850*					
		5	*146 032.249*					
$3d^9(^2D_{5/2})5g$	$^2[^3/_2]$	1	146 051.110					
		2	146 051.224					
$3d^9(^2D_{5/2})5g$	$^2[^{13}/_2]$	6	146 068.840					
		7	146 068.893					
$3d^9(^2D_{5/2})5g$	$^2[^5/_2]$	3	146 072.763					
		2	146 072.797					
$3d^9(^2D_{5/2})5g$	$^2[^7/_2]$	3	146 093.918					
		4	146 093.940					
$3d^9(^2D_{5/2})5g$	$^2[^{11}/_2]$	5	146 103.209					
		6	146 103.243					
$3d^9(^2D_{5/2})5g$	$^2[^9/_2]$	4	146 107.091					
		5	146 107.114					
$3d^9(^2D)6d$	^3S	1	146 215.629					
$3d^9(^2D)6d$	^3G	5	146 402.708					
		4	146 423.204					
		3	148 481.757					

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9(^2D)6d$	^3P	2	146 415.597		
		1	146 427.933		
		0	147 097.830		
$3d^9(^2D)6d$	^3D	3	146 496.097		
		2	146 575.091		
		1	148 521.562		
$3d^9(^2D)6d$	^3F	3	146 556.374		
		4	146 559.706		
		2	148 642.477		
$3d^9(^2D_{3/2})7s$	$(^3/_2,^1/_2)$	1	146 886.154		
		2	146 936.315		
$3d^9(^2D)7p$	$^3P^\circ$	2	*147 327.646*		
		1	*147 562.663*		
$3d^9(^2D)7p$	$^3F^\circ$	3	*147 491.887*		
		4	*147 596.646*		
$3d^9(^2D)7p$	$^3D^\circ$	2	*147 647.690*		
		3	*147 762.982*		
$3d^9(^2D_{3/2})5f$	$^2[^3/_2]^\circ$	2	*147 987.343*		
		1	*148 016.146*		
$3d^9(^2D_{3/2})5f$	$^2[^9/_2]^\circ$	5	*148 028.722*		
		4	*148 033.556*		
$3d^9(^2D_{3/2})5f$	$^2[^5/_2]^\circ$	3	*148 061.456*		
		2	*148 065.998*		
$3d^9(^2D_{3/2})5f$	$^2[^7/_2]^\circ$	3	*148 102.973*		
		4	*148 105.347*		
$3d^9(^2D_{3/2})5g$	$^2[^5/_2]$	3	148 133.746		
		2	148 133.818		
$3d^9(^2D_{3/2})5g$	$^2[^{11}/_2]$	5	148 145.779		
		6	148 145.812		
$3d^9(^2D_{3/2})5g$	$^2[^7/_2]$	3	148 167.546		
		4	148 167.575		
$3d^9(^2D_{3/2})5g$	$^2[^9/_2]$	4	148 179.138		
		5	148 179.170		
$3d^9(^2D)6d$	^1P	1	148 361.532		
$3d^9(^2D)6d$	^1G	4	148 515.539		
$3d^9(^2D)6d$	^1D	2	148 559.947		
$3d^9(^2D)6d$	^1F	3	148 631.090		
$3d^9(^2D)6d$	^1S	0	149 202.599		
$3d^8(^1D)4s4p(^1P^\circ)$	$^1D^\circ$	2	*150 249.874*		52 43 $(^3P)(^1P^\circ)\ ^3P^\circ$

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9(^2D_{5/2})8s$	$(^5/_2,^1/_2)$	3	150 742.894		
		2	150 782.450		
$3d^9(^2D_{5/2})6f$	$^2[^1/_2]^\circ$	0	*151 327.249*		
		1	*151 373.829*		
$3d^9(^2D_{5/2})6f$	$^2[^{11}/_2]^\circ$	5	*151 372.322*		
		6	*151 377.678*		
$3d^9(^2D_{5/2})6f$	$^2[^3/_2]^\circ$	2	*151 375.305*		
		1	*151 424.228*		
$3d^9(^2D_{5/2})6f$	$^2[^5/_2]^\circ$	3	*151 402.608*		
		2	*151 403.933*		
$3d^9(^2D_{5/2})6f$	$^2[^9/_2]^\circ$	4	*151 419.012*		
		5	*151 423.044*		
$3d^9(^2D_{5/2})6f$	$^2[^7/_2]^\circ$	4	*151 421.781*		
		3	*151 441.894*		
$3d^9(^2D_{5/2})6g$	$^2[^3/_2]$	1	151 440.066		
		2	151 440.158		
$3d^9(^2D_{5/2})6g$	$^2[^{13}/_2]$	6	151 450.401		
		7	151 450.478		
$3d^9(^2D_{5/2})6g$	$^2[^5/_2]$	3	151 452.674		
		2	151 452.684		
$3d^9(^2D_{5/2})6g$	$^2[^7/_2]$	3	151 464.772		
		4	151 464.782		
$3d^9(^2D_{5/2})6g$	$^2[^{11}/_2]$	5	151 470.102		
		6	151 470.118		
$3d^9(^2D_{5/2})6g$	$^2[^9/_2]$	4	151 472.246		
		5	151 472.264		
$3d^9(^2D)7d$	^3S	1	151 552.186		
$3d^9(^2D)7d$	^3G	5	151 656.312		
		4	151 668.324		
		3	153 730.915		
$3d^9(^2D)7d$	^3P	2	151 662.972		
		1	151 671.657		
		0	152 179.043		
$3d^9(^2D)7d$	^3D	3	151 708.343		
		2	151 757.594		
		1	153 753.728		
$3d^9(^2D)7d$	^3F	3	151 743.551		
		4	151 744.913		
		2	153 821.944		

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9(^2D_{3/2})8s$	$(^3/_2,^1/_2)$	1	152 814.022		
		2	152 840.468		
$3d^9(^2D_{3/2})6f$	$^2[^5/_2]^\circ$	3	*153 410.201*		
		2	*153 426.611*		
$3d^9(^2D_{3/2})6f$	$^2[^9/_2]^\circ$	5	*153 449.629*		
		4	*153 455.175*		
$3d^9(^2D_{3/2})6f$	$^2[^3/_2]^\circ$	1	*153 457.732*		
		2	*153 487.656*		
$3d^9(^2D_{3/2})6f$	$^2[^7/_2]^\circ$	4	*153 495.849*		
		3	*153 498.822*		
$3d^9(^2D_{3/2})6g$	$^2[^5/_2]$	3	153 517.888		
		2	153 517.976		
$3d^9(^2D_{3/2})6g$	$^2[^{11}/_2]$	5	153 524.907		
		6	153 524.942		
$3d^9(^2D_{3/2})6g$	$^2[^7/_2]$	3	153 537.380		
		4	153 537.394		
$3d^9(^2D_{3/2})6g$	$^2[^9/_2]$	4	153 544.041		
		5	153 544.056		
$3d^9(^2D)7d$	^1P	1	153 658.562		
$3d^9(^2D)7d$	^1G	4	153 750.852		
$3d^9(^2D)7d$	^1D	2	153 773.873		
$3d^9(^2D)7d$	^1F	3	153 815.633		
$3d^9(^2D)7d$	^1S	0	153 853.755		
$3d^9(^2D_{5/2})9s$	$(^5/_2,^1/_2)$	3	154 255.811		
		2	154 281.240		
$3d^9(^2D_{5/2})7f$	$^2[^{11}/_2]^\circ$	5	*154 641.382*		
		6	*154 647.042*		
$3d^9(^2D_{5/2})7f$	$^2[^5/_2]^\circ$	3	*154 672.111*		
$3d^9(^2D_{5/2})7f$	$^2[^9/_2]^\circ$	4	*154 672.755*		
		5	*154 675.237*		
$3d^9(^2D_{5/2})7f$	$^2[^7/_2]^\circ$	4	*154 674.542*		
		3	*154 678.865*		
$3d^9(^2D_{5/2})7g$	$^2[^3/_2]$	1	154 688.009		
		2	154 688.100		
$3d^9(^2D_{5/2})7g$	$^2[^{13}/_2]$	6	154 694.577		
		7	154 694.605		
$3d^9(^2D_{5/2})7g$	$^2[^5/_2]$	3	154 695.989		

Cu II — Continued

Configuration	Term	J	Level (cm^{-1})	g	Leading percentages
$3d^9(^2D_{5/2})7g$	$^2[^7/_2]$	3	154 703.581		
		4	154 703.611		
$3d^9(^2D_{5/2})7g$	$^2[^{11}/_2]$	5	154 706.898		
$3d^9(^2D_{5/2})7g$	$^2[^9/_2]$	4	154 708.229		
$3d^9(^2D)8d$	^3S	1	154 766.024		
$3d^9(^2D)8d$	^3G	5	154 828.717		
		4	154 836.426		
$3d^9(^2D)8d$	^3P	2	154 832.650		
		1	154 838.962		
		0	155 244.832		
$3d^9(^2D)8d$	^3D	3	154 860.735		
		2	154 892.905		
$3d^9(^2D)8d$	^3F	3	154 883.095		
		4	154 883.624		
		2	156 958.096		
$3d^9(^2D_{3/2})9s$	$(^3/_2,^1/_2)$	1	156 326.908		
		2	156 341.872		
$3d^9(^2D_{5/2})10s$	$(^5/_2,^1/_2)$	3	156 508.497		
		2	156 526.430		
$3d^9(^2D_{3/2})7f$	$^2[^9/_2]^\circ$	5	*156 711.893*		
		4	*156 721.301*		
$3d^9(^2D_{3/2})7f$	$^2[^{11}/_2]^\circ$	5	*156 761.443*		
		6	*156 767.059*		
$3d^9(^2D_{3/2})7g$	$^2[^5/_2]$	3	156 763.027		
		2	156 763.083		
$3d^9(^2D_{3/2})7g$	$^2[^{11}/_2]$	5	156 767.609		
$3d^9(^2D_{3/2})7g$	$^2[^7/_2]$	3	156 775.403		
$3d^9(^2D_{3/2})7g$	$^2[^9/_2]$	4	156 779.838		
$3d^9(^2D)8d$	^1G	4	156 912.741		
Cu III ($^2D_{5/2}$)	***Limit***		**163 669.2**		

Cu III

Z = 29

Co I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9\ ^2D_{5/2}$

Ionization energy 297 140 ± 100 cm^{-1} (36.841 ± 0.012 eV)

The early work on this spectrum is summarized by Shenstone and Wilets [1951] where much of the low structure is given. New observations by Shenstone [1975] with pulsed hollow cathode and sliding-spark light sources produced a line list covering the range of 500–5820 Å, measured to three decimal places, and 5821–6852 Å, measured to two decimal places. With this improved line list the levels of $3d^9$, $3d^84s$, and $3d^84p$ were redetermined and completed with the addition of the levels based on the $3d^8\ ^1S$ parent. Following this, all but one level of $3d^84d$ and most levels of $3d^85d$ were found. In addition, levels of $3d^84f$, $3d^74s^2$, $3d^85s-7s$, $3d^85p$, and $3d^85g$ were identified. Six levels identified as $3d^74s4p$ were not assigned term designations, but were given numerical names. The percentage compositions of most of the levels have been calculated by Sugar and Martin [1976], and their designations for the levels have been adopted.

The ionization energy was derived by Shenstone from the ns series.

References

Shenstone, A. G. [1975], J. Res. Natl. Bur. Stand. (U.S.), Sect. A **79**, 497.

Shenstone, A. G., and Wilets, L. [1951], Phys. Rev. **83**, 104.

Sugar, J., and Martin, W. C. [1976], J. Res. Natl. Bur. Stand. (U.S.), Sect. A **80**, 465.

Cu III

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^9$	^2D	5/2	0.00			
		3/2	2071.69			
$3d^8(^3F)4s$	^4F	9/2	60 805.22	100		
		7/2	62 065.09	97	3	$(^3F)\ ^2F$
		5/2	63 143.77	99	1	$(^3F)\ ^2F$
		3/2	63 886.51	99	1	$(^1D)\ ^2D$
$3d^8(^3F)4s$	^2F	7/2	67 016.71	97	3	$(^3F)\ ^4F$
		5/2	68 963.78	98	1	$(^1D)\ ^2D$
$3d^8(^1D)4s$	^2D	5/2	77 968.25	51	48	$(^3P)\ ^4P$
		3/2	78 780.00	80	16	
$3d^8(^3P)4s$	^4P	3/2	80 305.74	84	16	$(^1D)\ ^2D$
		1/2	80 423.54	100		
		5/2	80 552.14	52	47	$(^1D)\ ^2D$
$3d^8(^3P)4s$	^2P	3/2	85 447.29	96	3	$(^1D)\ ^2D$
		1/2	86 133.66	100		
$3d^8(^1G)4s$	^2G	9/2	89 018.30	100		
		7/2	89 046.71	100		
$3d^8(^3F)4p$	$^4D°$	7/2	*118 864.85*	93	4	$(^3P)\ ^4D°$
		5/2	*120 577.85*	92	4	
		3/2	*121 864.48*	93	5	
		1/2	*122 637.26*	94	5	

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^8(^3F)4p$	$^4G°$	9/2	*121 337.72*	62	24	$^2G°$
		11/2	*121 699.08*	100		
		7/2	*122 504.09*	78	12	$^4F°$
		5/2	*123 440.69*	92	7	$^4F°$
$3d^8(^1S)4s$	^2S	1/2	122 860.82	100		
$3d^8(^3F)4p$	$^4F°$	9/2	*123 550.38*	80	16	$(^3F)\ ^2G°$
		7/2	*124 557.85*	70	15	$(^3F)\ ^2F°$
		5/2	*125 382.09*	82	7	$(^3F)\ ^4G°$
		3/2	*125 744.81*	89	6	$(^3F)\ ^2D°$
$3d^8(^3F)4p$	$^2G°$	9/2	*124 442.77*	59	35	$(^3F)\ ^4G°$
		7/2	*126 094.14*	77	13	$(^3F)\ ^2F°$
$3d^8(^3F)4p$	$^2F°$	7/2	*126 829.76*	70	13	$(^3F)\ ^4F°$
		5/2	*128 679.85*	70	15	$(^3F)\ ^2D°$
$3d^8(^3F)4p$	$^2D°$	5/2	*126 892.24*	75	16	$(^3F)\ ^2F°$
		3/2	*128 435.61*	81	8	$(^1D)\ ^2D°$
$3d^8(^3P)4p$	$^4P°$	3/2	*136 483.63*	75	11	$(^1D)\ ^2P°$
		5/2	*136 607.85*	76	15	$(^1D)\ ^2D°$
		1/2	*137 041.60*	89	7	$(^1D)\ ^2P°$
$3d^8(^1D)4p$	$^2F°$	5/2	*138 084.98*	80	9	$(^3P)\ ^4P°$
		7/2	*138 982.86*	83	10	$(^3P)\ ^4D°$
$3d^8(^1D)4p$	$^2D°$	3/2	*138 989.01*	48	20	$(^3P)\ ^4P°$
		5/2	*139 757.46*	77	13	
$3d^8(^1D)4p$	$^2P°$	1/2	*139 261.52*	61	25	$(^3P)\ ^2P°$
		3/2	*140 201.72*	52	31	$(^1D)\ ^2D°$
$3d^8(^3P)4p$	$^4D°$	5/2	*142 427.10*	74	15	$(^3P)\ ^2D°$
		3/2	*142 513.20*	87	5	$(^3P)\ ^2D°$
		1/2	*142 550.75*	93	5	$(^3F)\ ^4D°$
		7/2	*142 820.01*	85	8	$(^1D)\ ^2F°$
$3d^8(^3P)4p$	$^2D°$	5/2	*144 195.35*	79	18	$(^3P)\ ^4D°$
		3/2	*144 876.29*	61	29	$(^3P)\ ^2P°$
$3d^8(^3P)4p$	$^2P°$	3/2	*145 353.84*	49	32	$(^3P)\ ^2D°$
		1/2	*146 675.34*	64	23	$(^1D)\ ^2P°$
$3d^8(^1G)4p$	$^2H°$	9/2	*146 534.51*	99	1	$(^1G)\ ^2G°$
		11/2	*147 647.87*	100		
$3d^8(^3P)4p$	$^2S°$	1/2	*147 653.36*	88	7	$(^1D)\ ^2P°$
$3d^8(^1G)4p$	$^4S°$	3/2	*147 806.69*	98	1	$(^1D)\ ^2P°$
$3d^8(^3P)4p$	$^2F°$	7/2	*147 817.32*	88	8	$(^1D)\ ^2F°$
		5/2	*148 663.85*	92	5	
$3d^8(^1G)4p$	$^2G°$	7/2	*153 609.87*	99	1	$(^1G)\ ^2F°$
		9/2	*153 808.22*	99	1	$(^1G)\ ^2H°$

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^7 4s^2$	^{4}F	9/2	166 159.36	99			
		7/2	167 739.09	100			
		5/2	168 856.96	99			
		3/2	169 608.26	99			
$3d^8(^1S)4p$	^{2}P°	1/2	*182 900.11*	99		1	(^{1}D) ^{2}P°
		3/2	*184 197.12*	99		1	
$3d^7 4s^2$	^{2}G	9/2	188 097.72	94		3	^{2}H
		7/2	189 602.62	98		2	$3d^8(^3F)4d$ ^{2}G
$3d^8(^3F)5s$	^{4}F	9/2	193 370.76	100			
		7/2	194 117.14	64		36	(^{3}F) ^{2}F
		5/2	195 555.12	89		11	(^{3}F) ^{2}F
		3/2	196 442.14	99		1	(^{1}D) ^{2}D
$3d^8(^3F)4d$	^{4}D	7/2	193 520.75	93		5	(^{3}F) ^{4}F
		5/2	193 885.30	56		40	(^{3}F) ^{4}P
		3/2	194 683.69	51		23	(^{3}F) ^{2}P
		1/2	195 722.78	84		9	(^{3}F) ^{4}P
$3d^8(^3F)4d$	^{2}H	11/2	194 033.26	51		35	$3d^7 4s^2$ ^{2}H
		9/2	198 687.18	60		26	
$3d^8(^3F)4d$	^{4}H	13/2	194 331.79	100			
$3d^8(^3F)4d$	^{4}G	11/2	194 818.37	68		27	(^{3}F) ^{4}H
		7/2	197 593.69	40		35	(^{3}F) ^{4}H
		5/2	197 900.51	49		45	(^{3}F) ^{2}F
$3d^8(^3F)4d$		9/2	195 061.88	39	^{4}G	36	^{4}F
$3d^8(^3F)4d$	^{4}P	5/2	195 340.40	51		28	(^{3}F) ^{4}D
		3/2	196 806.22	69		16	(^{3}F) ^{2}P
		1/2	197 199.63	77		12	(^{3}F) ^{4}D
$3d^8(^3F)4d$	^{2}F	7/2	195 343.79	53		24	(^{3}F) ^{4}F
$3d^8(^3F)4d$		9/2	195 518.43	33	^{4}F	21	^{2}H
$3d^8(^3F)4d$	^{4}H	11/2	195 757.94	41		31	$3d^7 4s^2$ ^{2}G
		9/2	196 795.53	65		18	(^{3}F) ^{2}G
$3d^8(^3F)5s$	^{2}F	7/2	195 788.65	64		36	(^{3}F) ^{4}F
		5/2	197 400.19	88		11	
$3d^7 4s^2$		9/2	196 028.66	30	^{2}H	23	$3d^8(^3F)4d$ ^{4}G
$3d^8(^3F)4d$	^{2}P	3/2	196 100.20	50		39	(^{3}F) ^{4}D
		1/2	198 033.60	81		13	(^{3}F) ^{4}P
$3d^8(^3F)4d$		5/2	196 730.75	34	^{4}F	30	(^{3}F) ^{2}F
$3d^8(^3F)4d$		7/2	196 742.34	36	^{4}G	34	(^{3}F) ^{4}H
$3d^8(^3F)4d$		11/2	197 038.62	47	^{2}H	31	$3d^7 4s^2$ ^{2}H
$3d^8(^3F)4d$	^{4}F	7/2	197 055.18	47		28	(^{3}F) ^{4}H
		3/2	197 985.57	93		4	(^{3}F) ^{4}D
		5/2	198 061.23	56		24	(^{3}F) ^{4}G

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^8(^3F)4d$	^{2}G	9/2	197 375.85	49		26	(^{3}F) ^{4}G
		7/2	198 930.42	81		8	(^{3}F) ^{4}G
$3d^8(^3F)4d$	^{2}D	5/2	201 215.00	79		6	(^{3}F) ^{2}F
		3/2	201 732.15	74		10	$3d^74s^2$ ^{2}D2
$3d^8(^1D)5s$	^{2}D	5/2	209 875.15	77		22	(^{3}P) ^{4}P
		3/2	210 033.19	86		10	(^{3}P) ^{2}P
$3d^8(^1D)4d$	^{2}F	5/2	210 159.14	63		13	(^{3}P) ^{4}D
		7/2	210 239.88	69		24	(^{3}P) ^{4}D
$3d^8(^1D)4d$	^{2}D	3/2	211 123.91	48		27	(^{3}P) ^{2}D
$3d^8(^1D)4d$	^{2}G	7/2	211 271.32	83		10	(^{3}P) ^{2}F
		9/2	211 313.62	82		16	(^{3}P) ^{4}F
$3d^8(^1D)4d$	^{2}P	1/2	211 286.05	62		29	(^{3}P) ^{4}D
		3/2	211 652.05	62		26	(^{3}P) ^{4}D
$3d^8(^1D)4d$		5/2	211 679.61	34	^{2}D	30	(^{3}P) ^{4}D
$3d^8(^3F)5p$	^{4}D°	7/2	*211 821.00*	91		7	(^{3}F) ^{4}F°
		5/2	*213 025.70*	73		17	(^{3}F) ^{2}D°
		3/2	*214 357.95*	88		7	(^{3}F) ^{4}F°
		1/2	*215 160.74*	99		1	(^{1}D) ^{2}P°
$3d^8(^1D)4d$	^{2}S	1/2	212 208.63	85		10	(^{3}P) ^{4}P
$3d^8(^3F)5p$		9/2	*212 415.20*	41	^{4}G°	33	(^{3}F) ^{2}G°
$3d^8(^3F)5p$	^{4}G°	11/2	*212 525.35*	100			
		7/2	*214 328.03*	59		23	(^{3}F) ^{2}F°
		9/2	*214 588.27*	56		37	(^{3}F) ^{2}G°
		5/2	*215 417.25*	60		28	(^{3}F) ^{4}F°
$3d^8(^3P)4d$	^{4}D	7/2	212 752.39	72		19	(^{1}D) ^{2}F
		5/2	213 133.65	51		30	(^{1}D) ^{2}D
		1/2	213 141.65	70		27	(^{1}D) ^{2}P
		3/2	213 312.19	57		26	(^{1}D) ^{2}P
$3d^8(^3P)5s$	^{4}P	5/2	212 951.03	78		22	(^{1}D) ^{2}D
		3/2	213 127.07	94		5	(^{1}D) ^{2}D
		1/2	213 418.17	98		1	(^{3}P) ^{2}P
$3d^8(^3F)5p$	^{4}F°	9/2	*212 995.16*	67		30	^{2}G°
		7/2	*215 000.50*	46		36	^{2}F°
		3/2	*215 782.96*	90		5	^{4}D°
$3d^8(^3F)5p$		7/2	*213 311.78*	36	^{4}F°	35	^{2}F°
$3d^74s^2$	^{2}F	5/2	213 514.78	73		20	$3d^8(^3P)4d$ ^{2}F
		7/2	213 815.69	56		23	
$3d^8(^3P)5s$	^{2}P	3/2	214 264.50	90		8	(^{1}D) ^{2}D
		1/2	214 730.18	98		1	(^{3}P) ^{4}P
$3d^8(^3F)5p$	^{2}D°	5/2	*214 702.78*	39		36	(^{3}F) ^{4}F°
		3/2	*216 448.63*	90		7	(^{3}F) ^{4}D°

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^8(^3P)4d$	^4F	9/2	214 747.99	83		16	$(^1D)\ ^2G$
		7/2	214 844.87	90		3	$(^1D)\ ^2G$
		5/2	215 100.44	83		4	$(^1D)\ ^2F$
		3/2	215 197.18	97		1	$(^3P)\ ^2D$
$3d^8(^3F)5p$		5/2	*214 766.34*	38	$^2D°$	23	$^4D°$
$3d^8(^3P)4d$	^2D	5/2	214 989.62	45		16	$(^1G)\ ^2D$
		3/2	216 235.32	35		23	$(^1G)\ ^2D$
$3d^8(^3P)4d$	^4P	1/2	215 761.54	86		11	$(^1D)\ ^2S$
		5/2	216 145.05	77		10	$(^3P)\ ^2F$
$3d^8(^3P)4d$	^2P	3/2	215 807.35	92		4	$(^1D)\ ^2D$
		1/2	216 833.51	89		7	$(^1D)\ ^2P$
$3d^8(^3P)4d$	^2F	7/2	215 976.94	65		29	$3d^74s^2\ ^2F$
		5/2	216 376.27	68		14	
$3d^8(^3F)5p$	$^2G°$	7/2	*216 017.68*	65		22	$(^3F)\ ^4G°$
$3d^8(^3F)5p$	$^2F°$	5/2	*216 565.74*	76		16	$(^3F)\ ^4F°$
$3d^8(^1G)4d$	^2I	11/2	220 311.20	100			
		13/2	220 413.54	100			
$3d^8(^1G)5s$	^2G	9/2	220 563.89	100			
		7/2	220 569.48	100			
$3d^8(^1G)4d$	^2F	7/2	221 861.15	98		2	$3d^74s^2\ ^2F$
		5/2	221 878.97	98		1	
$3d^8(^1G)4d$	^2H	9/2	223 089.88	91		9	$(^1G)\ ^2G$
		11/2	223 175.15	100			
$3d^7(^4F)4s4p(^3P°)$	$^4F°$	9/2	*223 134.65*				
		7/2	*223 570.61*				
		5/2	*224 450.45*				
		3/2	*225 235.39*				
$3d^8(^1G)4d$	^2G	7/2	223 174.34	99		1	$(^1D)\ ^2G$
		9/2	223 200.87	90		9	$(^1G)\ ^2H$
$3d^7(^4F)4s4p(^3P°)$	$^4G°$	11/2	*223 229.90*				
		9/2	*224 048.02*				
$3d^8(^1G)4d$	^2D	5/2	223 787.07	73		19	$(^3P)\ ^2D$
		3/2	224 503.61	68		20	
$3d^7(^4F)4s4p(^3P°)$	$^4D°$	7/2	*225 923.90*				
		5/2	*226 857.54*				
		3/2	*227 494.85*				
		1/2	*227 964.02?*				
$3d^8(^1D)5p$	$^2D°$	5/2	*228 423.50*	52		23	$^2F°$
		3/2	*228 468.86*	57		18	$^2P°$
$3d^8(^1D)5p$	$^2F°$	5/2	*228 960.05*	62		20	$(^1D)\ ^2D°$
		7/2	*229 098.47*	81		18	$(^3P)\ ^4D°$

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^8(^1D)5p$	$^2P^\circ$	1/2	229 054.02	75	12	$(^3P)\ ^2P^\circ$
		3/2	229 505.30	55	28	$(^1D)\ ^2D^\circ$
$3d^8(^3P)5p$	$^4P^\circ$	1/2	231 298.41?	91	6	$(^1D)\ ^2P^\circ$
		5/2	231 333.00	72	25	$(^1D)\ ^2D^\circ$
		3/2	231 457.50	73	21	$(^1D)\ ^2P^\circ$
$3d^8(^3P)5p$	$^4D^\circ$	7/2	232 435.96	82	18	$(^1D)\ ^2F^\circ$
		5/2	232 458.10	71	15	$(^3P)\ ^2P^\circ$
		3/2	232 478.23?	87	6	$(^3P)\ ^2P^\circ$
$3d^8(^3P)5p$	$^2P^\circ$	3/2	232 814.29	85	9	$(^1D)\ ^2D^\circ$
$3d^7(^4F)4s4p(^3P^\circ)$	$^2D^\circ$	5/2	232 989.62?			
		3/2	234 650.41?			
$3d^8(^3P)5p$	$^2D^\circ$	5/2	233 285.96	75	20	$(^3P)\ ^4D^\circ$
		3/2	233 653.51	87	7	$(^3P)\ ^4D^\circ$
$3d^8(^3P)5p$	$^4S^\circ$	3/2	234 036.16	90	4	$(^1D)\ ^2P^\circ$
$3d^8(^3F_4)4f$	$^2[1]^\circ$	3/2	234 427.01	84	16	$^2[2]^\circ$
		1/2	234 530.60	100		
$3d^8(^3F_4)4f$	$^2[2]^\circ$	5/2	234 490.73	88	12	$^2[3]^\circ$
		3/2	234 660.53	84	16	$^2[1]^\circ$
$3d^8(^3F_4)4f$	$^2[7]^\circ$	13/2	234 532.91	99	1	$^2[6]^\circ$
		15/2	234 537.43	100		
$3d^8(^3F_4)4f$	$^2[3]^\circ$	7/2	234 562.13	94	6	$^2[4]^\circ$
		5/2	234 775.00	88	12	$^2[2]^\circ$
$3d^8(^3F_4)4f$	$^2[4]^\circ$	9/2	234 654.68	99	1	$^2[5]^\circ$
		7/2	234 812.88	94	6	$^2[3]^\circ$
$3d^8(^3F_4)4f$	$^2[6]^\circ$	13/2	234 670.98	99	1	$^2[7]^\circ$
		11/2	234 681.35	93	7	$^2[5]^\circ$
$3d^8(^3F_4)4f$	$^2[5]^\circ$	11/2	234 716.80	93	7	$^2[6]^\circ$
		9/2	234 774.74	99	1	$^2[4]^\circ$
$3d^8(^3F_3)4f$	$^2[1]^\circ$	1/2	236 323.71	75	25	$^2[0]^\circ$
		3/2	236 395.02	71	28	$^2[2]^\circ$
$3d^8(^3F_3)4f$	$^2[0]^\circ$	1/2	236 370.88	74	25	$^2[1]^\circ$
$3d^8(^3F_3)4f$	$^2[6]^\circ$	13/2	236 417.68	100		
		11/2	236 418.68	100		
$3d^8(^3F_3)4f$	$^2[2]^\circ$	5/2	236 471.28	99		
		3/2	236 484.91	71	28	$^2[1]^\circ$
$3d^8(^3F_3)4f$	$^2[3]^\circ$	7/2	236 511.51	93	7	$(^3F_3)\ ^2[4]^\circ$
		5/2	236 590.41	99	1	$(^3F_2)\ ^2[2]^\circ$
$3d^8(^3F_3)4f$	$^2[5]^\circ$	11/2	236 531.91	100		
		9/2	236 537.18	88	12	$^2[3]^\circ$

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^8(^3F_3)4f$	$^2[4]°$	9/2	*236 550.40*	88	12	$^2[5]°$
		7/2	*236 611.48*	93	7	$^2[3]°$
$3d^8(^3F_2)4f$	$^2[1]°$	3/2	*237 538.57*	74	25	$(^3F_2)\ ^2[2]°$
		1/2	*237 591.35*	99	1	$(^1D_2)\ ^2[1]°$
$3d^8(^3F_2)4f$	$^2[5]°$	11/2	*237 641.05*	99	1	$(^1D_2)\ ^2[5]°$
		9/2	*237 644.52*	99	1	
$3d^8(^3F_2)4f$	$^2[2]°$	5/2	*237 674.38*	72	26	$^2[3]°$
		3/2	*237 734.00*	74	24	$^2[1]°$
$3d^8(^3F_2)4f$	$^2[4]°$	7/2	*237 751.21*	79	20	$(^3F_2)\ ^2[3]°$
		9/2	*237 778.99*	99	1	$(^1D_2)\ ^2[4]°$
$3d^8(^3F_2)4f$	$^2[3]°$	7/2	*237 814.57*	79	20	$^2[4]°$
		5/2	*237 830.63*	72	26	$^2[2]°$
$3d^8(^3F)6s$	^4F	9/2	238 280.09	100		
		7/2	240 303.20	63	37	$(^3F)\ ^2F$
		5/2	240 325.65	73	27	$(^3F)\ ^2F$
		3/2	241 391.60	99	1	$(^1D)\ ^2D$
$3d^8(^3F)6s$	^2F	7/2	238 638.49	63	37	^4F
		5/2	241 693.54	72	27	^4F
$3d^8(^3F)5d$	^4D	7/2	238 730.93	86	11	^4F
		1/2	240 764.06	56	22	^2P
		3/2	240 794.56	45	40	^2P
$3d^8(^1G)5p$	$^2H°$	9/2	*238 788.16*	99	1	$(^1G)\ ^2G°$
		11/2	*239 142.42*	100		
$3d^8(^3F)5d$	^4P	5/2	238 818.98	65	32	^4D
		3/2	241 328.02	65	16	^4D
		1/2	241 899.60	60	36	^4D
$3d^8(^1G)5p$	$^2F°$	7/2	*238 833.78*	98	1	$^2G°$
		5/2	*239 148.82*	99		
$3d^8(^3F)5d$	^4H	13/2	238 994.08	100		
		11/2	240 960.52	55	34	^2H
		9/2	240 972.55	60	22	^2H
		7/2	242 088.67	71	22	^4G
$3d^8(^3F)5d$	^4G	11/2	239 112.04	51	36	^4H
		7/2	241 074.10	44	32	^2F
		5/2	242 290.02	56	38	^4F
$3d^8(^3F)5d$	^2H	11/2	239 240.10	53	38	^4G
		9/2	242 297.51	62	20	^4H
$3d^8(^3F)5d$	^4F	9/2	239 290.03	58	35	^4G
		7/2	241 249.83	46	23	^2G
		3/2	242 219.08	80	16	^4D
$3d^8(^3F)5d$	^2P	3/2	239 326.97	53	23	^4P
		1/2	242 247.32	74	17	

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^8(^3F)5d$	^2F	7/2	239 440.71	59		21	^4F
$3d^8(^3F)5d$	^2G	9/2	239 568.88	51		24	^4F
		7/2	242 610.05	69		14	^4G
$3d^7(^2G)4s4p(^3P°)$	$^4F°$	9/2	*239 606.85*				
$3d^8(^3F)5d$		5/2	240 062.88	34	^4D	27	^4P
$3d^8(^1G)5p$	$^2G°$	7/2	*240 786.48*	99		1	$^2F°$
		9/2	*240 852.75*	99		1	$^2H°$
$3d^8(^3F)5d$		5/2	240 994.59	39	^2F	23	^4D
$3d^8(^3F)5d$		9/2	241 215.61	36	^4G	31	^2G
$3d^8(^3F)5d$		5/2	242 006.56	38	^2F	25	^4F
$3d^7(^2P)4s4p(^3P°)$	$^4D°$	7/2	*243 234.10*				
		5/2	*244 602.61*				
$3d^8(^3F)5d$	^2D	5/2	243 780.33	77		15	$(^3F)\ ^2F$
		3/2	244 618.53	89		3	$(^1D)\ ^2D$
$3d^7(^2H)4s4p(^3P°)$	$^4G°$	11/2	*245 139.94*				
		9/2	*246 439.20*				
$3d^7(^2D)4s4p(^3P°)$	$^4D°$	7/2	*245 671.35*				
$3d^74s4p$	1°	9/2	*246 202.65*				
$3d^7(^2D)4s4p(^3P°)$	$^4F°$	9/2	*246 510.54*				
		7/2	*247 475.26*				
		5/2	*248 281.96*				
		3/2	*248 896.92*				
$3d^7(^4F)4s4p(^1P°)$	$^4G°$	11/2	*247 578.66*				
		9/2	*249 077.07*				
		7/2	*250 168.06*				
		5/2	*251 052.76?*				
$3d^7(^4F)4s4p(^1P°)$	$^4F°$	9/2	*247 902.05*				
		7/2	*250 636.95*				
		5/2	*252 437.63*				
		3/2	*254 147.19?*				
$3d^74s4p$	2°	9/2	*247 924.26*				
$3d^74s4p$	3°	7/2	*248 013.84*				
$3d^74s4p$	4°	9/2	*248 360.45*				
$3d^74s4p$	5°	5/2	*249 353.93*				
$3d^74s4p$	6°	5/2	*249 421.55*				

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^7(^4F)4s4p(^1P^\circ)$	$^4D^\circ$	7/2	*250 419.48*			
		5/2	*251 932.36*			
		3/2	*253 102.60*			
		1/2	*253 713.29*			
$3d^8(^1D_2)4f$	$^2[3]^\circ$	5/2	*250 731.98*	81	18	$(^3P_2)\ ^2[3]^\circ$
		7/2	*250 817.68*	69	14	
$3d^8(^1D_2)4f$	$^2[4]^\circ$	7/2	*250 733.55*	69	14	$(^3P_2)\ ^2[4]^\circ$
		9/2	*250 734.45*	81	17	
$3d^8(^1D_2)4f$	$^2[2]^\circ$	5/2	*250 955.22?*	82	16	$(^3P_2)\ ^2[2]^\circ$
$3d^8(^1D_2)4f$	$^2[5]^\circ$	9/2	*250 999.71*	83	16	$(^3P_2)\ ^2[5]^\circ$
		11/2	*251 010.62*	83	16	
$3d^8(^3P_2)4f$	$^2[4]^\circ$	9/2	*254 030.84*	80	16	$(^1D_2)\ ^2[4]^\circ$
$3d^8(^3P_2)4f$	$^2[3]^\circ$	5/2	*254 125.74*	45	32	$^2[2]^\circ$
		7/2	*254 132.14*	65	16	$^2[4]^\circ$
$3d^8(^3P_2)4f$	$^2[5]^\circ$	9/2	*254 448.81*	83	16	$(^1D_2)\ ^2[5]^\circ$
		11/2	*254 467.96*	84	16	
$3d^8(^1D)6s$	^2D	5/2	254 620.28	78	21	$(^3P)\ ^4P$
		3/2	254 694.27	82	14	$(^3P)\ ^2P$
$3d^8(^3P_2)4f$	$^2[1]^\circ$	3/2	*254 673.30?*	81	15	$(^1D_2)\ ^2[1]^\circ$
$3d^8(^3P_1)4f$	$^2[4]^\circ$	7/2	*254 772.26*	97	1	$(^1D_2)\ ^2[4]^\circ$
		9/2	*254 784.41*	94	3	$(^3P_2)\ ^2[4]^\circ$
$3d^8(^3P_1)4f$	$^2[2]^\circ$	5/2	*254 794.45*	89	5	$(^3P_2)\ ^2[2]^\circ$
$3d^8(^3P_1)4f$	$^2[3]^\circ$	7/2	*254 926.68*	98	1	$(^3P_0)\ ^2[3]^\circ$
$3d^8(^1D)5d$	^2F	7/2	255 173.30	77	17	$(^3P)\ ^4D$
$3d^8(^1D)5d$	^2G	9/2	255 458.91?	81	18	$(^3P)\ ^4F$
		7/2	255 486.66?	83	11	$(^3P)\ ^2F$
$3d^8(^1D)5d$	^2P	3/2	255 750.15	71	11	$(^3P)\ ^4P$
$3d^8(^1D)5d$	^2D	5/2	256 093.09?	61	20	$(^1D)\ ^2F$
$3d^8(^3F_4)5g$	$^2[2]$	5/2	257 488.98	74	25	$^2[3]$
		3/2	257 602.70	69	30	$^2[1]$
$3d^8(^3F_4)5g$	$^2[1]$	1/2	257 495.26	63	37	$^2[0]$
$3d^8(^3F_4)5g$	$^2[8]$	15/2	257 504.55	100		
		17/2	257 504.70	100		
$3d^8(^3F_4)5g$	$^2[3]$	7/2	257 514.75	80	20	$^2[4]$
		5/2	257 671.85	74	25	$^2[2]$
$3d^8(^3F_4)5g$	$^2[5]$	11/2	257 530.89	100		
		9/2	257 625.54	87	12	$^2[4]$

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^8(^3F_4)5g$	^{2}[7]	13/2	257 540.31	99		
		15/2	257 540.49	99		
$3d^8(^3F_4)5g$	^{2}[6]	13/2	257 565.23	100		
		11/2	257 566.45	100		
$3d^8(^3F_4)5g$	^{2}[4]	9/2	257 574.15?	87	12	^{2}[5]
		7/2	257 668.09?	80	19	^{2}[3]
$3d^8(^3P)6s$	^{4}P	5/2	257 885.87	79	21	(^{1}D) ^{2}D
$3d^8(^3P)5d$	^{4}D	7/2	258 199.34?	80	19	(^{1}D) ^{2}F
$3d^8(^3P)5d$	^{4}F	9/2	258 855.31?	82	18	(^{1}D) ^{2}G
		7/2	259 018.09?	90	9	
$3d^8(^3F)7s$	^{4}F	9/2	259 147.46?			
$3d^8(^3F_3)5g$	^{2}[7]	13/2	259 371.79	100		
		15/2	259 372.09	100		
$3d^8(^3F_3)5g$	^{2}[4]	9/2	259 402.75?	92	7	^{2}[5]
$3d^8(^3F_3)5g$	^{2}[6]	11/2	259 404.25	100		
		13/2	259 404.43	99	1	(^{3}F$_2$) ^{2}[6]
$3d^8(^3F_3)5g$	^{2}[5]	11/2	259 417.64	100		
$3d^8(^3F_3)5g$	^{2}[1]	3/2	259 432.58	90	10	^{2}[2]
$3d^8(^3F_3)5g$	^{2}[3]	5/2	259 470.16	88	11	^{2}[2]
$3d^8(^3F_2)5g$	^{2}[6]	11/2	260 590.96	98	1	(^{1}D$_2$) ^{2}[6]
		13/2	260 591.04	98	1	
$3d^8(^3F_2)5g$	^{2}[3]	7/2	260 632.62?	57	41	^{2}[5]
$3d^8(^3F_2)5g$	^{2}[5]	11/2	260 646.03?	99	1	(^{1}D$_2$) ^{2}[5]
$3d^8(^3F_2)5g$	^{2}[4]	9/2	260 676.45?	74	25	^{2}[5]
$3d^8(^1G_4)4f$	^{2}[7]°	15/2	*261 167.97*	100		
		13/2	*261 169.55*	100		
$3d^8(^1G_4)4f$	^{2}[3]°	7/2	*261 563.41*	100		
$3d^8(^1G_4)4f$	^{2}[4]°	9/2	*261 757.14*	100		
		7/2	*261 762.79*	100		
$3d^8(^1G_4)4f$	^{2}[6]°	13/2	*261 812.11*	100		
		11/2	*261 820.32*	100		
$3d^8(^1G_4)4f$	^{2}[5]°	9/2	*261 995.84*	100		
		11/2	*261 998.41*	100		
$3d^8(^1G)6s$	^{2}G	9/2	265 292.86?	100		

Cu III — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^8(^1G)5d$	^2I	$^{11}/_2$	265 544.10	100		
		$^{13}/_2$	265 589.57	100		
$3d^8(^1G)5d$	^2F	$^7/_2$	266 079.82	100		
		$^5/_2$	266 091.84	99		
$3d^8(^1G)5d$	^2H	$^9/_2$	266 597.63	99	1	^2G
		$^{11}/_2$	266 637.30	100		
$3d^8(^1G)5d$	^2G	$^7/_2$	266 643.08	100		
		$^9/_2$	266 653.32	99	1	^2H
$3d^8(^1G)5d$	^2D	$^5/_2$	267 031.05	91	6	$(^3P)\ ^2D$
		$^3/_2$	267 310.38	89	7	
$3d^8(^1D_2)5g$	$^2[5]$	$^{11}/_2$	273 732.91?	82	14	$(^3P_2)\ ^2[5]$
		$^9/_2$	273 738.68?	70	12	
$3d^8(^1D_2)5g$	$^2[6]$	$^{11}/_2$	273 799.53?	82	17	$(^3P_2)\ ^2[6]$
		$^{13}/_2$	273 802.30?	82	17	
$3d^8(^1D_2)5g$	$^2[3]$	$^7/_2$	273 800.58	82	14	$(^3P_2)\ ^2[3]$
$3d^8(^1D_2)5g$	$^2[4]$	$^9/_2$	273 807.19	70	13	$^2[5]$
$3d^8(^1G_4)5g$	$^2[8]$	$^{17}/_2$	284 095.50	100		
		$^{15}/_2$	284 098.12	100		
Cu IV ($^3F_4$)	***Limit***		**297 140**			

Cu IV

$Z=29$

Fe I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8\ ^3F_4$

Ionization energy 462 800±400 cm^{-1} (57.38±0.05 eV)

The earlier analysis of Cu IV by Schröder and van Kleef [1970] has been superseded by the analyses by Meinders [1976] and Meinders and Uijlings [1980]. Meinders [1976] reobserved the spectrum using a sliding spark light source. She carefully separated lines of various ionization stages by comparing spectra taken at various peak currents. The analysis led Meinders to find all nine levels of $3d^8$, 37 of the 38 levels of $3d^7 4s$, and 109 of the 110 levels of $3d^7 4p$. The level uncertainty is ±1 cm^{-1}.

New spectrograms were made by Meinders and Uijlings [1980] to obtain better exposures of the transition arrays $3d^7 4p - 3d^7 4d$ and $3d^7 4p - 3d^7 5s$. Additional measurements in the known arrays permitted a correction to the positions of the known levels. Downward shifts of 0.3 cm^{-1} for the $3d^7 4p$ levels and 1.7 cm^{-1} for the $3d^7 4s$ levels were recommended with respect to those published by Meinders [1976]. In addition, 27 levels of $3d^7 5s$ and 113 levels of $(3d^7 4d + 3d^6 4s^2)$ were found.

Percentage compositions were given by Meinders [1976] for the $3d^8$, $3d^7 4s$, and $3d^7 4p$ configurations. Meinders and Uijlings [1980] gave percentages for $3d^7(4d+5s) + 3d^6 4s^2$.

An experimental value for the ionization energy was derived from $3d^7 ns$ series. It agrees within 0.5% with the extrapolated value given by Lotz [1967].

References

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Cu IV

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^8$	^3F	4	0.0	100		
		3	1861.4	100		
		2	3077.6	99	1	^1D
$3d^8$	^1D	2	16 248.0	84	15	^3P
$3d^8$	^3P	2	19 696.6	85	15	^1D
		1	20 096.6	100		
		0	20 422.6	100		
$3d^8$	^1G	4	26 913.0	100		
$3d^8$	^1S	0	61 456.4	100		
$3d^7(^4F)4s$	^5F	5	119 632.4	100		
		4	120 918.7	99	1	$(^4F)\ ^3F$
		3	121 929.8	99		
		2	122 663.8	100		
		1	123 139.8	100		
$3d^7(^4F)4s$	^3F	4	128 343.3	99	1	$(^4F)\ ^5F$
		3	130 060.3	99		
		2	131 218.6	99		
$3d^7(^4P)4s$	^5P	3	139 695.3	100		
		2	140 065.7	95	5	$(^2P)\ ^3P$
		1	140 715.0	97	3	$(^2P)\ ^3P$

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^7(^2G)4s$	^3G	5	144 065.9	97	2	$(^2H)\ ^3H$
		4	144 749.0	94	3	$(^2G)\ ^1G$
		3	145 579.9	100		
$3d^7(^2P)4s$	^3P	2	147 736.6	47	45	$(^4P)\ ^3P$
		0	148 233.8	55	45	
		1	149 667.2	55	38	
$3d^7(^4P)4s$	^3P	1	147 929.8	49	32	$(^2P)\ ^3P$
		2	148 903.6	54	39	
$3d^7(^2G)4s$	^1G	4	148 860.7	89	6	$(^2H)\ ^3H$
$3d^7(^2H)4s$	^3H	6	151 622.7	100		
		5	152 301.7	96	3	$(^2H)\ ^1H$
		4	153 198.2	92	7	$(^2G)\ ^1G$
$3d^7(^2D2)4s$	^3D	3	152 231.7	77	23	$(^2D1)\ ^3D$
		2	153 375.7	68	18	$(^2D1)\ ^3D$
		1	155 476.7	44	40	$(^2P)\ ^1P$
$3d^7(^2P)4s$	^1P	1	152 400.2	46	30	$(^2D2)\ ^3D$
$3d^7(^2H)4s$	^1H	5	156 458.7	97	2	$(^2H)\ ^3H$
$3d^7(^2D2)4s$	^1D	2	157 536.1	71	19	$(^2D1)\ ^1D$
$3d^7(^2F)4s$	^3F	2	170 066.5	100		
		3	170 277.7	99	1	$(^2F)\ ^1F$
		4	170 619.0	100		
$3d^7(^2F)4s$	^1F	3	174 831.3	99	1	$(^2F)\ ^3F$
$3d^7(^4F)4p$	$^5F°$	5	*190 527.7*	91	7	$(^4F)\ ^5G°$
		4	*190 553.6*	54	38	$(^4F)\ ^5D°$
		3	*191 761.8*	71	22	$(^4F)\ ^5D°$
		2	*192 741.0*	83	12	$(^4F)\ ^5D°$
		1	*193 434.4*	94	5	$(^4F)\ ^5D°$
$3d^7(^4F)4p$	$^5D°$	4	*192 752.8*	52	34	$(^4F)\ ^5F°$
		3	*194 132.4*	64	18	$(^4F)\ ^5F°$
		2	*195 085.9*	72	10	$(^4F)\ ^5G°$
		1	*195 684.3*	85	10	$(^4P)\ ^5D°$
		0	*195 932.0*	89	11	$(^4P)\ ^5D°$
$3d^7(^4F)4p$	$^5G°$	6	*193 947.8*	99	1	$(^2G)\ ^3H°$
		5	*194 339.1*	76	16	$(^4F)\ ^3G°$
		4	*195 054.9*	79	10	$(^4F)\ ^5F°$
		3	*195 544.1*	81	9	$(^4F)\ ^5F°$
		2	*195 827.0*	85	6	$(^4F)\ ^5F°$
$3d^7(^2D1)4s$	^3D	1	196 853.5	81	19	$(^2D2)\ ^3D$
		2	197 138.5	79	20	
		3	197 659.5	77	23	
$3d^7(^4F)4p$	$^3G°$	5	*197 325.0*	82	18	$(^4F)\ ^5G°$
		4	*199 202.3*	87	10	
		3	*200 482.6*	93	4	

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^7(^4F)4p$	$^3F^\circ$	4	*198 179.2*	89		4	$(^4F)\ ^3G^\circ$
		3	*199 598.8*	84		5	$(^4F)\ ^3D^\circ$
		2	*200 720.0*	89		5	$(^2G)\ ^3F^\circ$
$3d^7(^4F)4p$	$^3D^\circ$	3	*201 210.9*	87		6	$(^4F)\ ^3F^\circ$
		2	*202 360.6*	89		3	$(^4F)\ ^3F^\circ$
		1	*203 139.5*	91		3	$(^4P)\ ^3D^\circ$
$3d^7(^2D1)4s$	^1D	2	201 771.0	78		21	$(^2D2)\ ^1D$
$3d^7(^4P)4p$	$^5S^\circ$	2	*203 868.9*	98		1	$(^2P)\ ^3P^\circ$
$3d^7(^4P)4p$	$^5D^\circ$	1	*213 360.4*	44		18	$(^2P)\ ^3P^\circ$
		2	*213 534.5*	74		9	$(^4F)\ ^5D^\circ$
		3	*213 664.9*	78		8	$(^4F)\ ^5D^\circ$
		0	*213 932.1*	78		11	$(^2P)\ ^3P^\circ$
		4	*214 318.7*	88		6	$(^4F)\ ^5D^\circ$
$3d^7(^4P)4p$		1	*214 413.4*	37	$(^4P)\ ^5D^\circ$	32	$(^4P)\ ^3S^\circ$
$3d^7(^2G)4p$	$^3H^\circ$	5	*214 835.3*	67		17	$(^2G)\ ^1H^\circ$
		4	*215 733.9*	83		6	$(^2G)\ ^3F^\circ$
		6	*216 071.3*	95		3	$(^2H)\ ^3I^\circ$
$3d^7(^2G)4p$	$^3F^\circ$	4	*215 132.8*	53		12	$(^2G)\ ^3G^\circ$
		3	*217 079.2*	73		16	$(^2G)\ ^3G^\circ$
		2	*218 726.2*	93		5	$(^4F)\ ^3F^\circ$
$3d^7(^2P)4p$	$^3P^\circ$	0	*216 428.9*	67		13	$(^2D2)\ ^3P^\circ$
		2	*216 702.9*	54		14	$(^4P)\ ^5P^\circ$
		1	*217 109.3*	49		17	$(^4P)\ ^3S^\circ$
$3d^7(^2G)4p$	$^1G^\circ$	4	*217 444.6*	46		27	$(^2G)\ ^3F^\circ$
$3d^7(^4P)4p$	$^5P^\circ$	3	*217 621.1*	62		22	$(^4P)\ ^3D^\circ$
		2	*218 027.5*	54		23	$(^4P)\ ^3D^\circ$
		1	*218 170.7*	66		19	$(^4P)\ ^3S^\circ$
$3d^7(^4P)4p$		2	*217 649.6*	18	$^5P^\circ$	18	$(^2P)\ ^3D^\circ$
$3d^7(^2G)4p$	$^3G^\circ$	5	*217 999.5*	80		14	$(^2G)\ ^1H^\circ$
		3	*218 628.0*	45		29	$(^2G)\ ^1F^\circ$
		4	*218 944.8*	74		9	$(^2G)\ ^1G^\circ$
$3d^7(^4P)4p$	$^3D^\circ$	3	*218 137.6*	52		23	$(^4P)\ ^5P^\circ$
		1	*218 631.1*	53		24	$(^2P)\ ^3D^\circ$
		2	*221 738.5*	25		24	$(^4P)\ ^3D^\circ$
$3d^7(^2G)4p$	$^1H^\circ$	5	*218 814.5*	64		27	$(^2G)\ ^3H^\circ$
$3d^7(^2G)4p$		3	*219 402.7*	35	$^1F^\circ$	34	$(^2G)\ ^3G^\circ$
$3d^7(^2P)4p$	$^1S^\circ$	0	*219 867.4*	53		37	$(^4P)\ ^3P^\circ$
$3d^7(^4P)4p$	$^3P^\circ$	2	*220 315.6*	59		11	$(^4P)\ ^3D^\circ$
		1	*221 271.6*	49		25	$(^2P)\ ^3D^\circ$
		0	*223 847.4*	56		43	$(^2P)\ ^1S^\circ$
$3d^7(^2H)4p$	$^3G^\circ$	5	*220 917.0*	92		5	$(^2F)\ ^3G^\circ$
		4	*222 397.7*	87		6	
		3	*223 623.0*	80		6	

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^7(^2H)4p$	$^3I^\circ$	6	*221 601.6*	69		29	$(^2H)\ ^1I^\circ$
		5	*222 527.4*	93		4	$(^2G)\ ^1H^\circ$
		7	*222 665.8*	100			
$3d^7(^2P)4p$	$^3D^\circ$	3	*221 650.0*	72		8	$(^2D2)\ ^3F^\circ$
$3d^7(^4P)4p$		1	*222 335.9*	38	$^3P^\circ$	22	$(^2P)\ ^3D^\circ$
$3d^7(^2P)4p$		2	*222 602.5*	34	$^3D^\circ$	25	$(^2P)\ ^1D^\circ$
$3d^7(^2D2)4p$	$^3D^\circ$	3	*223 000.0*	58		17	$(^2D1)\ ^3D^\circ$
		2	*224 070.6*	40		16	$(^2P)\ ^3D^\circ$
$3d^7(^2D2)4p$		1	*223 764.1*	32	$^3D^\circ$	28	$(^2P)\ ^1P^\circ$
$3d^7(^2H)4p$	$^1I^\circ$	6	*224 959.1*	69		28	$(^2H)\ ^3I^\circ$
$3d^7(^2D2)4p$	$^3F^\circ$	4	*225 386.9*	77		20	$(^2D1)\ ^3F^\circ$
		3	*225 858.9*	53		12	
		2	*226 271.3*	57		12	
$3d^7(^2P)4p$	$^3S^\circ$	1	*226 558.0*	60		10	$(^2P)\ ^1P^\circ$
$3d^7(^2P)4p$	$^1P^\circ$	1	*227 159.6*	42		17	$(^2P)\ ^3S^\circ$
$3d^7(^2D2)4p$		2	*227 959.5*	34	$^1D^\circ$	23	$(^2D2)\ ^3P^\circ$
$3d^7(^2H)4p$	$^3H^\circ$	6	*227 993.2*	97		1	$(^2H)\ ^1H^\circ$
		5	*228 479.7*	94		3	$(^2H)\ ^1H^\circ$
		4	*229 064.0*	95		2	$(^2H)\ ^1G^\circ$
$3d^7(^2D2)4p$		2	*229 694.2*	36	$^3P^\circ$	20	$(^2D2)\ ^1D^\circ$
$3d^7(^2H)4p$	$^1G^\circ$	4	*230 235.9*	67		31	$(^2G)\ ^1G^\circ$
$3d^7(^2D2)4p$	$^1F^\circ$	3	*230 331.1*	57		17	$(^2G)\ ^1F^\circ$
$3d^7(^2D2)4p$	$^3P^\circ$	1	*231 216.3*	53		12	$(^2D1)\ ^3P^\circ$
		0	*231 825.2*	67		15	$(^2P)\ ^3P^\circ$
$3d^7(^2D2)4p$	$^1P^\circ$	1	*232 441.8*	75		12	$(^2D1)\ ^1P^\circ$
$3d^7(^2H)4p$	$^1H^\circ$	5	*233 298.6*	95		2	$(^2H)\ ^3H^\circ$
$3d^7(^2F)4p$	$^1D^\circ$	2	*241 854.9*	59		31	$(^2F)\ ^3F^\circ$
$3d^7(^2F)4p$	$^3G^\circ$	3	*242 529.8*	73		16	$(^2F)\ ^3F^\circ$
		4	*243 028.9*	59		23	$(^2F)\ ^3F^\circ$
		5	*244 671.4*	93		6	$(^2H)\ ^3G^\circ$
$3d^7(^2F)4p$	$^3F^\circ$	3	*243 725.3*	40		42	$(^2F)\ ^3D^\circ$
		2	*244 071.6*	63		29	$(^2F)\ ^1D^\circ$
		4	*244 753.1*	44		33	$(^2F)\ ^3G^\circ$
$3d^7(^2F)4p$	$^3D^\circ$	3	*244 417.1*	47		38	$(^2F)\ ^3F^\circ$
		2	*244 812.8*	83		8	$(^2F)\ ^1D^\circ$
		1	*244 943.0*	91		5	$(^2D1)\ ^3D^\circ$
$3d^7(^2F)4p$	$^1G^\circ$	4	*245 204.3*	68		29	$(^2F)\ ^3F^\circ$

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^7(^2F)4p$	$^1F^o$	3	*250 622.8*	96		2	$(^2F)\ ^3D^o$
$3d^7(^2D1)4p$	$^3P^o$	2	*266 196.5*	77		21	$(^2D2)\ ^3P^o$
		1	*266 460.9*	78		18	
		0	*266 775.0*	81		18	
$3d^7(^2D1)4p$	$^3F^o$	2	*268 006.0*	76		18	$(^2D2)\ ^3F^o$
		3	*268 956.3*	75		20	
		4	*270 239.5*	75		22	
$3d^7(^2D1)4p$	$^1P^o$	1	*272 352.4*	80		12	$(^2D2)\ ^1P^o$
$3d^7(^2D1)4p$	$^1F^o$	3	*272 943.7*	75		20	$(^2D2)\ ^1F^o$
$3d^7(^2D1)4p$	$^3D^o$	1	*275 672.9*	71		22	$(^2D2)\ ^3D^o$
		2	*275 970.3*	60		18	
		3	*277 108.7*	70		24	
$3d^7(^2D1)4p$	$^1D^o$	2	*276 545.9*	56		20	$(^2D2)\ ^1D^o$
$3d^7(^4F)4d$	^5F	5	287 319.5	90			
		4	287 589.3	75		13	$(^4F)\ ^5D$
		3	288 566.4	63		17	
		2	289 370.2	80			
		1	289 974.0	93			
$3d^7(^4F)4d$	^5G	6	288 697.8	94			
		5	289 572.9	69		16	$(^4F)\ ^3G$
		4	290 552.8	67		12	$(^4F)\ ^5F$
		3	291 298.7	61		14	$(^4F)\ ^5F$
		2	291 730.0	87			
$3d^7(^4F)4d$	^5P	3	289 529.7	70		18	$(^4F)\ ^5F$
		2	290 773.5	55		26	$(^4F)\ ^5D$
		1	292 639.1	71		17	$(^4F)\ ^5D$
$3d^7(^4F)4d$	^5D	4	289 641.5	54		25	$3d^64s^2\ ^5D$
		1	291 570.8	51		27	$(^4F)\ ^5F$
$3d^7(^4F)4d$	^5H	7	289 688.2	99			
		6	290 445.4	65		30	$(^4F)\ ^3H$
		5	291 561.6	81			
		4	292 296.7	46		29	$(^4F)\ ^3G$
		3	292 913.3	93			
$3d^74d$		3	290 885.1	34	$(^4F)\ ^5D$	25	$(^4F)\ ^5G$
$3d^7(^4F)4d$	^3G	5	291 147.3	72		17	$(^4F)\ ^5G$
		4	292 440.0	54		43	$(^4F)\ ^5H$
		3	293 513.5	92			
$3d^7(^4F)4d$	^3H	6	291 865.0	69		29	$(^4F)\ ^5H$
		5	293 399.2	82		12	
		4	294 464.4	91			
$3d^7(^4F)4d$	^3D	3	291 953.9	81			
		2	293 021.7	87			
		1	294 015.3	96			

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^7 4d$		2	291 997.1	35	$(^4F)\ ^5P$	32	$(^4F)\ ^5D$
$3d^6 4s^2$	^5D	4	294 152.0	69		28	$3d^7(^4F)4d\ ^5D$
		3	295 307.8	69		27	
		2	296 040.3	69		26	
		1	296 494.2	71		25	
$3d^7(^4F)4d$	^3F	4	295 910.4	82			
		3	296 912.3	80			
		2	297 554.4	80			
$3d^7(^4F)4d$	^3P	2	296 573.4	83			
		1	297 931.0	89			
$3d^7(^4F)5s$	^5F	5	301 632.0	99			
		4	302 682.3	83		16	$(^4F)\ ^3F$
		3	303 798.4	92			
		2	304 599.7	97			
		1	305 116.0	99			
$3d^7(^4F)5s$	^3F	4	304 244.9	83		16	$(^4F)\ ^5F$
		3	305 856.0	92			
		1	306 941.8	97			
$3d^7(^4P)4d$	^5P	1	306 982.5	99			
		2	307 167.0	97			
		3	307 517.3	95			
$3d^7(^4P)4d$	^5F	5	309 413.9	98			
		4	309 490.4	92			
		3	309 653.1	88			
		2	309 864.7	87			
		1	310 057.1	86			
$3d^7(^2G)4d$	^3D	3	310 800.2	82			
		2	311 274.0	53		19	$(^4P)\ ^3F$
$3d^7(^4P)4d$	^3F	3	311 010.7	44		29	$(^2G)\ ^1F$
		4	311 177.0	83			
		2	312 061.4	57		20	$(^2G)\ ^3D$
$3d^7(^2G)4d$	^3I	7	311 628.0	95			
		6	311 742.9	71		20	$(^2G)\ ^1I$
		5	313 253.3	49		27	$(^2G)\ ^3H$
$3d^7 4d$		1	311 726.7	32	$(^4P)\ ^3P$	24	$(^2G)\ ^3D$
$3d^7(^2G)4d$	^3G	5	311 998.3	78		13	$(^2G)\ ^3H$
		4	312 466.7	80			
		3	313 257.0	92			
$3d^7(^2G)4d$	^1F	3	312 082.5	52		27	$(^4P)\ ^3F$
$3d^7 4d$		5	312 415.5	44	$(^2G)\ ^3I$	18	$(^2G)\ ^3H$
$3d^7(^2G)4d$	^3H	6	312 514.9	77		18	$(^2G)\ ^1I$
		4	313 871.5	90			
$3d^7 4d$		2	312 601.5	32	$(^4P)\ ^3P$	28	$(^4P)\ ^5D$

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^7(^4P)4d$	^5D	4	312 629.9	85			
		3	312 956.8	81			
		2	313 294.7	60		16	$(^4P)\ ^3P$
$3d^7(^2G)4d$	^1I	6	313 715.4	58		26	$(^2G)\ ^3I$
$3d^7(^2G)4d$	^1H	5	314 262.2	57		39	$(^2G)\ ^3H$
$3d^7(^2G)4d$	^3F	4	314 987.8	55		13	$(^2P)\ ^3F$
		3	315 450.0	53		12	
		2	316 191.7	54			
$3d^7(^2G)4d$	^1G	4	315 598.5	68		13	$(^2H)\ ^1G$
$3d^7(^2P)4d$	^3D	2	315 846.0	53		10	$(^4P)\ ^3P$
		3	315 912.2	74			
$3d^7(^2P)4d$	^3F	4	316 732.3	47		22	$(^2H)\ ^3F$
		3	317 810.5	42		21	$(^2P)\ ^1F$
$3d^74d$		3	317 017.0	25	$(^2P)\ ^1F$	22	$(^2H)\ ^3F$
$3d^7(^2H)4d$	^3K	8	318 452.4	100			
		7	318 510.0	62		38	$(^2H)\ ^1K$
		6	319 703.7	95			
$3d^7(^2H)4d$	^3G	5	318 746.1	93			
		4	319 896.1	68		11	$(^2D)\ ^3F$
$3d^7(^2H)4d$	^1F	3	319 268.4	58		11	$(^2P)\ ^1F$
$3d^74d$		4	319 586.7	36	$(^2D2)\ ^3F$	17	$(^2H)\ ^3G$
$3d^74d$		3	319 992.7	26	$(^2D2)\ ^3F$	21	$(^2D2)\ ^3D$
$3d^7(^2H)4d$	^1K	7	320 141.7	60		36	$(^2H)\ ^3K$
$3d^7(^2H)4d$	^3H	6	320 601.1	62		4	$4s^2\ ^3H$
		5	321 064.0	44		21	
$3d^7(^2D)4d$	^3G	5	320 781.7	66		18	$(^2D1)\ ^3G$
$3d^74d$		4	320 952.7	36	$(^2D2)\ ^3G$	34	$(^2D2)\ ^1G$
$3d^7(^2H)4d$	^3I	7	321 135.1	99			
		6	321 542.1	86		11	$(^2H)\ ^1I$
		5	322 524.0	68		26	$(^2H)\ ^3H$
$3d^7(^2D2)4d$	^1F	3	322 051.3	38		11	$(^2D1)\ ^1F$
$3d^7(^2H)4d$	^1H	5	322 317.4	48		25	$(^2H)\ ^3I$
$3d^7(^4P)5s$	^5P	3	322 338.2	99			
		2	322 608.1	84			
		1	323 249.0				
$3d^74d$		4	323 155.3	32	$(^2D2)\ ^1G$	29	$(^2D2)\ ^3G$

Cu IV — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^7(^2H)4d$	^1I	6	323 754.8	84		
$3d^64s^2$	^3H	6	324 118.1	57	36	$(^2H)\ ^3H$
		5	324 619.3	42	30	
		4	324 731.4	35	31	
$3d^7(^4P)5s$	^3P	2	324 418.7	95		
$3d^7(^2G)5s$	^3G	5	324 759.9	78	10	$4s^2\ ^3H$
		4	325 225.9	73	21	$(^2G)5s\ ^1G$
		3	326 247.5	88		
$3d^7(^2G)5s$	^1G	4	326 979.8	73	24	$(^2G)\ ^3G$
$3d^7(^2H)4d$	^3F	4	327 356.7	46	13	$(^2D2)\ ^3F$
		3	328 720.0	43	13	
		2	329 341.2	36	11	
$3d^7(^2P)5s$	^3P	2	329 181.7	79		
		1	329 632.8	58	20	$(^2P)\ ^1P$
$3d^7(^2P)5s$	^1P	1	331 041.9	59	33	$(^2P)\ ^3P$
$3d^7(^2H)4d$	^1G	4	332 035.9	62	13	$(^2F)\ ^1G$
$3d^7(^2H)5s$	^3H	6	332 436.4	100		
		5	332 854.7	78	22	$(^2H)\ ^1H$
		4	333 868.7	95		
$3d^7(^2D2)5s$	^3D	3	333 005.7	76	23	$(^2D1)\ ^3D$
		2	333 736.7	42	20	$(^2D2)\ ^1D$
$3d^7(^2H)5s$	^1H	5	334 564.8	77	20	$(^2H)\ ^3H$
$3d^7(^2D2)5s$	^1D	2	335 885.5	46	24	$(^2D2)\ ^3D$
$3d^7(^2F)4d$	^3H	5	338 974.8	92		
		6	339 378.8	90		
$3d^7(^2F)4d$	^3G	3	339 392.7	79	10	$(^2F)\ ^1F$
		4	339 763.8	90		
		5	340 161.9	94		
$3d^7(^2F)4d$	^1H	5	339 808.5	93		
$3d^7(^2F)4d$	^1G	4	347 248.7	84	10	$(^2H)\ ^1G$
$3d^7(^2F)5s$	^3F	3	351 520.2	93		
		4	351 908.8	100		
Cu V ($^4F_{9/2}$)	*Limit*		462 800			

Cu v

$Z=29$

Mn I isoelectronic sequence

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

Ionization energy 644 000 ± 6000 cm^{-1} (79.8 ± 0.7 eV)

The first work on Cu v was reported by van Kleef, Joshi, and Benschop [1975] who found the ^{4}F term of $3d^7$ and the ^{6}P°, ^{4}D°, and ^{4}F° terms of $3d^6(^5\text{D})4p$.

New observations of this spectrum were obtained by van Kleef, Raassen, and Joshi [1976]. They identified the $3d^7-3d^64p$ array in the region 270–410 Å and the $3d^64s-3d^64p$ array in the region 1100–1330 Å. All levels of the $3d^7$ were reported as well as 53 of the 63 levels of the $3d^64s$ and 175 of the 180 levels of $3d^64p$. The uncertainty of the level values is ±3 cm^{-1}. Percentage compositions were obtained for these configurations without taking into account configuration interaction between $3d^7$ and $3d^64s$.

The value for the ionization energy was obtained by Lotz [1967] by extrapolation.

References

Lotz, W. [1967], J. Opt. Soc. Am. **57**, 873.

van Kleef, T. A. M., Joshi, Y. N., and Benschop, H. [1975], Can. J. Phys. **53**, 230.

van Kleef, T. A. M., Raassen, A. J. J., and Joshi, Y. N. [1976], Physica (Utrecht) **84C**, 401.

Cu v

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^7$	^{4}F	9/2	0.0	100		
		7/2	1615.9	100		
		5/2	2759.3	100		
		3/2	3528.1	99		
$3d^7$	^{4}P	5/2	20 826.8	99		
		3/2	21 065.9	89	10	^{2}P
		1/2	21 935.1	96	4	^{2}P
$3d^7$	^{2}G	9/2	22 575.3	96	3	^{2}H
		7/2	24 099.8	100		
$3d^7$	^{2}P	3/2	27 015.9	78	10	^{4}P
		1/2	28 366.6	96	4	
$3d^7$	^{2}H	11/2	30 401.7	100		
		9/2	31 823.4	97	3	^{2}G
$3d^7$	^{2}D2	5/2	30 966.0	76	23	^{2}D1
		3/2	33 292.4	70	17	
$3d^7$	^{2}F	5/2	49 490.0	100		
		7/2	50 071.9	100		
$3d^7$	^{2}D1	3/2	76 838.2	80	20	^{2}D2
		5/2	77 668.0	77	23	
$3d^6(^5\text{D})4s$	^{6}D	9/2	187 779.4	100		
		7/2	188 832.7	100		
		5/2	189 586.9	100		
		3/2	190 100.3	100		
		1/2	190 400.3	99		

Cu v — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^6(^5D)4s$	^4D	7/2	199 441.3	99		
		5/2	200 648.2	100		
		3/2	201 412.8	99		
		1/2	201 849.7	99		
$3d^6(^3P2)4s$	^4P	5/2	219 203.4	62	37	$(^3P1)\ ^4P^\circ$
		3/2	221 664.1	59	34	
		1/2	223 375.5	62	35	
$3d^6(^3H)4s$	^4H	13/2	220 207.8	99	1	$(^1I)\ ^2I^\circ$
		11/2	220 622.8	97	3	$(^3G)\ ^4G^\circ$
		9/2	220 938.1	90	5	$(^3G)\ ^4G^\circ$
		7/2	221 271.9	93	5	$(^3G)\ ^4G^\circ$
$3d^6(^3F2)4s$	^4F	9/2	222 401.3	68	20	$(^3F1)\ ^4F^\circ$
		7/2	222 885.7	72	19	
		5/2	223 214.2	77	19	
		3/2	223 476.5	80	19	
$3d^6(^3G)4s$	^4G	11/2	226 310.8	64	34	$(^3H)\ ^2H^\circ$
		9/2	227 542.6	59	34	$(^3H)\ ^2H^\circ$
		7/2	228 020.3	81	8	$(^3F2)\ ^2F^\circ$
		5/2	228 105.3	85	8	$(^3F2)\ ^2F^\circ$
$3d^6(^3P2)4s$	^2P	3/2	226 888.8	58	34	$(^3P1)\ ^2P^\circ$
		1/2	229 773.6	61	35	
$3d^6(^3H)4s$	^2H	11/2	227 800.5	64	33	$(^3G)\ ^4G^\circ$
		9/2	228 047.5	60	32	
$3d^6(^3F2)4s$	^2F	7/2	229 587.5	64	18	$(^3F1)\ ^2F^\circ$
		5/2	230 531.7	71	17	
$3d^6(^3G)4s$	^2G	9/2	234 036.4	95	4	$(^3H)\ ^2H^\circ$
		7/2	235 052.5	94	5	$(^3F2)\ ^2F^\circ$
$3d^6(^3D)4s$	^4D	3/2	236 039.8	98	1	$(^1D1)\ ^2D^\circ$
		5/2	236 058.9	98	1	$(^1D1)\ ^2D^\circ$
		1/2	236 108.8	99	1	$(^3P1)\ ^2P^\circ$
		7/2	236 331.2	99		
$3d^6(^1I)4s$	^2I	13/2	238 233.6	99	1	$(^3H)\ ^4H^\circ$
		11/2	238 305.2	99	1	$(^3H)\ ^2H^\circ$
$3d^6(^1G2)4s$	^2G	9/2	239 540.9	65	32	$(^1G1)\ ^2G^\circ$
		7/2	239 614.5	65	31	
$3d^6(^3D)4s$	^2D	5/2	243 140.4	96	2	$(^1D2)\ ^2D^\circ$
$3d^6(^1D2)4s$	^2D	5/2	246 476.5	74	20	$(^1D1)\ ^2D^\circ$
		3/2	246 624.3	72	20	
$3d^6(^1F)4s$	^2F	7/2	256 272.5	97	2	$(^3F1)\ ^4F^\circ$
		5/2	256 272.9	97	1	
$3d^6(^3F1)4s$	^4F	3/2	265 691.5	80	19	$(^3F2)\ ^4F^\circ$
		9/2	265 752.4	78	22	
		5/2	265 886.0	79	19	
		7/2	265 975.0	77	20	

Cu V — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^6(^5\text{D})4p$	^{6}D°	9/2	*266 226.7*	97		2	(^{5}D) ^{6}F°
		7/2	*266 560.0*	95		2	
		5/2	*267 068.8*	96		2	
		3/2	*267 488.7*	98		1	
		1/2	*267 759.0*	99			
$3d^6(^3\text{F}1)4s$	^{2}F	7/2	272 755.1	77		21	(^{3}F2) ^{2}F°
		5/2	272 800.8	80		20	
$3d^6(^5\text{D})4p$	^{6}F°	11/2	*274 003.9*	100			
		9/2	*274 064.5*	92		5	(^{5}D) ^{4}F°
		7/2	*274 073.2*	89		4	(^{5}D) ^{4}F°
		5/2	*274 146.2*	92		3	(^{5}D) ^{4}D°
		3/2	*274 188.5*	94		3	(^{5}D) ^{4}D°
		1/2	*274 209.7*	95		3	(^{5}D) ^{4}D°
$3d^6(^5\text{D})4p$	^{6}P°	7/2	*276 368.0*	78		14	(^{5}D) ^{4}D°
		5/2	*278 294.6*	81		14	
		3/2	*279 589.5*	88		9	
$3d^6(^1\text{G}1)4s$	^{2}G	9/2	278 281.8	66		33	(^{1}G2) ^{2}G
		7/2	278 380.0	66		33	
$3d^6(^5\text{D})4p$	^{4}D°	7/2	*278 663.1*	78		18	(^{5}D) ^{6}P°
		5/2	*279 496.8*	77		16	(^{5}D) ^{6}P°
		3/2	*280 065.7*	82		11	(^{5}D) ^{6}P°
		1/2	*280 373.3*	91		4	(^{5}D) ^{6}F°
$3d^6(^5\text{D})4p$	^{4}F°	9/2	*279 421.1*	92		6	(^{5}D) ^{6}F°
		7/2	*280 928.7*	93		4	(^{5}D) ^{6}F°
		5/2	*281 942.4*	95		2	(^{5}D) ^{6}F°
		3/2	*282 621.5*	97		1	(^{3}G) ^{4}F°
$3d^6(^5\text{D})4p$	^{4}P°	5/2	*284 520.9*	96		2	(^{3}D) ^{4}P°
		3/2	*285 546.4*	97		1	
		1/2	*286 068.7*	97		1	
$3d^6(^3\text{H})4p$	^{4}G°	11/2	*300 401.2*	69		19	(^{3}F2) ^{4}G°
		9/2	*300 837.1*	45		27	
		7/2	*301 255.4*	36		33	
		5/2	*309 569.9*	30		17	
$3d^6(^3\text{P}2)4p$	^{4}P°	5/2	*301 080.5*	23		20	(^{3}P1) ^{4}P°
		1/2	*302 961.2*	46		41	
$3d^6(^3\text{H})4p$	^{4}I°	11/2	*301 286.4*	49		34	(^{3}H) ^{4}H°
		13/2	*301 336.1*	46		37	(^{3}H) ^{4}H°
		9/2	*302 980.4*	46		19	(^{3}H) ^{2}G°
		15/2	*303 456.4*	99		1	(^{1}I) ^{2}K°
$3d^6(^3\text{H})4p$		9/2	*301 385.6*	37	^{4}I°	36	(^{3}H) ^{4}H°
$3d^6(^3\text{F}2)4p$	^{4}G°	5/2	*301 533.4*	41		38	(^{3}H) ^{4}G°
		7/2	*307 990.7*	26		15	(^{3}H) ^{4}G°
		11/2	*308 064.9*	51		15	(^{3}F1) ^{4}G°
$3d^6(^3\text{H})4p$		7/2	*301 586.7*	36	^{4}H°	21	(^{3}H) ^{2}G°
$3d^6(^3\text{F}2)4p$		7/2	*303 209.3*	18	^{4}F°	17	(^{3}H) ^{4}H°

Cu v — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^6(^3P2)4p$		5/2	*303 241.7*	29	$^2D^\circ$	21	$(^3P2)\ ^4P^\circ$
$3d^6(^3F2)4p$	$^4F^\circ$	5/2	*303 479.1*	49		16	$(^3F)\ ^4F^\circ$
		3/2	*303 734.1*	61		19	
		9/2	*304 092.2*	44		16	
$3d^6(^3P2)4p$		3/2	*303 679.5*	23	$^4D^\circ$	22	$(^3P2)\ ^4S^\circ$
$3d^6(^3H)4p$	$^4H^\circ$	11/2	*303 931.7*	42		44	$(^3H)\ ^4I^\circ$
		13/2	*304 062.3*	51		38	
$3d^6(^3P2)4p$	$^4D^\circ$	7/2	*304 199.0*	48		26	$(^3P1)\ ^4D^\circ$
		5/2	*306 905.8*	37		16	
$3d^6(^3H)4p$		9/2	*304 456.1*	30	$^2G^\circ$	26	$(^3H)\ ^4H^\circ$
$3d^6(^3H)4p$		7/2	*304 655.0*	26	$^2G^\circ$	18	$(^3F2)\ ^4F^\circ$
$3d^6(^3F2)4p$	$^4D^\circ$	7/2	*305 453.3*	43		10	$(^3H)\ ^2G^\circ$
		5/2	*306 115.6*	47		10	$(^3F1)\ ^4D^\circ$
		3/2	*306 678.1*	53		10	$(^3F1)\ ^4D^\circ$
		1/2	*306 989.1*	64		13	$(^3D)\ ^4D^\circ$
$3d^6(^3P2)4p$		3/2	*305 844.4*	18	$^4P^\circ$	16	$(^3P1)\ ^4P^\circ$
$3d^6(^3H)4p$	$^2I^\circ$	13/2	*305 882.7*	81		15	$(^3H)\ ^4I^\circ$
		11/2	*306 892.2*	79		5	
$3d^6(^3P2)4p$		3/2	*307 138.8*	21	$^4D^\circ$	16	$(^3P2)\ ^2D^\circ$
$3d^6(^3F2)4p$		9/2	*307 824.5*	32	$^4G^\circ$	16	$(^3H)\ ^4G^\circ$
$3d^6(^3F2)4p$		5/2	*307 909.5*	23	$^2F^\circ$	16	$(^3F2)\ ^4G^\circ$
$3d^6(^3G)4p$	$^4F^\circ$	9/2	*308 817.8*	54		24	$(^3G)\ ^4G^\circ$
		7/2	*309 801.3*	42		36	$(^3G)\ ^4G^\circ$
		3/2	*311 706.3*	62		16	$(^3D)\ ^4F^\circ$
$3d^6(^3G)4p$		11/2	*309 269.1*	30	$^2H^\circ$	27	$(^3G)\ ^4G^\circ$
$3d^6(^3F2)4p$		7/2	*309 294.1*	22	$^2F^\circ$	14	$(^3H)\ ^4G^\circ$
$3d^6(^3P2)4p$		1/2	*309 702.9*	27	$^2P^\circ$	24	$(^3P2)\ ^2S^\circ$
$3d^6(^3G)4p$		9/2	*309 772.0*	25	$^2H^\circ$	22	$(^3F2)\ ^2G^\circ$
$3d^6(^3P2)4p$	$^2P^\circ$	3/2	*310 450.4*	46		30	$(^3P1)\ ^2P^\circ$
$3d^6(^3G)4p$	$^4G^\circ$	11/2	*310 483.1*	45		19	$(^3H)\ ^2H^\circ$
$3d^6(^3G)4p$		5/2	*310 753.8*	33	$^4F^\circ$	30	$(^3G)\ ^4G^\circ$
$3d^6(^3F2)4p$		9/2	*310 874.9*	23	$^2G^\circ$	18	$(^3G)\ ^4G^\circ$
$3d^6(^3F2)4p$	$^2G^\circ$	7/2	*311 220.3*	57		13	$(^3F2)\ ^2G^\circ$
$3d^6(^3G)4p$		9/2	*311 232.9*	31	$^4G^\circ$	20	$(^3H)\ ^2H^\circ$
$3d^6(^3G)4p$		7/2	*311 582.4*	38	$^4G^\circ$	26	$(^3G)\ ^4F^\circ$

Cu V — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^6(^3G)4p$		5/2	*311 837.8*	37	$^4G^\circ$	32	$(^3G)\ ^4F^\circ$
$3d^6(^3G)4p$	$^4H^\circ$	13/2	*311 888.8*	84		11	$(^3H)\ ^4H^\circ$
		7/2	*312 073.1*	63		11	$(^3H)\ ^4H^\circ$
		11/2	*312 105.5*	69		12	$(^3H)\ ^2H^\circ$
		9/2	*312 138.0*	67		8	$(^3H)\ ^4H^\circ$
$3d^6(^3P2)4p$	$^2S^\circ$	1/2	*311 982.0*	46		18	$(^3P1)\ ^2S^\circ$
$3d^6(^3F2)4p$	$^2D^\circ$	5/2	*314 237.9*	62		11	$(^3P2)\ ^2D^\circ$
		3/2	*314 988.0*	61		16	
$3d^6(^3G)4p$	$^2F^\circ$	5/2	*316 134.0*	41		19	$(^3D)\ ^2F^\circ$
		7/2	*316 642.6*	47		18	
$3d^6(^3H)4p$	$^2H^\circ$	11/2	*316 149.4*	50		38	$(^3G)\ ^2H^\circ$
		9/2	*317 201.1*	36		36	
$3d^6(^1I)4p$	$^2K^\circ$	13/2	*317 240.4*	96		3	$(^1I)\ ^2I^\circ$
		15/2	*319 407.6*	99		1	$(^3H)\ ^4I^\circ$
$3d^6(^3D)4p$	$^4P^\circ$	5/2	*318 923.1*	85		4	$(^3P2)\ ^4P^\circ$
		3/2	*319 404.1*	67		11	$(^3D)\ ^2P^\circ$
		1/2	*320 216.4*	46		21	$(^3D)\ ^4D^\circ$
$3d^6(^3G)4p$	$^2G^\circ$	7/2	*319 304.2*	65		9	$(^3H)\ ^2G^\circ$
		9/2	*319 689.0*	46		13	$(^1G2)\ ^2H^\circ$
$3d^6(^1G2)4p$		9/2	*319 418.8*	29	$^2H^\circ$	21	$(^3G)\ ^2G^\circ$
$3d^6(^1I)4p$	$^2H^\circ$	11/2	*319 951.5*	55		21	$(^1G2)\ ^2H^\circ$
		9/2	*323 616.8*	62		14	$(^1G1)\ ^2H^\circ$
$3d^6(^3D)4p$		1/2	*320 935.3*	44	$^4P^\circ$	19	$(^3D)\ ^2P^\circ$
$3d^6(^3D)4p$	$^4F^\circ$	3/2	*321 074.0*	55		22	$(^3G)\ ^4F^\circ$
		5/2	*321 364.9*	50		18	$(^3G)\ ^4F^\circ$
		7/2	*322 464.1*	45		12	$(^1G2)\ ^2G^\circ$
		9/2	*322 875.8*	73		11	$(^3G)\ ^4F^\circ$
$3d^6(^3D)4p$		7/2	*321 433.0*	22	$^4D^\circ$	20	$(^3D)\ ^4F^\circ$
$3d^6(^3D)4p$		3/2	*321 443.1*	30	$^2P^\circ$	23	$(^3D)\ ^4D^\circ$
$3d^6(^1G2)4p$	$^2G^\circ$	7/2	*321 795.8*	38		14	$(^1G1)\ ^2G^\circ$
		9/2	*322 375.9*	48		20	
$3d^6(^3D)4p$	$^4D^\circ$	5/2	*322 192.1*	64		17	$(^3D)\ ^4F^\circ$
		3/2	*322 470.0*	44		37	$(^3D)\ ^2P^\circ$
		7/2	*322 744.4*	50		11	$(^1G2)\ ^2F^\circ$
$3d^6(^3D)4p$		1/2	*322 569.0*	38	$^4D^\circ$	35	$(^3D)\ ^2P^\circ$
$3d^6(^1G2)4p$		5/2	*323 222.4*	33	$^2F^\circ$	16	$(^3G)\ ^2F^\circ$
$3d^6(^1G)4p$	$^2H^\circ$	11/2	*323 506.3*	39		28	$(^1G1)\ ^2H^\circ$
$3d^6(^1I)4p$	$^2I^\circ$	13/2	*324 623.5*	97		3	$(^1I)\ ^2K^\circ$
		11/2	*324 668.3*	78		12	$(^1I)\ ^2H^\circ$

Cu v — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^6(^3D)4p$	$^2D^\circ$	3/2	*324 908.8*	64		13	$(^1D2)\ ^2P^\circ$
		5/2	*325 518.5*	82		3	$(^3D)\ ^2F^\circ$
$3d^6(^1D2)4p$	$^2P^\circ$	3/2	*325 923.4*	28		19	$(^1S2)\ ^2P^\circ$
		1/2	*331 353.6*	42		24	
$3d^6(^3D)4p$	$^2F^\circ$	7/2	*326 477.1*	61		16	$(^1D2)\ ^2F^\circ$
		5/2	*327 268.0*	46		26	
$3d^6(^1S2)4p$	$^2P^\circ$	1/2	*327 379.7*	32		22	$(^1D2)\ ^2P^\circ$
		3/2	*332 946.3*	37		22	
$3d^6(^1D2)4p$	$^2D^\circ$	5/2	*329 339.6*	34		15	$(^1F)\ ^2D^\circ$
		3/2	*329 960.8*	58		11	$(^1D1)\ ^2D^\circ$
$3d^6(^1D2)4p$	$^2F^\circ$	5/2	*330 765.1*	27		20	$(^1D1)\ ^2F^\circ$
		7/2	*331 435.0*	48		2	$(^1D1)\ ^4F^\circ$
$3d^6(^1F)4p$	$^2G^\circ$	7/2	*335 935.2*	87		3	$(^3G)\ ^2G^\circ$
		9/2	*338 059.3*	92		2	$(^1G2)\ ^2G^\circ$
$3d^6(^1F)4p$	$^2D^\circ$	5/2	*338 015.8*	55		18	$(^1D2)\ ^2D^\circ$
		3/2	*339 377.8*	45		18	$(^3F1)\ ^4D^\circ$
$3d^6(^3P1)4p$	$^4D^\circ$	1/2	*339 845.5*	39		36	$(^3F1)\ ^4D^\circ$
$3d^6(^1F)4p$		3/2	*340 482.7*	32	$^2D^\circ$	24	$(^3P1)\ ^4D^\circ$
$3d^6(^3F1)4p$	$^4D^\circ$	5/2	*340 722.8*	42		29	$(^3P1)\ ^4D^\circ$
		7/2	*340 819.5*	52		23	
		1/2	*353 590.0*	46		23	
$3d^6(^1F)4p$	$^2F^\circ$	5/2	*343 301.1*	80		5	$(^1G2)\ ^2F^\circ$
		7/2	*343 337.2*	81		5	
$3d^6(^3F)4p$	$^4G^\circ$	5/2	*347 219.0*	77		16	$(^3F2)\ ^4G^\circ$
		7/2	*347 793.1*	76		17	
		9/2	*348 323.7*	71		17	
		11/2	*349 167.6*	77		19	
$3d^6(^3P1)4p$	$^4S^\circ$	3/2	*349 300.5*	74		23	$(^3P2)\ ^4S^\circ$
$3d^6(^3F)4p$	$^2D^\circ$	3/2	*351 430.8*	49		22	$(^3P1)\ ^2D^\circ$
		5/2	*352 419.2*	44		23	
$3d^6(^3P1)4p$	$^4P^\circ$	1/2	*351 671.9*	48		38	$(^3P2)\ ^4P^\circ$
		3/2	*352 004.5*	50		40	
		5/2	*353 485.7*	31		25	
$3d^6(^3F1)4p$	$^2G^\circ$	9/2	*352 582.3*	63		15	$(^3F2)\ ^2G^\circ$
		7/2	*353 645.9*	64		14	
$3d^6(^3F1)4p$		3/2	*354 039.3*	31	$^4D^\circ$	21	$(^3P1)\ ^4D^\circ$
$3d^6(^3F1)4p$		5/2	*354 548.0*	22	$^4F^\circ$	17	$(^3P1)\ ^4P^\circ$
$3d^6(^3F1)4p$	$^4F^\circ$	3/2	*354 796.7*	52		17	$(^3F2)\ ^4F^\circ$
		9/2	*355 875.0*	64		24	

Cu v — Continued

Configuration	Term	*J*	Level (cm^{-1})	Leading percentages			
$3d^6(^3F1)4p$		7/2	*354 905.2*	36	$^4F°$	16	$(^3P1)\ ^4D°$
$3d^6(^3F1)4p$		5/2	*355 606.0*	39	$^4F°$	13	$(^3P1)\ ^4D°$
$3d^6(^3F1)4p$		7/2	*356 372.1*	26	$^4F°$	22	$(^3P1)\ ^4D°$
$3d^6(^3F1)4p$	$^2D°$	3/2	*356 661.9*	26		21	$(^3P1)\ ^2D°$
$3d^6(^3P1)4p$	$^2P°$	1/2	*357 881.0*	54		34	$(^3P2)\ ^2P°$
		3/2	*359 141.2*	44		29	
$3d^6(^3P1)4p$	$^2D°$	5/2	*357 948.3*	34		25	$(^3F1)\ ^2D°$
$3d^6(^3F1)4p$	$^2F°$	7/2	*358 724.8*	47		20	$(^3F2)\ ^2F°$
		5/2	*359 491.9*	64		24	
$3d^6(^1G1)4p$	$^2H°$	9/2	*360 058.2*	58		33	$(^1G2)\ ^2H°$
		11/2	*362 144.7*	62		35	
$3d^6(^1G1)4p$		7/2	*362 142.8*	27	$^2G°$	23	$(^1G1)\ ^2F°$
$3d^6(^1G1)4p$	$^2F°$	5/2	*363 396.8*	53		24	$(^1G2)\ ^2F°$
$3d^6(^1G1)4p$	$^2G°$	9/2	*364 606.6*	63		26	$(^1G2)\ ^2G°$
		7/2	*365 071.1*	39		16	
$3d^6(^1D1)4p$	$^2D°$	3/2	*386 004.2*	79		17	$(^1D2)\ ^2D°$
		5/2	*386 705.0*	78		17	
$3d^6(^1D1)4p$	$^2F°$	5/2	*392 652.5*	69		21	$(^1D2)\ ^2F°$
		7/2	*394 391.0*	73		22	
$3d^6(^1D1)4p$	$^2P°$	3/2	*394 248.5*	65		24	$(^1D2)\ ^2P°$
		1/2	*394 912.4*	65		25	
Cu vi ($^5D_4$)	*Limit*		644 000				

Cu VI

$Z=29$

Cr I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6\ ^5D_4$

Ionization energy 831 000 ± 8000 cm^{-1} (103 ± 1 eV)

The initial line identifications in this spectrum were the $3d^6\ ^5D - 3d^5(^6S)4p\ ^5P^\circ$ multiplet found by Poppe *et al.* [1974]. A considerable extension was made by Raassen and van Kleef [1981] using new exposures of a sliding spark discharge. They reported an analysis of the $3d^6 - 3d^5 4p$ array that produced all levels of $3d^6$, except for the highest $^1S_0$, and 208 of the 214 levels of $3d^5 4p$. They also analyzed the $3d^5 4s - 3d^5 4p$ array and found 13 of the 74 levels of $3d^5 4s$. The level accuracy is estimated to be $\pm 1.5\ cm^{-1}$. The percentage compositions for all the levels were calculated by these authors without taking into account configuration interaction between $3d^6$ and $3d^5 4s$.

The value for the ionization energy was derived by Lotz [1967] by extrapolation.

References

Lotz, W. [1967], J. Opt. Soc. Am. 57, 873.

Poppe, R., van Kleef, T. A. M., and Raassen, A. J. J. [1974], Physica (Utrecht) 77, 165.

Raassen, A. J. J., and van Kleef, T. A. M. [1981], Physica (Utrecht) 103C, 412.

Cu VI

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^6$	^5D	4	0.0	100		
		3	1 195.8	100		
		2	1 986.8	100		
		1	2 489.6	99		
		0	2 733.4	99		
$3d^6$	$^3P2$	2	29 285.0	62	37	$^3P1$
		1	32 684.9	63	36	
		0	33 867.8	62	35	
$3d^6$	^3H	6	30 417.6	99	1	^1I
		5	31 009.2	96	4	^3G
		4	31 287.6	81	8	$^3F2$
$3d^6$	$^3F2$	4	32 756.0	63	18	$^3F1$
		3	33 295.8	74	20	
		2	33 739.6	80	19	
$3d^6$	^3G	5	37 378.1	96	4	^3H
		4	38 468.9	91	5	$^3F2$
		3	38 907.4	94	5	$^3F2$
$3d^6$	^1I	6	46 405.8	99	1	^3H
$3d^6$	^3D	2	46 714.2	96	2	$^1D2$
		1	46 848.3	100		
		3	47 119.1	99		
$3d^6$	$^1G2$	4	47 611.6	65	32	$^1G1$
$3d^6$	$^1S2$	0	53 786.6	75	22	$^1S1$
$3d^6$	$^1D2$	2	54 747.1	75	21	$^1D1$
$3d^6$	^1F	3	64 967.6	98	1	$^3F1$

Cu VI — Continued

Configuration	Term	*J*	Level (cm^{-1})	Leading percentages			
$3d^6$	^{3}P1	0	74 712.0	64		35	^{3}P2
		1	75 774.1	63		37	
		2	77 908.8	62		38	
$3d^6$	^{3}F1	2	77 145.0	80		19	^{3}F2
		4	77 223.8	77		22	
		3	77 467.9	78		20	
$3d^6$	^{1}G1	4	87 505.9	66		33	^{3}G
$3d^6$	^{1}D1	2	117 084.3	78		22	^{1}D2
$3d^5(^6S)4s$	^{7}S	3	250 876.6	100			
$3d^5(^6S)4s$	^{5}S	2	265 639.1	100			
$3d^5(^4G)4s$	^{5}G	6	299 143.0	100			
		2	299 250.6	99			
		5	299 256.0	100			
		3	299 282.1	99			
		4	299 292.9	100			
$3d^5(^4G)4s$	^{3}G	5	308 997.5	100			
		3	309 046.1	84		14	$(^4D)\ ^5D$
		4	309 110.8	98			
$3d^5(^2I)4s$	^{3}I	5	322 791.9	98			
		6	322 804.7	99			
		7	322 877.3	100			
$3d^5(^6S)4p$	^{7}P°	2	*342 225.2*	98			
		3	*343 276.6*	97			
		4	*345 137.1*	100			
$3d^5(^6S)4p$	^{5}P°	3	*355 259.2*	95			
		2	*356 137.2*	96			
		1	*356 674.0*	97			
$3d^5(^4G)4p$	^{5}G°	2	*388 191.7*	89		5	^{3}F°
		3	*388 236.1*	80		12	^{5}H°
		4	*388 312.3*	76		12	^{5}H°
		5	*388 442.1*	76		17	^{5}H°
		6	*388 707.5*	80		14	^{5}H°
$3d^5(^4G)4p$	^{5}H	3	*390 618.2*	84		10	^{5}G°
		4	*391 198.1*	75		13	^{5}G°
		5	*391 691.7*	54		33	^{5}F°
		6	*392 593.6*	82		16	^{5}G°
		7	*393 090.2*	100			
$3d^5(^4P)4p$	^{5}D°	2	*391 986.5*	46		17	$(^4D)\ ^5D°$
		4	*395 407.1*	58		20	
$3d^5(^4G)4p$		3	*392 255.1*	29	^{5}F°	28	$(^4P)\ ^5D°$
$3d^5(^4G)4p$	^{5}F°	5	*392 516.7*	51		26	^{5}H°
		4	*392 712.6*	62		11	$(^4D)\ ^5F°$
		1	*394 014.7*	68		14	$(^6D)\ ^5F°$
		3	*394 117.4*	46		23	$(^4P)\ ^5D°$

Cu VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^5(^4P)4p$	$^5S^\circ$	2	*393 425.4*	45		25	$(^4G)\ ^5F^\circ$
$3d^5(^4G)4p$		2	*394 133.8*	37	$^5F^\circ$	29	$(^4P)\ ^5S^\circ$
$3d^5(^4P)4p$	$^5P^\circ$	3	*395 601.0*	37		33	$(^4D)\ ^5P^\circ$
		2	*396 454.5*	54		28	
		1	*396 523.6*	68		13	
$3d^5(^4G)4p$	$^3F^\circ$	2	*396 283.7*	80		5	$(^4G)\ ^5G^\circ$
		3	*396 617.1*	79			
		4	*396 929.1*	86		5	$(^4F)\ ^3F^\circ$
$3d^5(^4G)4p$	$^3H^\circ$	6	*397 404.4*	91			
		5	*398 022.8*	93			
		4	*398 376.6*	94			
$3d^5(^4P)4p$	$^3P^\circ$	2	*398 273.1*	43		17	$(^4D)\ ^3P^\circ$
		1	*398 722.7*	37		15	
		0	*399 329.0*	59		20	
$3d^5(^4D)4p$	$^5F^\circ$	1	*399 112.8*	58		18	$(^4G)\ ^5F^\circ$
		2	*399 434.6*	70		17	$(^4G)\ ^5F^\circ$
		3	*399 881.3*	72		11	$(^4G)\ ^5F^\circ$
		4	*400 562.7*	73		9	$(^4P)\ ^5D$
		5	*401 264.1*	90		6	$(^4G)\ ^5F^\circ$
$3d^5(^4D)4p$	$^5D^\circ$	3	*402 134.1*	50		20	$(^4P)\ ^5D^\circ$
		4	*402 534.3*	66		22	
		2	*402 766.8*	52		18	
		1	*403 358.0*	47		17	
		0	*404 184.0*	58		21	$(^4P)\ ^5D^\circ$
$3d^5(^4G)4p$	$^3G^\circ$	3	*402 988.8*	88			
		4	*403 086.6*	89			
		5	*403 132.9*	91			
$3d^5(^4P)4p$	$^3D^\circ$	3	*403 366.0*	58		15	$(^4D)\ ^5P^\circ$
		2	*403 961.1*	51		19	
$3d^5(^4D)4p$	$^5P^\circ$	1	*404 096.2*	46		26	$(^4P)\ ^3D^\circ$
		2	*405 505.8*	33		18	$(^4P)\ ^5P^\circ$
$3d^5(^4P)4p$		1	*404 901.7*	30	$^3D^\circ$	22	$(^4D)\ ^5P^\circ$
$3d^5(^4D)4p$	$^3D^\circ$	3	*405 213.5*	47		14	$(^4D^\circ)\ ^5D^\circ$
		2	*406 659.4*	69		8	$(^4F)\ ^3D^\circ$
		1	*407 217.4*	54		26	$(^4P)\ ^3D^\circ$
$3d^5(^4D)4p$		3	*406 752.6*	33	$^5P^\circ$	29	$(^4D)\ ^3D^\circ$
$3d^5(^4D)4p$	$^3F^\circ$	4	*407 355.9*	80		6	$(^2G2)\ ^3F^\circ$
		3	*408 177.6*	69		11	$(^4P)\ ^3D^\circ$
		2	*408 281.7*	75		10	$(^4P)\ ^3D^\circ$
$3d^5(^4P)4p$	$^3S^\circ$	1	*410 288.7*	88			
$3d^5(^2I)4p$	$^3K^\circ$	6	*411 872.1*	66		27	$(^2I)\ ^3I^\circ$
		7	*412 439.9*	54		35	$(^2I)\ ^3I^\circ$
		8	*415 520.0*	100			

Cu VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^5(^2I)4p$	$^3I°$	5	412 326.4	58		22	$(^2I)\ ^1H°$
		6	414 203.7	42		27	$(^2I)\ ^3H°$
		7	415 694.4	60		39	$(^2I)\ ^3K°$
$3d^5(^4D)4p$	$^3P°$	0	412 469.3	71		23	$(^4P)\ ^3P°$
		1	413 072.5	63		21	
		2	413 692.0	46		23	
$3d^5(^2F1)4p$	$^3F°$	2	414 298.5	24		19	$(^2D3)\ ^3F°$
$3d^5(^2D3)4p$	$^3F°$	3	415 258.3	33		21	$(^2F2)\ ^3F°$
		4	417 511.5	34		24	$(^2F1)\ ^3F°$
$3d^5(^2D3)4p$		2	415 851.8	28	$^3F°$	21	$(^2D3)\ ^1D°$
$3d^5(^2I)4p$	$^1H°$	5	416 024.9	45		34	$(^2I)\ ^3I°$
$3d^5(^2I)4p$	$^3H°$	6	416 410.9	62		25	$(^2I)\ ^3I°$
		4	417 099.5	69		7	$(^2G2)\ ^3H°$
		5	417 221.3	74		14	$(^2I)\ ^1H°$
$3d^5(^2I)4p$	$^1K°$	7	417 267.3	89		6	$(^2I)\ ^3K°$
$3d^5(^2I)4p$		4	419 364.9	39	$^1G°$	11	$(^2I)\ ^3H°$
$3d^5(^2D3)4p$		2	419 365.2	36	$^3P°$	15	$(^2F1)\ ^3D°$
$3d^5(^2D3)4p$		1	419 605.8	30	$^3D°$	27	$(^2D3)\ ^3P°$
$3d^5(^2F1)4p$		3	419 864.2	25	$^3F°$	24	$(^2F1)\ ^3G°$
$3d^5(^4F)4p$	$^5G°$	2	420 151.2	78		8	$(^2F1)\ ^3F°$
		3	420 355.8	47		21	$(^2F1)\ ^3D°$
		4	420 699.4	62		7	$(^4F)\ ^5F°$
		5	420 914.7	52		10	$(^4F)\ ^5F°$
		6	422 269.8	45		31	$(^2I)\ ^1I°$
$3d^5(^4F)4p$		3	420 201.1	22	$^5G°$	21	$(^2F)\ ^3D°$
$3d^5(^2D3)4p$	$^3P°$	0	421 423.5	63		19	$(^2D1)\ ^3P°$
$3d^5(^2D3)4p$	$^3D°$	2	421 467.7	41		16	$(^4F)\ ^5F°$
$3d^5(^2D3)4p$		1	421 516.1	28	$^3P°$	24	$(^2D3)\ ^3D°$
$3d^5(^2D3)4p$		3	421 622.9	28	$^3D°$	12	$(^2D3)\ ^3F°$
$3d^5(^4F)4p$		4	421 924.7	30	$^5F°$	27	$(^4F)\ ^5D°$
$3d^5(^4F)4p$	$^5F°$	3	422 221.2	56		26	$(^4F)\ ^5D°$
		1	423 078.0	70		11	$(^4F)\ ^5D°$
		5	423 123.7	40		24	$(^2F1)\ ^3G°$
$3d^5(^2F1)4p$		4	422 425.6	31	$^3F°$	29	$(^2F1)\ ^3G°$
$3d^5(^4F)4p$		2	422 613.1	37	$^5F°$	26	$(^4F)\ ^5D°$
$3d^5(^2F1)4p$	$^3G°$	5	422 833.7	57		26	$(^4F)\ ^5G°$

Cu VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^5(^2G2)4p$	$^3H^\circ$	4	*422 841.4*	30		28	$(^2H)\ ^3H^\circ$
		5	*423 618.3*	30		25	
		6	*434 722.8*	43		35	
$3d^5(^2I)4p$	$^1I^\circ$	6	*422 858.7*	49		44	$(^4F)\ ^5G^\circ$
$3d^5(^2F1)4p$	$^3D^\circ$	1	*423 304.7*	46		20	$(^2D3)\ ^1P^\circ$
$3d^5(^2F1)4p$		2	*423 374.7*	31	$^3D^\circ$	18	$(^2F1)\ ^3F^\circ$
$3d^5(^2F1)4p$		3	*423 403.4*	19	$^3G^\circ$	19	$(^2D3)\ ^3F^\circ$
$3d^5(^2D3)4p$		4	*424 332.5*	21	$^3F^\circ$	20	$(^2F1)\ ^3G^\circ$
$3d^5(^2H)4p$		3	*424 482.8*	20	$^3G^\circ$	14	$(^2F2)\ ^3G^\circ$
$3d^5(^2F1)4p$		2	*424 511.8*	25	$^3F^\circ$	17	$(^2F1)\ ^3D^\circ$
$3d^5(^2H)4p$	$^3G^\circ$	5	*424 590.4*	44		12	$(^2G2)\ ^3G^\circ$
		4	*424 697.7*	38		14	$(^2G2)\ ^3G^\circ$
$3d^5(^4F)4p$	$^5D^\circ$	4	*425 101.8*	43		30	$(^4F)\ ^5F^\circ$
		0	*425 954.6*	85		9	$(^2D3)\ ^3P^\circ$
		1	*426 008.4*	72		10	$(^4F)\ ^5F^\circ$
		2	*426 112.6*	59		15	$(^4F)\ ^5F^\circ$
$3d^5(^2H)4p$	$^3H^\circ$	6	*425 544.3*	34		29	$(^2G2)\ ^3H^\circ$
		4	*432 939.3*	40		31	
$3d^5(^4F)4p$		3	*425 599.1*	19	$^5D^\circ$	14	$(^2H)\ ^3G^\circ$
$3d^5(^4F)4p$		3	*425 877.0*	38	$^5D^\circ$	13	$(^4F)\ ^5F^\circ$
$3d^5(^2H)4p$	$^3I^\circ$	5	*427 330.6*	81		8	$(^2H)\ ^3H^\circ$
		6	*428 430.6*	71		11	$(^2H)\ ^1I^\circ$
		7	*429 749.9*	95			
$3d^5(^2G2)4p$		4	*427 367.3*	19	$^1G^\circ$	17	$(^2F1)\ ^1G^\circ$
$3d^5(^2G2)4p$	$^3G^\circ$	3	*427 940.9*	27		22	$(^4F)\ ^3G^\circ$
$3d^5(^2D3)4p$	$^1P^\circ$	1	*428 048.7*	40		24	$(^2F1)\ ^3D^\circ$
$3d^5(^4F)4p$	$^3G^\circ$	5	*428 386.0*	64		11	$(^2G2)\ ^3G^\circ$
		4	*428 672.9*	56		13	$(^2G2)\ ^3G^\circ$
$3d^5(^2F2)4p$	$^1D^\circ$	2	*428 503.5*	44		27	$(^2D3)\ ^1D^\circ$
$3d^5(^2G2)4p$	$^3F^\circ$	3	*429 135.6*	42		27	$(^4F)\ ^3G^\circ$
		4	*429 577.5*	46		17	$(^2G2)\ ^1G^\circ$
		2	*429 657.4*	51		8	$(^4F)\ ^3F^\circ$
$3d^5(^2F1)4p$	$^1F^\circ$	3	*429 873.4*	59		7	$(^2G2)\ ^3F^\circ$
$3d^5(^2H)4p$	$^1I^\circ$	6	*431 218.3*	70		12	$(^2H)\ ^3H^\circ$
$3d^5(^4F)4p$	$^3D^\circ$	2	*431 231.7*	43		17	$(^2F2)\ ^1D^\circ$
		3	*431 530.7*	39		14	$(^2F2)\ ^3F^\circ$
		1	*432 272.4*	77		8	$(^4D)\ ^3D^\circ$

Cu VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3d^5(^4F)4p$	$^3F^\circ$	4	431 766.6	53		30	$(^2F2)\ ^3F^\circ$
		3	432 839.7	53		18	$(^4F)\ ^3D^\circ$
		2	433 257.9	45		22	$(^4F)\ ^3D^\circ$
$3d^5(^2G2)4p$		5	432 840.8	34	$^3H^\circ$	24	$(^2G2)\ ^3G^\circ$
$3d^5(^3F2)4p$	$^3G^\circ$	5	434 063.7	20		21	$(^2F2)\ ^3G^\circ$
		3	434 264.0	28		26	$(^2G2)\ ^3G^\circ$
		4	434 286.4	27		16	$(^2G2)\ ^3G^\circ$
$3d^5(^2F2)4p$	$^1G^\circ$	4	434 812.2	28		11	$(^2H)\ ^1G^\circ$
$3d^5(^2F2)4p$	$^3F^\circ$	3	435 369.7	39		15	$(^4F)\ ^3F^\circ$
		4	436 506.5	41		16	$(^4F)\ ^3F^\circ$
$3d^5(^4F)4p$		2	435 379.2	31	$^3F^\circ$	20	$(^2G2)\ ^3F^\circ$
$3d^5(^2G2)4p$	$^1H^\circ$	5	435 676.7	46		30	$(^2H)\ ^1H^\circ$
$3d^5(^2G2)4p$	$^1F^\circ$	3	436 243.7	53		7	$(^2G2)\ ^3F^\circ$
$3d^5(^2F2)4p$	$^1D^\circ$	2	436 475.9	55		27	$(^2F2)\ ^3F^\circ$
$3d^5(^2H)4p$	$^1H^\circ$	5	437 233.9	58		32	$(^2G2)\ ^1H^\circ$
$3d^5(^2S)4p$	$^3P^\circ$	1	438 607.7	42		32	$(^2F2)\ ^3D^\circ$
		2	441 375.8	70		16	$(^2D2)\ ^3P^\circ$
$3d^5(^2F2)4p$		3	439 180.1	37	$^3D^\circ$	18	$(^2H)\ ^3G^\circ$
$3d^5(^2F2)4p$	$^3D^\circ$	2	439 327.1	66		12	$(^2F1)\ ^3D^\circ$
		1	439 775.0	44		36	$(^2S)\ ^3P^\circ$
$3d^5(^2H)4p$	$^3G^\circ$	3	439 706.8	29		23	$(^2F2)\ ^3G^\circ$
$3d^5(^2F2)4p$	$^3G^\circ$	4	440 372.2	44		38	$(^2H)\ ^3G^\circ$
		5	440 896.3	56		31	
$3d^5(^2H)4p$	$^1G^\circ$	4	443 432.9	39		36	$(^2F2)\ ^1G^\circ$
$3d^5(^2S)4p$	$^1P^\circ$	1	444 432.7	67		19	$(^2D2)\ ^1P^\circ$
$3d^5(^2F2)4p$	$^1F^\circ$	3	445 290.5	85			
$3d^5(^2D2)4p$	$^3F^\circ$	2	453 663.5	65		22	$(^2D2)\ ^3D^\circ$
		3	454 176.3	47		27	$(^2D2)\ ^3D^\circ$
		4	456 545.2	91		6	$(^2G2)\ ^3F^\circ$
$3d^5(^2D2)4p$	$^3D^\circ$	1	454 317.5	87			
		2	454 921.2	62		21	$(^2D2)\ ^3F^\circ$
		3	456 264.2	59		33	$(^2D2)\ ^3F^\circ$
$3d^5(^2D2)4p$	$^1F^\circ$	3	457 544.9	68		13	$(^2G1)\ ^1F^\circ$
$3d^5(^2D2)4p$	$^3P^\circ$	0	458 688.9	84		14	$(^2S)\ ^3P^\circ$
		2	458 731.8	67		17	
		1	458 778.9	73		15	
$3d^5(^2D2)4p$	$^1P^\circ$	1	460 536.5	70		17	$(^2S)\ ^1P^\circ$

Cu VI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3d^5(^2D2)4p$	$^1D°$	2	*461 609.3*	84	5	(^{2}F2) ^{1}D°
$3d^5(^2G1)4p$	$^3F°$	4	*464 741.7*	54	20	(^{2}G1) ^{3}H°
		3	*465 803.6*	52	38	(^{2}G1) ^{3}G°
		2	*467 531.5*	89	6	(^{2}D1) ^{3}F°
$3d^5(^2G1)4p$	$^3H°$	4	*465 130.4*	64	25	(^{2}G1) ^{3}F°
		5	*465 460.0*	71	18	(^{2}G1) ^{3}G°
		6	*467 599.8*	98		
$3d^5(^2G1)4p$	$^3G°$	3	*467 819.2*	56	38	(^{2}G1) ^{3}F°
		4	*468 335.2*	78	10	(^{2}G1) ^{3}H°
		5	*468 738.6*	74	22	(^{2}G1) ^{3}H°
$3d^5(^2G1)4p$	$^1H°$	5	*471 595.2*	88	5	(^{2}G1) ^{3}G°
$3d^5(^2G1)4p$	$^1G°$	4	*471 769.3*	91		
$3d^5(^2G1)4p$	$^1F°$	3	*473 212.1*	75	11	(^{2}D2) ^{1}F°
$3d^5(^2P)4p$	$^3P°$	0	*481 411.7*	75	20	(^{2}D1) ^{3}P°
		1	*481 793.2*	72	21	
		2	*483 006.9*	71	23	
$3d^5(^2P)4p$	$^3D°$	2	*488 810.3*	55	28	(^{2}P) ^{1}D°
		1	*488 869.4*	88	5	(^{2}D1) ^{3}D°
		3	*491 155.1*	88	8	(^{2}D1) ^{3}D°
$3d^5(^2P)4p$	$^1D°$	2	*491 878.9*	46	34	(^{2}P) ^{3}D°
$3d^5(^2P)4p$	$^3S°$	1	*493 316.5*	85	10	(^{2}P) ^{1}P°
$3d^5(^2P)4p$	$^1P°$	1	*495 292.7*	63	16	(^{2}D1) ^{1}P°
$3d^5(^2D1)4p$	$^3F°$	2	*502 689.0*	60	19	(^{2}D3) ^{3}F°
		3	*503 114.1*	57	18	
		4	*505 107.8*	72	22	
$3d^5(^2D1)4p$	$^3D°$	1	*504 630.2*	70	21	(^{2}D3) ^{3}D°
		3	*507 108.1*	58	17	
$3d^5(^2D1)4p$	$^1D°$	2	*507 132.9*	39	16	(^{2}P) ^{1}D°
$3d^5(^2D1)4p$	$^3P°$	2	*509 325.1*	41	20	(^{2}P) ^{3}P°
		1	*510 178.2*	55	24	
		0	*510 942.6*	55	24	
$3d^5(^2D1)4p$	$^1F°$	3	*509 967.2*	68	21	(^{2}D3) ^{1}F°
Cu VII ($^6S_{5/2}$)	***Limit***		**831 000**			

Cu VII

$Z=29$

V I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5\ ^6S_{5/2}$

Ionization energy 1 120 000 ± 8000 cm^{-1} (139 ± 1 eV)

The $3d^5\ ^6S - 3d^4 4p\ ^6P°$ multiplet was identified in the spectrum of a spark discharge by Kruger and Gilroy [1935].

The value for the ionization energy was obtained by Lotz [1967] by extrapolation.

References

Kruger, P. G., and Gilroy, H. T. [1935], Phys. Rev. **48**, 720.
Lotz, W. [1967], J. Opt. Soc. Am. **57**, 873.
van het Hof, G. J., Raassen, A. J. J., Uylings, P. H. M., Joshi, Y. N., Podobedova, L. I., and Ryabtsev, A. N. [1990], Phys. Scr. **41**, 240.

Note added in proof:

A new analysis of this spectrum by van het Hof et al. [1990] appeared too late for inclusion in the present compilation. They determined all 37 levels of the $3d^5$ ground configuration and 129 of the 180 possible levels of the $3d^4 4p$ configuration.

Cu VII

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3d^5$	^6S	5/2	0	
$3d^4(^5D)4p$	$^6P°$	3/2	*497 641*	
		5/2	*497 881*	
		7/2	*498 343*	
Cu VIII ($^5D_0$)	*Limit*		1 120 000	

Cu VIII

$Z = 29$

Ti I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4\ {}^5D_0$

Ionization energy $1\,340\,000 \pm 16\,000\ cm^{-1}$ $(166 \pm 2\ eV)$

No classified lines have been reported for this spectrum.

The value for the ionization energy was obtained by Lotz [1967] by extrapolation.

Reference

Lotz, W. [1967], J. Opt. Soc. Am. 57, 873.

Cu IX

$Z = 29$

Sc I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3\ {}^4F_{3/2}$

Ionization energy $1\,605\,000 \pm 16\,000\ cm^{-1}$ $(199 \pm 2\ eV)$

No classified lines have been given for this spectrum.

The value for the ionization energy was obtained by Lotz [1967] by extrapolation.

Reference

Lotz, W. [1967], J. Opt. Soc. Am. 57, 873.

Cu X

$Z = 29$

Ca I isoelectronic sequence

Ground state $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2\ ^3F_2$

Ionization energy 1 870 000 ± 16 000 cm^{-1} (232 ± 2 eV)

Alexander *et al.* [1966] reported the transition array $3d^2 - 3d4f$. New observations by Even-Zohar and Fraenkel [1968] led to additional classified lines and improved wavelengths with an accuracy of ±0.005 Å in the range of 86–88 Å.

Fawcett *et al.* [1980] provided measurements and classifications of the $3p^6 3d^2 - 3p^5 3d^3$ array in the range of 132–154 Å with an uncertainty of ±0.007 Å. Two lines classified as transitions to the unknown term $3d^2\ ^1G$ could not be used here.

We estimated the position of the $3d^2\ ^1D_2$ level by extrapolation with an uncertainty of ±200 cm^{-1}. All levels followed by "$+x$" are dependent on the $^1D_2$ level value.

The value for the ionization energy was obtained by Lotz [1967] by extrapolation.

References

Alexander, E., Feldman, U., Fraenkel, B. S., and Hoory, S. [1966], J. Opt. Soc. Am. **56**, 651.

Even-Zohar, M., and Fraenkel, B. S. [1968], J. Opt. Soc. Am. **58**, 1420.

Fawcett, B. C., Ridgeley, A., and Ekberg, J. O. [1980], Phys. Scr. **21**, 155.

Lotz, W. [1967], J. Opt. Soc. Am. **57**, 873.

Cu X

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3p^6(^1S)3d^2$	^3F	2	0	
		3	2 486	
		4	5 487	
$3p^6(^1S)3d^2$	^1D	2	23 900+x	
$3p^6(^1S)3d^2$	^3P	2	30 600+x	
$3p^5(^2P^\circ)3d^3(^2H)$	$^3G^\circ$	3	*646 870*	
		4	*650 310*	
		5	*655 820*	
$3p^5(^2P^\circ)3d^3(^4F)$	$^3F^\circ$	2	*713 920*	
		3	*717 450*	
		4	*720 940*	
$3p^5(^2P^\circ)3d^3(^4F)$	$^3D^\circ$	1	*756 200*	
		3	*757 170*	
		2	*757 330*	
$3p^6(^1S)3d4f$	$^3F^\circ$	2	*1 152 390*	
		3	*1 153 140*	
		4	*1 154 670*	

Cu X — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3p^6(^1S)3d4f$	$^3G°$	3	*1 160 630*	
		4	*1 162 520*	
		5	*1 163 750*	
$3p^6(^1S)3d4f$	$^1D°$	2	*1 161 140+x*	
$3p^6(^1S)3d4f$	$^1F°$	3	*1 164 110+x*	
$3p^6(^1S)3d4f$	$^3D°$	3	*1 166 550+x*	
Cu XI ($^2D_{3/2}$)	***Limit***		**1 870 000**	

Cu XI

$Z=29$

K I isoelectronic sequence

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

Ionization energy 2 140 000 ± 2000 cm^{-1} (265.3 ± 0.2 eV)

Alexander *et al.* [1965] identified the resonance doublet $3p^63d\ ^2D-3p^64f$ at 78 Å. This was remeasured and the series extended by Even-Zohar and Fraenkel [1968] with a measurement uncertainty of ±0.01 Å.

The transition array $3p^63d-3p^53d^2$ was first analyzed by Goldsmith and Fraenkel [1970] from spectra obtained with a triggered spark source. Their estimated wavelength uncertainty of ±0.005 Å was found to be an order of magnitude too small by Ramonas and Ryabtsev [1980] who remeasured the spectrum in the range of 108–184 Å with a reported uncertainty of ±0.003 Å. Their improved analysis of this array and newly discovered $4p\ ^2P^\circ$ levels are quoted here.

Levels of the $3p^53d4s$ configuration were found by Hoory *et al.* [1970]. They identified the transitions to the ground ^2D term in the range of 72–76 Å, which they measured with an uncertainty of ±0.005 Å.

We derived the value for the ionization energy from the three-member *nf* series.

References

Alexander, E., Feldman, U., and Fraenkel, B. S. [1965], J. Opt. Soc. Am. **55**, 650.

Even-Zohar, M., and Fraenkel, B. S. [1968], J. Opt. Soc. Am. **58**, 1420.

Goldsmith, S., and Fraenkel, B. S. [1970], Astrophys. J. **161**, 317.

Hoory, S., Goldsmith, S., and Fraenkel, B. S. [1970], Astrophys. J. **160**, 781.

Ramonas, A. A., and Ryabtsev, A. N. [1980], Opt. Spectrosc. (USSR) **48**, 348.

Cu XI

Configuration	Term	*J*	Level (cm^{-1})	Leading percentages
$3p^63d$	^2D	3/2	0	
		5/2	4 060	
$3p^5(^2P^\circ)3d^2(^1G)$	$^2F^\circ$	7/2	*546 595*	
$3p^5(^2P^\circ)3d^2(^1D)$	$^2F^\circ$	7/2	*559 612*	
		5/2	*581 818*	
$3p^5(^2P^\circ)3d^2(^3F)$	$^2F^\circ$	5/2	*669 098*	
		7/2	*680 916*	
$3p^5(^2P^\circ)3d^2(^3P)$	$^2P^\circ$	1/2	*732 213*	
		3/2	*739 173*	
$3p^5(^2P^\circ)3d^2(^3F)$	$^2D^\circ$	5/2	*740 798*	
		3/2	*741 219*	
$3p^64p$	$^2P^\circ$	1/2	*918 459*	
		3/2	*925 897*	
$3p^64f$	$^2F^\circ$	5/2	*1 273 200*	
		7/2	*1 273 300*	
$3p^53d(^3P^\circ)4s$	$^2P^\circ$	3/2	*1 315 420*	

Cu XI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3p^5 3d(^3F^\circ)4s$	$^4F^\circ$	7/2	*1 322 170*	
		5/2	*1 324 990*	
$3p^5 3d(^3F^\circ)4s$	$^2F^\circ$	7/2	*1 331 640*	
		5/2	*1 339 930*	
$3p^5 3d(^3D^\circ)4s$	$^4D^\circ$	7/2	*1 355 740*	
		5/2	*1 360 260*	
$3p^5 3d(^1F^\circ)4s$	$^2F^\circ$	7/2	*1 374 750*	
$3p^5 3d(^3D^\circ)4s$	$^2D^\circ$	3/2	*1 377 810*	
		5/2	*1 381 830*	
$3p^6 5f$	$^2F^\circ$	5/2	*1 586 300*	
		7/2	*1 586 400*	
$3p^6 6f$	$^2F^\circ$	5/2	*1 757 000*	
		7/2	*1 757 000*	
Cu XII ($^1S_0$)	*Limit*		2 140 000	

Cu XII

$Z=29$

Ar I isoelectronic sequence

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

Ionization energy 2 975 000 ± 30 000 cm^{-1} (369 ± 4 eV)

Goldsmith and Fraenkel [1970] reported the $3p^6\ ^1S-3p^53d\ ^1P°$ resonance line at 139.180±0.005 Å from a spark discharge. It was later observed in a tokamak plasma by Sugar, Kaufman, and Rowan [1987] who gave the value 139.174±0.005 Å and reported an interpolated value for the $3p^6\ ^1S-3p^53d\ ^3D_1^\circ$ line of 174.739±0.010 Å. The results of Sugar *et al.* are quoted, including their calculation of the percentage compositions.

Even-Zohar and Fraenkel [1968] added the $3p^6\ ^1S_0-3p^54s$ and $4d$ resonance lines with an uncertainty of ±0.01 Å.

Swartz *et al.* [1975] give the transition array $3p^53d-3p^54f$, but these lines are not connected to the known lower levels.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

References

Even-Zohar, M., and Fraenkel, B. S. [1968], J. Opt. Soc. Am. **58**, 1420.
Goldsmith, S., and Fraenkel, B. S. [1970], Astrophys. J. **161**, 317.
Lotz, W. [1967], J. Opt. Soc. Am. **57**, 873.
Swartz, M., Kastner, S. O., Goldsmith, L., and Neupert, W. M. [1976], J. Opt. Soc. Am. **66**, 240.
Sugar, J., Kaufman, V., and Rowan, W. L. [1987], J. Opt. Soc. Am. B **4**, 1927.

Cu XII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3p^6$	^1S	0	0			
$3p^53d$	$^3D°$	1	*572 280*	98	2	$^3P°$
$3p^53d$	$^1P°$	1	*718 520*	100		
$3p^5(^2P^\circ_{3/2})4s_{1/2}$	$(^3/_2,^1/_2)°$	1	*1 446 600*		or	$^3P°$
$3p^5(^2P^\circ_{1/2})4s_{1/2}$	$(^1/_2,^1/_2)°$	1	*1 473 100*		or	$^1P°$
$3p^5(^2P^\circ_{3/2})4d_{5/2}$	$(^3/_2,^5/_2)°$	1	*1 775 200*		or	$^3D°$
$3p^5(^2P^\circ_{1/2})4d_{3/2}$	$(^1/_2,^3/_2)°$	1	*1 802 900*		or	$^1P°$
Cu XIII ($^2P^\circ_{3/2}$)	***Limit***		***2 975 000***			

Cu XIII

$Z=29$

Cl I isoelectronic sequence

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

Ionization energy 3 234 000 ± 30 000 cm^{-1} (401 ± 4 eV)

The magnetic dipole (M1) transition between the levels of the $^2P^\circ$ ground term was observed in a tokamak plasma by Hinnov *et al.* [1982] at 3500.4±0.3 Å.

Sugar and Kaufman [1986] reported several lines of the $3p^5-3p^43d$ array observed in a laser-generated plasma. Following a study of the Cl I isoelectronic sequence, Kaufman, Sugar, and Rowan [1988] revised the analysis and gave the levels reported here. In a later revision by Kaufman and Sugar [1989] the level $3s^23p^4(^3P)3d\ ^2P_{1/2}$ was removed and an interpolated value was given. The ground term splitting is obtained from the M1 transition with an uncertainty of ±2 cm^{-1}. All the other levels have an uncertainty of 50 cm^{-1}.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

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Cu XIII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^5$	$^2P^\circ$	3/2	*0*	100		
		1/2	*28 560*	100		
$3s^23p^4(^1D)3d$	^2S	1/2	663 840	51	38	$(^3P)\ ^2P$
$3s^23p^4(^3P)3d$	^2P	3/2	690 990	53	21	$(^1D)\ ^2P$
		1/2	[701 500]			
$3s^23p^4(^3P)3d$	^2D	5/2	699 480	68	24	$(^1D)\ ^2D$
		3/2	724 240	61	16	
Cu XIV ($^3P_2$)	*Limit*		3 234 000			

Cu XIV

$Z=29$

S I isoelectronic sequence

Ground state $1s^22s^22p^63s^23p^4\ ^3P_2$

Ionization energy $3\,508\,000 \pm 30\,000$ cm^{-1} (435 ± 4 eV)

Two magnetic dipole lines, giving the intervals $3s^23p^4\ ^3P_2-^3P_1$ and $^3P_1-^1S_0$, were observed by Roberts *et al.* [1987] in a tokamak plasma at 4183.4±0.3 Å and 1190.4±0.5 Å, respectively. The latter establishes the relative position of the singlet system. We include the predicted value for the $^3P_0$ level from the calculation of Sugar and Kaufman [1984]. The uncertainty in this prediction is about ±100 cm^{-1}.

An analysis of the configurations $3s3p^5$ and $3s^23p^33d$ was given by Sugar and Kaufman [1986]. Revisions have been made by Kaufman, Sugar, and Rowan [1990] in a study of the isoelectronic sequence. We compiled the results of the latter work.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

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Cu XIV

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^4$	^3P	2	0	92	8	^1D
		0	[23 192]	88	12	^1S
		1	23 897	100		
$3s^23p^4$	^1D	2	52 540	92	8	^3P
$3s^23p^4$	^1S	0	107 902	88	12	^3P
$3s3p^5$	$^3P^\circ$	2	*354 570*	82	13	$3p^3(^2D^\circ)3d\ ^3P^\circ$
$3s3p^5$	$^1P^\circ$	1	*451 850*	57	34	$3p^3(^2D^\circ)3d\ ^1P^\circ$
$3s^23p^3(^2D^\circ)3d$	$^3P^\circ$	2	*648 960*	77	14	$3s3p^5\ ^3P^\circ$
$3s^23p^3(^4S^\circ)3d$	$^3D^\circ$	3	*674 230*	46	28	$(^2P^\circ)\ ^3D^\circ$
		2	*686 870*	32	25	
$3s^23p^3(^2D^\circ)3d$	$^1D^\circ$	2	*710 700*	55	18	$(^2P^\circ)\ ^1D^\circ$
$3s^23p^3(^2D^\circ)3d$	$^1F^\circ$	3	*726 770*	62	32	$(^2P^\circ)\ ^1F^\circ$
$3s^23p^3(^2P^\circ)3d$	$^1P^\circ$	1	*763 830*	85	4	$(^4S^\circ)\ ^3D^\circ$
Cu XV ($^4S^\circ_{3/2}$)	*Limit*		*3 508 000*			

Cu XV

$Z=29$

P I isoelectronic sequence

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

Ionization energy 3 903 000 ± 40 000 cm^{-1} (484 ± 5 eV)

Two magnetic dipole lines, giving the intervals $3s^23p^3\ ^4S^\circ_{3/2}-^2D^\circ_{3/2}$ and $^4S^\circ_{3/2}-^2P^\circ_{3/2}$, were observed by Denne *et al.* [1984] in a tokamak plasma at 2085.3±0.2 and 944.6±0.2 Å, respectively. The $^2P^\circ_{1/2}$ energy is a calculated value by Sugar and Kaufman [1984].

Fawcett and Hayes [1975] classified two transitions between $3s^23p^3$ and $3s^23p^23d$, the $^2D^\circ_{5/2}-(^3P)\ ^2F_{7/2}$ and $^4S^\circ_{3/2}-(^3P)\ ^4P_{5/2}$ lines. These were confirmed in a subsequent analysis of the spectrum of a laser-generated plasma by Sugar and Kaufman [1986]. The latter authors reported an additional seven levels of $3s^23p^23d$. Hutton *et al.* [1987] used a beam-foil apparatus to reobserve this spectrum. They classified 9 lines of the $3p^3-3p^23d$ array, revising the analysis of Sugar and Kaufman. Their results are quoted here with levels based on improved wavelength measurements from the line list of Sugar and Kaufman. They also reported 3 lines arising from the $3s3p^3$ configuration. We found that they do not fit their isoelectronic sequences, and that one of them, at 296.6 Å, is a second order line.

The uncertainty of the levels of the ground configuration is ±20 cm^{-1}, except for the predicted value for $^2P^\circ_{1/2}$. This value was obtained from the fitted calculation of the $3p^3$ configuration. We estimate the uncertainty to be ±100 cm^{-1}. The uncertainty of the levels of $3s3p^4$ is also about ±20 cm^{-1}, and that of $3s^23p^23d$ is about ±60 cm^{-1}.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

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Cu XV

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s^23p^3$	$^4S^\circ$	3/2	*0*	
$3s^23p^3$	$^2D^\circ$	3/2	*47 940*	
		5/2	*57 803*	
$3s^23p^3$	$^2P^\circ$	1/2	[*91 106*]	
		3/2	*105 962*	
$3s^23p^2(^3P)3d$	^4P	5/2	619 652	
		3/2	626 264	
		1/2	633 300	
$3s^23p^2(^1D)3d$	^2D	3/2	672 380	
		5/2	675 651	
$3s^23p^2(^3P)3d$	^2F	7/2	704 207	
$3s^23p^2(^1D)3d$	^2P	3/2	703 573	
$3s^23p^2(^3P)3d$	^2D	5/2	735 114	
		3/2	735 900	
Cu XVI ($^3P_0$)	***Limit***		**3 903 000**	

Cu XVI

$Z=29$

Si I isoelectronic sequence

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

Ionization energy 4 194 000 ± 40 000 cm^{-1} (520 ± 5 eV)

All the levels of the $3s^23p^2$ ground configuration are determined from magnetic dipole lines in tokamak plasmas. The transitions $^3P_0-^3P_1$, $^3P_2-^1D_2$, and $^3P_1-^1S_0$ were observed by Denne *et al.* [1983] and the $^3P_1-^1D_2$ transition was observed by Hinnov [1985] and Roberts *et al.* [1987]. The $^3P_2-^1D_2$ line was tentatively identified at 2539.7 Å. Datla *et al.* [1989] have revised this to a line they observed at 2544.7±0.5 Å.

The $^5S^\circ_2$ level of the $3s3p^3$ configuration was determined by Träbert *et al.* [1987] from beam-foil observations of transitions to the ground term. The remaining levels of $3s3p^3$ and those of $3s^23p3d$ were derived by Sugar and Kaufman [1986] from spectra of a laser-generated plasma. Improved wavelengths and new level values were given by Sugar, Kaufman and Rowan [1990] and are used here. The uncertainty of these level values is ±25 cm^{-1}. The percentage compositions are from their calculations which included configuration interaction between $3s3p^3$ and $3s^23p3d$.

Both Kastner *et al.* [1978] and Khan [1978] investigated $n=3-4$ transitions, identifying transitions $3p^2-3p4d$ and $3p3d-3p4f$. Khan also reported several lines of $3p^2-3p4s$. These data provided the levels given here (some questionable ones were omitted) with an uncertainty of ±5000 cm^{-1}.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

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Cu XVI

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^23p^2$	^3P	0	0.0	94	6	^1S
		1	18 596.7	100		
		2	32 747	82	18	^1D
$3s^23p^2$	^1D	2	72 035	82	18	^3P
$3s^23p^2$	^1S	0	123 550	94	6	^3P
$3s3p^3$	$^5S^\circ$	2	*276 430*	98	2	$^3P^\circ$
$3s3p^3$	$^3D^\circ$	1	*361 244*	84	8	$3s^23p3d\ ^3D^\circ$
		2	*361 409*	82	10	$3s3p^3\ ^3P^\circ$
		3	*368 135*	92	8	$3s^23p3d\ ^3D^\circ$
$3s3p^3$	$^3P^\circ$	1	*415 510*	85	7	$3s^23p3d\ ^3P^\circ$
		2	*417 574*	74	9	$3s3p^3\ ^3D^\circ$
$3s3p^3$	$^3S^\circ$	1	*510 832*	72	24	$^1P^\circ$

Cu XVI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$3s3p^3$	$^1P^\circ$	1	*547 354*	62		26	$^3S^\circ$
$3s^23p3d$	$^3P^\circ$	2	*591 646*	49		20	$3s^23p3d$ $^1D^\circ$
		0	*617 805*	93		7	$3s3p^3$ $^3P^\circ$
		1	*622 812*	51		40	$3s^23p3d$ $^3D^\circ$
$3s^23p3d$	$^3D^\circ$	1	*602 319*	49		40	$3s^23p3d$ $^3P^\circ$
		3	*624 887*	89		8	$3s3p^3$ $^3D^\circ$
		2	*626 942*	57		30	$3s^23p3d$ $^3P^\circ$
$3s^23p3d$		2	*613 709*	39	$^1D^\circ$	22	$^3D^\circ$
$3s^23p3d$	$^1F^\circ$	3	*680 949*	97		2	$^3D^\circ$
$3s^23p3d$	$^1P^\circ$	1	*698 524*	85		12	$3s3p^3$ $^1P^\circ$
$3s^23p4s$	$^3P^\circ$	2	*1 930 000*				
$3s^23p4s$	$^1P^\circ$	1	*1 940 000*				
$3s^23p4d$	$^3D^\circ$	1	*2 241 000?*				
		2	*2 242 000*				
		3	*2 244 000*				
$3s^23p4d$	$^3F^\circ$	3	*2 271 000*				
$3s^23p4d$	$^1F^\circ$	3	*2 282 000*				
$3s^23p4d$	$^1P^\circ$	1	*2 302 000*				
$3s^23p4f$	^3G	4	2 370 000				
		5	2 397 000				
Cu XVII ($^2P^\circ_{1/2}$)	***Limit***		**4 194 000**				

Cu XVII

$Z=29$

Al I isoelectronic sequence

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

Ionization energy 4 493 000 ± 48 000 cm^{-1} (557 ± 6 eV)

The ground $^2P^\circ$ term interval was obtained from the magnetic dipole transition observed in a tokamak plasma at 3007.6±0.3 Å by Hinnov *et al.* [1982].

The ^4P term of $3s3p^2$ was given by Träbert, Heckmann, Hutton, and Martinson [1988], who used beam-foil excitation to observe the transitions $3s^2 3p\ ^2P^\circ - 3s3p^2\ ^4P$. Sugar, Kaufman, and Rowan [1988] reported the multiplet $3s3p^2\ ^4P - 3p^3\ ^4S^\circ$. We used the data of Träbert *et al.* to derive the $^4P_{5/2}$ level and the more accurate data of Sugar, Kaufman, and Rowan to determine the ^4P intervals. The latter authors also gave the rest of the levels of $3s3p^2$ and the $3s^2 3d\ ^2D$ term. We use the levels derived by them from smoothed wavelengths for the isoelectronic sequence. The level uncertainty is ±50 cm^{-1}. The percentage compositions were calculated by them with configuration interaction between $3s3p^2$ and $3s^2 3d$.

Three levels of the $3s3p3d$ configuration are derived from the classifications of lines by Buchet-Poulizac and Buchet [1988] and the more accurate wavelengths of Sugar and Kaufman (private communication).

Khan [1978] obtained $n=3-4$ transitions in the range of 42−51 Å with an accuracy of ±0.02 Å by means of a laser-generated plasma. The level uncertainty is ±1000 cm^{-1}.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

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Cu XVII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2 3p$	$^2P^\circ$	1/2	*0*	100		
		3/2	*33 239*	100		
$3s3p^2$	^4P	1/2	277 231	98	2	^2S
		3/2	291 810	99	1	^2D
		5/2	307 708	95	4	^2D
$3s3p^2$	^2D	3/2	372 236	86	12	$3s^2 3d\ ^2D$
		5/2	377 783	84	11	
$3s3p^2$	^2S	1/2	444 759	60	38	^2P
$3s3p^2$	^2P	1/2	480 016	62	38	^2S
		3/2	490 467	98	1	^2D
$3s^2 3d$	^2D	3/2	574 180	86	12	$3s3p^2\ ^2D$
		5/2	578 243	88	12	
$3p^3$	$^4S^\circ$	3/2	*725 320*			

Cu XVII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s3p3d$	$^4D^\circ$	$^7/_2$	*856 700*	
		$^5/_2$	*861 200*	
$3s3p3d$	$^2D^\circ$	$^5/_2$	*876 780*	
$3s^24s$	^2S	$^1/_2$	2 026 000	
$3s3p4s$	$^4P^\circ$	$^3/_2$	*2 312 000*	
		$^5/_2$	*2 337 000*	
$3s3p4s$	$^2P^\circ$	$^3/_2$	*2 332 000*	
$3s^24d$	^2D	$^3/_2$	2 336 000	
		$^5/_2$	2 342 000	
$3s^24f$	$^2F^\circ$	$^7/_2$	*2 474 000*	
		$^5/_2$	*2 476 000*	
Cu XVIII ($^1S_0$)	*Limit*		4 493 000	

Cu XVIII

$Z=29$

Mg I isoelectronic sequence

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

Ionization energy $5\,105\,000 \pm 48\,000\ cm^{-1}$ (633 ± 6 eV)

Fawcett and Hayes [1975] classified five lines of this spectrum, including the $3s^2\ ^1S_0-3s3p\ ^1P^\circ_1$ resonance line. The configurations $3s3p$, $3p^2$, and $3p3d$ were completed by Sugar and Kaufman in a series of papers [1986a, 1986b, 1987]. The level uncertainty is $\pm 50\ cm^{-1}$. In the last paper they caution that the wavelengths in the first two papers should be lowered by 0.02 Å. The level interval $3s3p\ ^3P^\circ_1-{}^3P^\circ_2$ was observed directly with the magnetic dipole line at 3941.6±0.3 Å by Denne *et al.* [1983]. The percentage compositions of the levels were given by Litzén and Redfors [1987] with configuration interaction within the $3s^2$, $3s3d$, and $3p^2$ even and the $3s3p$ and $3p3d$ odd configurations.

The $^3F_4$ and $^1G_4$ levels of the $3d^2$ configuration were found by Redfors [1988] in an isoelectronic study of the spectra calcium through zinc. Sugar *et al.* [1989] identified the $^3F_3$ and $^3F_2$ levels of $3d^2$.

With a high voltage spark Feldman *et al.* [1971] produced and identified the transition arrays $3s3d-3s4f$ and $5f$, $3s3p-3s4s$, $3s3p-3s4d$ and $3s5d$, and the resonance line $3s^2\ ^1S_0-3s4p\ ^1P^\circ_1$. These wavelengths fall in the range of 30–49 Å and are measured with an accuracy of ±0.01 Å. Using a similar light source Kastner *et al.* [1978] found the $3p3d-3p4f$ array occurring at 49–51 Å. We assume the same wavelength accuracy of ±0.01 Å from the author's general remarks. The level uncertainty for these two groups of levels is $\pm 600\ cm^{-1}$ and $\pm 400\ cm^{-1}$.

Swartz *et al.* [1971] identified the resonance transition from the $2p^53s^23d\ ^1P^\circ_1$ autoionizing level at 11.774 Å.

The value for the ionization energy was obtained by Lotz [1967] by isoelectronic extrapolation.

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Cu XVIII

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s^2$	^1S	0	0	97	2	$3p^2\ ^1S$
$3s3p$	$^3P^\circ$	0	*279 816*	100		
		1	*289 401*	98	1	$^1P^\circ$
		2	*314 753*	100		
$3s3p$	$^1P^\circ$	1	*426 987*	96	3	$3p3d\ ^1P^\circ$
$3p^2$	^3P	0	664 977	94	6	^1S
		1	684 689	100		
		2	715 608	78	16	^1D
$3p^2$	^1D	2	679 710	64	22	^3P
$3p^2$	^1S	0	804 139	90	6	^3P

Cu XVIII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$3s3d$	^{3}D	1	818 630	100		
		2	820 704	100		
		3	823 970	100		
$3s3d$	^{1}D	2	917 020	81	19	$3p^2$ ^{1}D
$3p3d$	^{3}F°	2	*1 118 029*	84	15	^{1}D°
		3	*1 135 602*	97	2	^{3}D°
		4	*1 156 841*	100		
$3p3d$	^{1}D°	2	*1 149 319*	76	14	^{3}F°
$3p3d$	^{3}D°	1	*1 183 252*	76	21	^{3}P°
		2	*1 187 907*	49	41	^{3}P°
		3	*1 205 542*	96	3	^{3}F°
$3p3d$	^{3}P°	0	*1 208 022*	100		
		1	*1 208 326*	77	22	^{3}D°
		2	*1 209 104*	51	47	^{3}D°
$3p3d$	^{1}F°	3	*1 284 495*	98	1	^{3}D°
$3p3d$	^{1}P°	1	*1 298 970*	95	3	$3s3p$ ^{1}P°
$3d^2$	^{3}F	2	1 653 727	99		
		3	1 657 191	100		
		4	1 661 315	100		
$3d^2$	^{1}G	4	1 701 113	100		
$3s4s$	^{3}S	1	2 416 400			
$3s4p$	^{1}P°	1	*2 572 300*			
$3s4d$	^{3}D	1	2 742 100			
		2	2 743 500			
		3	2 745 800			
$3s4f$	^{3}F°	2	*2 840 800*			
		3	*2 841 300*			
		4	*2 841 800*			
$3p4f$	^{3}G	3	3 122 600			
		4	3 176 000			
		5	3 202 500			
$3p4f$	^{1}F	3	3 173 800			
$3p4f$	^{3}F	3	3 178 500			
		4	3 202 900			
$3p4f$	^{3}D	3	3 193 400			
		2	3 217 600			
		1	3 222 900			
$3s5d$	^{3}D	1	3 611 000			
		2	3 611 200			
		3	3 612 400			

Cu XVIII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s5f$	$^3F°$	2	*3 656 500*	
		3	*3 657 100*	
		4	*3 657 300*	
Cu XIX ($^2S_{1/2}$)	***Limit***		**5 105 000**	
$2p^53s^23d$	$^1P°$	1	*8 493 000*	

Cu XIX

$Z=29$

Na I isoelectronic sequence

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

Ionization energy 5 408 660 ± 250 cm^{-1} (670.588 ± 0.003 eV)

The $3d-4f$ doublet was first given by Edlén [1936]. Several more doublets were reported by Feldman, Cohen, and Swartz [1967] and considerably extended by Feldman *et al.* [1971]. New measurements were given by Kononov, Ryabtsev, and Churilov [1979] who improved the accuracy of the $n=3-3$ transitions and added the $4p-5d$, $4d-5f$, and $4f-5g$ doublets. We use their measurements to determine all levels for $n>3$ except for $6p$, $7d$, $8d$, $4f$, and $7f$, which were given only by Feldman *et al.* [1971]. Reader *et al.* [1987] derived least-squares adjusted wavelengths for the $3s-3p$, $3p-3d$, and $3d-4f$ multiplets along the Na I isoelectronic sequence. We use their values to find the $3s$, $3p$, $3d$, and $4f$ levels. Uncertainties in the level values are as follows: for $n=3$ ±15 cm^{-1}, for $n=4$ ±300 cm^{-1}, for $n=5$ ±1000 cm^{-1}, and for $n=6-8$ ±2000 cm^{-1}.

A line at 13.11 Å classified as the transition from the autoionizing level $2p^5 3s^2\ ^2P^\circ_{3/2}$ to the ground state was reported by Feldman and Cohen [1967] with an uncertainty of ±6000 cm^{-1}. Jupén *et al.* [1988] observed a line at 210.70±0.05 Å in a beam foil experiment, which they classified as the transition $2p^5 3s 3p\ ^4D^\circ_{7/2}-2p^5 3s 3d\ ^2F^\circ_{9/2}$ from experimental and theoretical isoelectronic studies. We have neither of these levels from which to derive the other.

The value for the ionization energy was derived by Kononov *et al.* from core-polarization theory applied to the $5g$ term.

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Cu XIX

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$3s$	^2S	1/2	0	
$3p$	$^2P^\circ$	1/2	*329 436*	
		3/2	*365 826*	
$3d$	^2D	3/2	811 791	
		5/2	817 560	
$4s$	^2S	1/2	2 535 440	
$4p$	$^2P^\circ$	1/2	*2 667 490*	
		3/2	*2 681 600*	
$4d$	^2D	3/2	2 847 000	
		5/2	2 849 500	
$4f$	$^2F^\circ$	5/2	*2 924 400*	
		7/2	*2 925 400*	

Cu XIX — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$5p$	$^2P^\circ$	$^1/_2$	*3 693 400*	
		$^3/_2$	*3 699 300*	
$5d$	^2D	$^3/_2$	3 779 300	
		$^5/_2$	3 780 600	
$5f$	$^2F^\circ$	$^5/_2$	*3 818 100*	
		$^7/_2$	*3 818 700*	
$5g$	^2G	$^7/_2$	3 823 100	
		$^9/_2$	3 823 400	
$6p$	$^2P^\circ$	$^1/_2$	*4 233 500*	
		$^3/_2$	*4 237 500*	
$6d$	^2D	$^3/_2$	4 282 500	
		$^5/_2$	4 283 400	
$6f$	$^2F^\circ$	$^5/_2$	*4 304 500*	
		$^7/_2$	*4 305 000*	
$7d$	^2D	$^3/_2$	4 584 200	
		$^5/_2$	4 584 500	
$7f$	$^2F^\circ$	$^5/_2$	*4 597 400*	
		$^7/_2$	*4 598 000*	
$8d$	^2D	$^3/_2$	4 778 800	
		$^5/_2$	4 778 800	
Cu XX ($^1S_0$)	*Limit*		5 408 660	
$2p^53s^2$	$^2P^\circ$	$^3/_2$	7 628 000	

Cu XX

$Z=29$

Ne I isoelectronic sequence

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

Ionization energy 13 630 000 ± 140 000 cm^{-1} (1697 ± 17 eV)

The resonance transitions from the $2s^22p^53s$, $2s^22p^53d$, and $2s2p^63p$ configurations were identified in a spark discharge by Feldman, Cohen, and Swartz [1967]. Feldman and Cohen [1967] reported the two resonance lines from $2s^22p^54d$. Swartz *et al.* added the resonance lines from $2s^22p^54s$, $5d$, and $6d$. All these resonance lines were given with improved accuracy of ±0.003 Å by Boiko, Faenov, and Pikuz [1978].

New observations of this sequence from Fe to Br were published by Gordon, Hobby, and Peacock [1980]. Their wavelengths for Cu in the range of 8 to 13 Å agree within a few thousandths Å with those of Boiko *et al.* Their calculations show that the transition $2s^22p^6-2s^22p^5(^2P^\circ_{1/2})4s$ given previously as 9.423 Å should be replaced with the line 9.375 Å. They have given additional resonance lines arising from the levels $2s^22p^54d$ $(^3/_2,^3/_2)^\circ_1$, and $2s2p^64p$ $(^1/_2,^1/_2)^\circ_1$, and $(^1/_2,^3/_2)^\circ_1$. We use an average of the wavelengths from the two sets of measurements.

The wavelengths and analysis of the $2p^53s-2p^53p$ and $2p^53p-2p^53d$ arrays were given by Buchet *et al.* [1987]. They observed these data in the range of 215–380 Å with beam-foil excitation, and reported a wavelength uncertainty of ±0.05 Å for the strong, well-resolved lines and ±0.1 Å for the remaining lines. Their level values are given relative to the lowest $2p^53s$ $J=1$ level as reference.

The value for the ionization energy was derived by Lotz [1967] by extrapolation.

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Cu XX

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^22p^6$	^1S	0	0	
$2s^22p^53s$	$(^3/_2,^1/_2)^\circ$	2	*7 777 270*	
		1	*7 795 650*	
$2s^22p^53s$	$(^1/_2,^1/_2)^\circ$	0	*7 943 950*	
		1	*7 955 050*	
$2s^22p^53p$	$(^3/_2,^1/_2)$	1	8 070 680	
		2	8 098 270	
$2s^22p^53p$	$(^3/_2,^3/_2)$	3	8 125 590	
		1	8 133 410	
		2	8 153 580	
$2s^22p^53p$	$(^1/_2,^1/_2)$	1	8 259 280	
		0	8 406 900	

Cu XX — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^22p^53p$	$(^1/_2,^3/_2)$	1	8 301 150	
		2	8 306 290	
$2s^22p^53d$	$(^3/_2,^3/_2)^\circ$	0	*8 509 560*	
		1	*8 520 820*	
		3	*8 545 040*	
		2	*8 562 820*	
$2s^22p^53d$	$(^3/_2,^5/_2)^\circ$	4	*8 540 100*	
		2	*8 540 750*	
		3	*8 574 510*	
		1	*8 626 510*	
$2s^22p^53d$	$(^1/_2,^3/_2)^\circ$	2	*8 711 110*	
$2s^22p^53d$	$(^1/_2,^5/_2)^\circ$	2	*8 720 400*	
		3	*8 727 220*	
$2s2p^63p$	$(^1/_2,^1/_2)^\circ$	1	*9 387 000*	
$2s2p^63p$	$(^1/_2,^3/_2)^\circ$	1	*9 436 000*	
$2s^22p^54s$	$(^3/_2,^1/_2)^\circ$	1	*10 504 000*	
$2s^22p^54s$	$(^1/_2,^1/_2)^\circ$	1	*10 667 000*	
$2s^22p^54d$	$(^3/_2,^3/_2)^\circ$	1	*10 783 000*	
$2s^22p^54d$	$(^3/_2,^5/_2)^\circ$	1	*10 828 000*	
$2s^22p^54d$	$(^1/_2,^3/_2)^\circ$	1	*10 984 000*	
$2s^22p^55d$	$(^3/_2,^5/_2)^\circ$	1	*11 840 000*	
$2s2p^64p$	$(^1/_2,^1/_2)^\circ$	1	*11 905 000*	
$2s2p^64p$	$(^1/_2,^3/_2)^\circ$	1	*11 926 000*	
$2s^22p^55d$	$(^1/_2,^3/_2)^\circ$	1	*12 002 000*	
$2s^22p^56d$	$(^3/_2,^5/_2)^\circ$	1	*12 389 000*	
$2s^22p^56d$	$(^1/_2,^3/_2)^\circ$	1	*12 544 000*	
Cu XXI ($^2P^\circ_{3/2}$)	*Limit*		*13 630 000*	

Cu XXI

$Z=29$

F I isoelectronic sequence

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

Ionization energy 14 550 000 ± 150 000 cm^{-1} (1804 ± 18 eV)

The splitting of the $^2P^\circ$ ground term was determined by Kononov *et al.* [1977] with their identification of the doublet $2s^22p^5\ ^2P^\circ-2s2p^6\ ^2S$ at 78.388(10) Å and 90.353(10) Å in a laser-produced plasma. We use the more accurate value obtained from the measurement by Hinnov *et al.* [1982] of the magnetic dipole transition $2s^22p^5\ ^2P^\circ_{3/2}-^2P^\circ_{1/2}$ at 592.3±0.3 Å observed in a tokamak discharge.

The $2p^5-2p^43s$ and $3d$ arrays were observed by Boiko *et al.* [1979], by Gordon *et al.* [1980], and by Hutcheon *et al.* [1980a] in the range of 10.8 Å to 12.2 Å using laser-produced plasmas. The reported wavelengths were in close agreement. We therefore use average values and estimate an uncertainty of ±0.003 Å. Gordon *et al.* also give the $2s^22p^5-2s2p^53p$ array in the range of 9.9 to 10.4 Å

Buchet-Poulizac and Buchet [1988], using beam-foil excitation, have identified the $2p^43s-2p^43p$ and $2p^43p-2p^43d$ transitions in the range of 168.82±0.5 Å to 346.25±0.5 Å. Those transitions involving known levels are used to determine the $2p^43p$ levels and the two $J=7/2$ levels of $2p^43d$.

The $2p^5-2p^44s, 4d$ arrays were observed by Hutcheon *et al.* [1980b] and by Gordeon *et al.* at ~8.5 Å. They are mostly blends and are not suitable for deriving energy levels.

The percentage compositions of the even levels were given by Chapman and Shadmi [1973].

The value for the ionization energy was derived by Lotz [1967] by isoelectronic extrapolation.

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Cu XXI

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^22p^5$	$^2P^\circ$	3/2	*0*			
		1/2	*168 830*			
$2s2p^6$	^2S	1/2	1 275 760	97		
$2s^22p^4(^3P)3s$	^4P	5/2	8 206 000	87		
		1/2	8 313 000	62	29	$(^1S)\ ^2S$
		3/2	8 363 000	74	24	$(^3P)\ ^2P$
$2s^22p^4(^3P)3s$	^2P	3/2	8 236 000	60	24	$(^3P)\ ^4P$
		1/2	8 388 000	78		
$2s^22p^4(^1D)3s$	^2D	5/2	8 452 000	87		
		3/2	8 458 000	82		
$2s^22p^4(^3P)3p$	$^4D^\circ$	7/2	*8 547 000*			
		3/2	*8 619 000*			
		5/2	*8 670 000*			

Cu XXI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2s^22p^4(^3P)3p$	$^2D^\circ$	$^5/_2$	*8 566 000*				
$2s^22p^4(^3P)3p$	$^4P^\circ$	$^1/_2$	*8 664 000*				
$2s^22p^4(^1S)3s$	^2S	$^1/_2$	8 690 000	64		19	$(^3P)\ ^4P$
$2s^22p^4(^1D)3p$	$^2F^\circ$	$^5/_2$	*8 747 000*				
		$^7/_2$	*8 779 000*				
$2s^22p^4(^1D)3p$	$^2D^\circ$	$^5/_2$	*8 810 000*				
$2s^22p^4(^3P)3d$	^2F	$^7/_2$	8 945 000	58		22	$(^3P)\ ^4F$
$2s^22p^4(^3P)3d$	^4P	$^1/_2$	8 959 000	55		23	$(^3P)\ ^2P$
		$^3/_2$	8 979 000	41		28	$(^3P)\ ^2D$
$2s^22p^4(^3P)3d$		$^5/_2$	8 998 000	39	^2F	32	$(^3P)\ ^2D$
$2s^22p^4(^3P)3d$	^4F	$^5/_2$	9 007 000	52		22	$(^1S)\ ^2D$
		$^7/_2$	9 066 000	52		22	$(^3P)\ ^2F$
$2s^22p^4(^3P)3d$	^4D	$^1/_2$	9 078 000	57		20	$(^3P)\ ^2P$
		$^3/_2$	9 079 000	55		18	$(^3P)\ ^4P$
$2s^22p^4(^3P)3d$	^2P	$^3/_2$	9 108 000	42		20	$(^1D)\ ^2P$
$2s^22p^4(^3P)3d$		$^5/_2$	9 114 000	27	$(^3P)\ ^2D$	26	$(^3P)\ ^2F$
$2s^22p^4(^1D)3d$	^2G	$^7/_2$	9 154 000	79			
$2s^22p^4(^1D)3d$	^2S	$^1/_2$	9 180 000	74		14	$(^3P)\ ^4P$
$2s^22p^4(^1D)3d$	^2F	$^7/_2$	9 195 000	62		26	$(^3P)\ ^4D$
$2s^22p^4(^1D)3d$	^2P	$^3/_2$	9 206 000	58		13	$(^3P)\ ^2P$
		$^1/_2$	9 258 000	52		32	
$2s^22p^4(^1D)3d$	^2D	$^5/_2$	9 209 000	36		18	$(^3P)\ ^2D$
		$^3/_2$	9 248 000	50		19	
$2s^22p^4(^1S)3d$	^2D	$^3/_2$	9 428 000	25		18	$(^3P)\ ^2D$
$2s2p^5(^3P^\circ)3p$	^4D	$^5/_2$	9 658 000				
		$^3/_2$	9 694 000				
$2s2p^5(^3P^\circ)3p$	^2D	$^5/_2$	9 717 000				
		$^3/_2$	9 872 000				
$2s2p^5(^3P^\circ)3p$	^2P	$^3/_2$	9 747 000				
		$^1/_2$	9 771 000				
$2s2p^5(^3P^\circ)3p$	^4P	$^3/_2$	9 792 000				
		$^5/_2$	9 801 000?				
$2s2p^5(^3P^\circ)3p$	^2S	$^1/_2$	9 894 000?				
$2s2p^5(^1P^\circ)3p$	^2D	$^3/_2$	10 049 000				
		$^5/_2$	10 089 000				

Cu XXI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s2p^5(^1P^\circ)3p$	^2P	$^1/_2$	10 095 000	
		$^3/_2$	10 112 000	
Cu XXII ($^3P_2$)	***Limit***		**14 550 000**	

Cu XXII

$Z=29$

O I isoelectronic sequence

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

Ionization energy 15 450 000 ± 150 000 cm^{-1} (1916 ± 19 eV)

Two magnetic dipole lines within the ground configuration, the $^3P_2-^3P_1$ at 657.7±0.3 Å and the $^3P_2-^1D_2$ at 420.0±0.3 Å, were observed in a tokamak discharge by Hinnov *et al.* [1982].

The transition array $2s^22p^4-2s2p^5$ was first given by Kononov *et al.* [1977], and was extended by Behring *et al.* [1985]. The $2s2p^5\ ^1P_1^\circ-2p^6\ ^1S_0$ line was first given by Peregudov *et al.* [1978]. Additional lines were found by Ekberg *et al.* [1987] who reobserved the spectrum in the range of 65–115 Å with a wavelength uncertainty of ±0.015 Å. The energy levels are quoted from Ekberg *et al.* with their uncertainty of ±200 cm^{-1}.

Observations of the $2p^4-2p^33d$, $4s$, $4d$ arrays were given by Gordon *et al.* [1980] in the range of 8–12 Å. Their data do not appear to be sufficiently resolved for reliable analysis.

The value for the ionization energy was derived by Lotz [1967] by isoelectronic extrapolation.

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Cu XXII

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^22p^4$	^3P	2	0	
		0	101 620	
		1	151 990	
$2s^22p^4$	^1D	2	237 950	
$2s^22p^4$	^1S	0	456 290	
$2s2p^5$	$^3P^\circ$	2	*1 107 710*	
		1	*1 202 170*	
		0	*1 283 280*	
$2s2p^5$	$^1P^\circ$	1	*1 528 080*	
$2p^6$	^1S	0	2 546 610	
Cu XXIII ($^4S^\circ_{3/2}$)	***Limit***		***15 450 000***	

Cu XXIII

$Z=29$

N I isoelectronic sequence

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

Ionization energy 16 620 000 ± 160 000 cm^{-1} (2060 ± 20 eV)

Three M1 transitions within the ground configuration have been observed. They are the $^4S^\circ_{3/2}-^2D^\circ_{3/2,5/2}$ lines at 434.8±0.3 Å and 585.0±0.3 Å by Hinnov *et al.* [1982] and the $^2D_{3/2}-^2D_{5/2}$ line at 1691.0±0.3 Å by Hinnov [1985].

Transitions of the $2s-2p$ type were observed and classified by Kononov *et al.* [1977] and Behring *et al.* [1985] using laser-produced plasmas. A more complete excitation of these arrays was produced by Ekberg *et al.* [1987], who found all the levels of the $2s^2 2p^3$, $2s2p^4$, and $2p^5$. We use the M1 lines of Hinnov *et al.* [1982] and Hinnov [1985] to derive the levels of $3p^3\ ^2D^\circ$. The remaining levels are derived from the wavelengths of Ekberg *et al.*

The value for the ionization energy was derived by Lotz [1967] by isoelectronic extrapolation.

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Cu XXIII

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^3$	$^4S^\circ$	3/2	*0*	
$2s^2 2p^3$	$^2D^\circ$	3/2	*170 940*	
		5/2	*230 080*	
$2s^2 2p^3$	$^2P^\circ$	1/2	*327 860*	
		3/2	*446 860*	
$2s2p^4$	^4P	5/2	900 320	
		3/2	1 011 650	
		1/2	1 036 430	
$2s2p^4$	^2D	3/2	1 249 360	
		5/2	1 283 950	
$2s2p^4$	^2S	1/2	1 427 030	
$2s2p^4$	^2P	3/2	1 485 390	
		1/2	1 646 760	
$2p^5$	$^2P^\circ$	3/2	*2 316 970*	
		1/2	*2 493 080*	
Cu XXIV ($^3P_0$)	*Limit*		16 620 000	

Cu XXIV

$Z=29$

C I isoelectronic sequence

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

Ionization energy 17 600 000 ± 180 000 cm^{-1} (2182 ± 22 eV)

Two M1 lines observed in a tokamak plasma determine the ground configuration levels, except for $^1S_0$. The transitions $^3P_0-^3P_1$ and $^3P_1-^3P_2$ were reported by Hinnov *et al.* [1982] at 756.9±0.3 Å and 1776.0±0.3 Å, respectively. The same authors measured two more M1 lines that determine the position of the $^1D_2$ level, the transitions $^3P_1-^1D_2$ and $^3P_2-^1D_2$ at 414.1(3) Å and 540.3(3), respectively.

Ekberg *et al.* [1987] determined all but one level, $2p^4\ ^1D_2$, of the $n=2$ complex from the spectrum of a laser-generated plasma.

The ionization energy was derived by Lotz [1967] by isoelectronic extrapolation.

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Cu XXIV

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^22p^2$	^3P	0	0	
		1	132 120	
		2	188 430	
$2s^22p^2$	^1D	2	373 620	
$2s^22p^2$	^1S	0	519 650	
$2s2p^3$	$^3D°$	1	*958 850*	
		2	*968 440*	
		3	*1 018 700*	
$2s2p^3$	$^3P°$	0	*1 147 900*	
		1	*1 164 700*	
		2	*1 196 100*	
$2s2p^3$	$^3S°$	1	*1 335 700*	
$2s2p^3$	$^1D°$	2	*1 404 900*	
$2s2p^3$	$^1P°$	1	*1 573 500*	
$2p^4$	^3P	2	1 983 000	
		0	2 107 500	
		1	2 141 600	
$2p^4$	^1S	0	2 518 200	
Cu XXV ($^2P°_{1/2}$)	***Limit***		***17 600 000***	

Cu XXV

$Z=29$

B I isoelectronic sequence

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

Ionization energy 18 620 000 ± 180 000 cm^{-1} (2308 ± 22 eV)

The ground term $^2P^\circ$ splitting was determined with the M1 line at 522.8±0.3 Å classified by Hinnov *et al.* [1982].

Ekberg *et al.* [1987] observed the $2s2p^2\ ^4P-2p^3\ ^4S^\circ$ multiplet. With Edlén's [1983] estimate of the position of $2p^3\ ^4S^\circ$ we give levels of both terms with "$+x$" equal to the systematic error.

The ionization energy was derived by Lotz [1967] by isoelectronic extrapolation.

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Cu XXV

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p$	$^2P^\circ$	1/2	*0*	
		3/2	*191 280*	
$2s2p^2$	^4P	1/2	485 730+x	
		3/2	584 920+x	
		5/2	662 770+x	
$2p^3$	$^4S^\circ$	3/2	*1 513 780*+x	
Cu XXVI ($^1S_0$)	***Limit***		**18 620 000**	

Cu XXVI

$Z=29$

Be I isoelectronic sequence

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

Ionization energy 19 986 000 ± 200 000 cm^{-1} (2478 ± 24 eV)

Buchet *et al.* [1985] classified ten lines in the range of 111−173 Å. These are sufficient to derive all the levels of $2s2p$ and $2p^2$ with an uncertainty of ±1000 cm^{-1}. The $2s^2\ ^1S_0 - 2s2p\ ^3P^\circ_1$ intersystem resonance line was observed at 227.80±0.15 Å by Denne and Hinnov [1987].

Spectra in the range of 8.5 to 9.7 Å were observed by Boiko *et al.* [1978] and Brown *et al.* [1987], the latter including additional lines at 27 Å and the $2s^2\ ^1S_0 - 2s2p\ ^1P^\circ_1$ resonance line at 111.071 Å. All levels with $n \geqslant 3$ are derived from the data of Brown *et al.* combined with the levels of Buchet *et al.* The uncertainty of the levels with $n \geqslant 3$ is ±8000 cm^{-1}. The wavelengths of Brown *et al.* were assigned an uncertainty of 0.005 Å for wavelengths below 12 Å and ±0.010 Å for those above.

New measurements of the resonance lines from $2s2p$ $^3P^\circ_1$ and $^1P^\circ_1$ were obtained by Hinnov at 227.808±0.01 Å and 111.186±0.01 Å and quoted by Denne *et al.* [1989]. The $2s2p\ ^3P^\circ_1 - ^3P^\circ_2$ interval was observed with the M1 transition at 648.0±0.2 Å by Hinnov *et al.* [1982].

The ionization energy was derived by Lotz [1967] by isoelectronic extrapolation.

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Cu XXVI

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2$	^1S	0	0	
$2s2p$	$^3P^\circ$	0	*393 900*	
		1	*438 970*	
		2	*593 290*	
$2s2p$	$^1P^\circ$	1	*899 390*	
$2p^2$	^3P	0	1 095 600	
		1	1 223 400	
		2	1 279 600	
$2p^2$	^1D	2	1 477 200	
$2p^2$	^1S	0	1 716 100	
$2s3s$	^1S	0	11 439 000	
$2s3p$	$^1P^\circ$	1	*11 546 000*	
$2s3d$	^3D	1	11 663 000	
		2	11 669 000	
		3	11 672 000	

Cu XXVI — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s3d$	^1D	2	11 777 000	
$2p3s$	$^1P^\circ$	1	*11 977 000*	
$2p3p$	^1P	1	12 049 000	
$2p3d$	$^3P^\circ$	2	*12 144 000*	
		1	*12 372 000*	
$2p3d$	$^3D^\circ$	2	*12 154 000*	
		1	*12 175 000*	
		3	*12 339 000*	
$2p3d$	^3F	3	12 156 000	
$2p3p$	^3P	2	12 197 000	
$2s3s$	^3S	1	12 278 000	
$2p3p$	^1D	2	12 293 000	
$2p3d$	$^1F^\circ$	3	12 428 000	
$2p3d$	$^1P^\circ$	1	*12 441 000*	
$2s4f$	$^3F^\circ$	4	*15 351 000*	
$2p4f$	$^3G^\circ$	4	*15 806 000*	
....	....	....	....	
Cu XXVII ($^2S_{1/2}$)	*Limit*		19 986 000	

Cu XXVII

$Z=29$

Li I isoelectronic sequence

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

Ionization energy 20 870 000 ± 10 000 cm^{-1} (2587.5 ± 1.2 eV)

Knize *et al.* [1987] measured the $2s-2p$ doublet in a tokamak plasma, and obtained the wavelengths 224.770±0.008 Å and 153.508±0.005 Å, giving a level uncertainty for $2p$ $^2P°$ of ±20 cm^{-1}. Transitions from more highly excited one-electron states were observed in a laser-generated plasma by Brown *et al.* [1987]. The uncertainty of levels derived from these lines is ±10 000 cm^{-1}. Aglitskii and Panin [1985] reported two lines from doubly excited states $1s2p3p$ and $1s2p4p$, observed in a spark discharge. Their level uncertainty is ±15 000 cm^{-1}. Lie and Elton reported the resonance transition from the $^2P°$ term of $1s2s2p$.

The value for the ionization energy was obtained by Brown *et al.* using core polarization formulas. Its uncertainty is based on the uncertainty of the $3d$, $4d$, and $4f$, levels from which it is derived.

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Cu XXVII

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$1s^2 2s$	^2S	1/2	0	
$1s^2 2p$	$^2P°$	1/2	*444 899*	
		3/2	*651 432*	
$1s^2 3s$	^2S	1/2	11 711 000	
$1s^2 3p$	$^2P°$	1/2	*11 841 000*	
		3/2	*11 903 000*	
$1s^2 3d$	^2D	3/2	11 947 000	
		5/2	11 967 000	
$1s^2 4p$	$^2P°$	3/2	*15 828 000*	
$1s^2 4d$	^2D	3/2	15 850 000	
		5/2	15 857 000	
$1s^2 4f$	$^2F°$	5/2	*15 862 000*	
		7/2	*15 866 000*	
Cu XXVIII ($^1S_0$)	***Limit***		**20 870 000**	
$1s2s2p$	$^2P°$		*67 020 000*	
$1s2p(^3P°)3p$	^2D	5/2	79 260 000	
$1s2p(^3P°)4p$	^2D	5/2	83 090 000	

Cu XXVIII

$Z=29$

He I isoelectronic sequence

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

Ionization energy 89 224 060 ± 5000 cm^{-1} (11 062.38 ± 0.62 eV)

Observations of the transition $1s^2\ ^1S_0-1s2p\ ^1P^\circ_1$ are reported in the following papers:

Lie and Elton [1971]	1.484±0.005 Å
Turechek and Kunze [1975]	1.4780±0.0010 Å
Aglitskii and Panin [1985]	1.478±0.003 Å
Morita and Fujita [1985]	1.4778±0.0004 Å
Aglitsky *et al.* [1988]	1.47758±0.00007 Å

Drake [1988] reports a calculated value of 1.477587(2) Å for this line.

Turechek and Kunze were able to resolve the $1s^2-1s2p\ ^3P^\circ_{1,2}$ levels at the wavelengths 1.4840 ± 0.0005 Å and 1.4805 ± 0.0010 Å, respectively. Transitions from $1s3p$ and $1s4p\ ^1P^\circ_1$ to the ground state were given by Aglitskii and Panin.

We give calculated values by Drake [1988] for the $1s2s$ and $1s2p$ levels and the ionization energy. His estimated level uncertainty is ±85 cm^{-1}. We adopt an uncertainty of 5 parts in 10^5 representing the approximate difference between the best observations in this region of the sequence (see, e.g., Beiersdorfer *et al.* [1989], and Drake [1988]). Drake's $n=2$ levels are 43±14 cm^{-1} lower than those circulated privately by Drake in 1985, which included levels of the $n=3$ shell. We include the latter reduced by 43 cm^{-1}.

Buchet *et al.* [1985] measured the energy of the transition $1s2s\ ^3S_1-1s2p\ ^3P^\circ_2$ as 483 910±200 cm^{-1}. Drake's calculation gives the energy as 483 663 cm^{-1}.

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Cu XXVIII

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$1s^2$	^1S	0	0	
$1s2s$	^3S	1	[67 035 100]	
$1s2p$	$^3P^\circ$	0	[*67 303 02*0]	
		1	[*67 322 65*0]	
		2	[*67 518 77*0]	
$1s2s$	^1S	0	[*67 324 77*0]	
$1s2p$	$^1P^\circ$	1	[*67 677 83*0]	
$1s3s$	^3S	1	[79 453 170]	
$1s3p$	$^3P^\circ$	0	[*79 526 97*0]	
		1	[*79 532 54*0]	
		2	[*79 591 18*0]	
$1s3s$	^1S	0	[79 530 270]	

Cu XXVIII — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
1s3d	^{3}D	2	[79 629 680]	
		1	[79 630 780]	
		3	[79 651 350]	
1s3p	^{1}P°	1	[*79 634 280*]	
1s3d	^{1}D	2	[79 654 140]	
Cu XXIX (^{2}S$_{1/2}$)	*Limit*		89 224 060	

Cu XXIX

$Z=29$

H I isoelectronic sequence

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

Ionization energy 93 299 090 ± 30 cm^{-1} (11 567.617 ± 0.004 eV)

No measurement of resolved lines of this ion are yet available. We give the theoretical values for the 1s, 2s, and 2p levels as well as the ionization energy calculated by Johnson and Soff [1985]. The estimated uncertainty of these quantities relative to the ground state is ±30 cm^{-1}, while that of 2p $^2P°$ term splitting is ±2 cm^{-1}. Johnson and Soff's values agree with those calculated by Mohr [1983] within the uncertainties.

For $n=3$ to 5 the values for the energy levels were obtained by subtracting the binding energies calculated by Erickson [1977] from the Johnson and Soff value for the ionization energy. 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 his error of 310 cm^{-1} for 2s. The resulting errors for 3s, 4s, and 5s are ±90 cm^{-1}, ±40 cm^{-1}, and ±20 cm^{-1}, respectively. For the rest of the levels with $n \geqslant 3$ we estimate the uncertainty to be ±20 cm^{-1}.

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Cu XXIX

Configuration	Term	*J*	Level (cm^{-1})	Leading percentages
1s	^2S	1/2	0	
2p	$^2P°$	1/2	[*69 896 140*]	
		3/2	[*70 162 455*]	
2s	^2S	1/2	[69 902 760]	
3p	$^2P°$	1/2	[*82 927 480*]	
		3/2	[*83 006 449*]	
3s	^2S	1/2	[82 929 560]	
3d	^2D	3/2	[83 006 306]	
		5/2	[83 032 077]	
4p	$^2P°$	1/2	[*87 477 540*]	
		3/2	[*87 510 822*]	
4s	^2S	1/2	[87 478 420]	
4d	^2D	3/2	[87 510 760]	
		5/2	[87 521 643]	
4f	$^2F°$	5/2	[*87 521 623*]	
		7/2	[*87 527 037*]	
5p	$^2P°$	1/2	[*89 578 924*]	
		3/2	[*89 596 047*]	

Cu XXIX — Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
5*s*	^{2}S	1/2	[89 579 376]	
5*d*	^{2}D	3/2	[89 595 915]	
		5/2	[89 601 488]	
5*f*	^{2}F°	5/2	[*89 601 478*]	
		7/2	[*89 604 251*]	
5*g*	^{2}G	7/2	[89 604 246]	
		9/2	[89 605 906]	
	Limit		**[93 299 090]**	