TRANSITIONS OF THE TYPE 2s-2p IN HIGHLY-IONIZED Cu THROUGH Rb

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INTRODUCTION

We report here the observation of spectral lines in the F I, O I, N I, and C I isoelectronic sequences of Cu, Zn, Ga, Ge, As, Se, Br, and Rb. The plasma was produced by the spherical irradiation of solid targets using six frequency-tripled beams from the OMEGA laser system at the University of Rochester. The wavelengths were recorded using a 3 meter grazing incidence spectrograph, and the wavelengths were determined relative to several previously observed lines in the F I, O I, and Na I sequences. There is good overall consistency with the wavelengths recommended by Edlen (1983) for the F I and O I sequences and with the wavelengths measured by Kononov (1979) for the Na I sequence. Most of the observed transitions in the N I and C I sequences represent new identifications, and a complete set of energies for the $2s2p^4$ configuration of the N-like ions Cu XXIII, Zn XXIV, Ga XXV, and Ge XXVI is presented.

EXPERIMENT

The targets were spherically irradiated with an approximately cubic array of six beams from the OMEGA laser system. For each laser shot, the energy incident on target was between 200 J and 300 J with a pulse duration of 600 psec to 700 psec. Each laser beam was focused by an f/3.7 lens to a point a distance of 4 target radii beyond the center of the target. The average intensity of 351 nm light at the target surface was in the range 1×10^{14} to 2.5×10^{14} W/cm^2. The overall absorption of laser energy by the target was 88 to 92%. At the irradiation intensities used, the absorption process for the 351 nm radiation was almost entirely inverse bremsstrahlung with a very small fraction ($< 10^{-4}$) of the absorbed energy going to superthermal electrons.

In the case of zinc, the targets were solid fragments of pure zinc and were roughly spherical in shape with an average diameters of 450 μm. The copper, gallium, and germanium targets were coated glass microballoons. The average diameter of the microballoons was 350 μm, and the thickness of the glass shell was 1 μm. The thickness of the copper, gallium, and germanium coatings was 3 μm to 10 μm, and this was sufficiently thick so that burn-through to the glass microballoon did not occur. Spectral lines from the glass microballoon material are not present in any of the data.

The spectral data were accumulated over six shots for each of the four target materials. The spectra were recorded by a 3 meter grazing incidence (88°) spectrograph that has been described in detail by Behring et al. (1973). The spectrograph was fitted with a 600 or 1200 line/mm gold-coated Bausch and Lomb replica grating, and spectral lines were observed in the range 30 Å to 260 Å.

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The wavelengths of the spectral lines from the N-like ions Cu XXIII, Zn XXIV, Ga XXV, and Ge XXVI are listed in Table I. These transitions were identified using recently calculated wavelengths (Cheng et al. 1979) and by extrapolating from the wavelengths of lower-Z ions (Z=22,24,26,27,28) measured by Lawson et al. (1981).

Listed in Table II are the energy levels that are derived from the wavelengths given in Table I. In most cases, the total number of observed transitions was insufficient to determine all the levels of the lower configuration $2s^2\ 2p^3$. In such cases, we have adopted the values recommended by Edlén (1982 and 1983) and have designated the relative uncertainties by +x, +y, etc. The accuracy of the presently measured energy levels is estimated to be 250 cm^{-1}.

A more detailed description of this work will be published in the Journal of the Optical Society of America B.

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Table I. Classification of lines isoelectronic with N I. (Å)

Transition	Cu XXIII	Zn XXIV	Ga XXV	Ge XXVI
$2s^2 2p^3 - 2s\,2p^4$				
$^4S_{3/2}-^2P_{3/2}$	[67.30]	63.330	[59.56]	[55.94]
$^2D_{3/2}-^2P_{3/2}$	[76.07]	71.901	68.011	[64.33]
$^2D_{3/2}-^2S_{1/2}$	79.636 bl	75.285	71.210 bl	67.425
$^2D_{5/2}-^2P_{3/2}$	79.636 bl,B	75.499 A	71.549	67.829
$^2P_{3/2}-^2P_{1/2}$	83.335 B	78.986 A	74.880	70.987
$^2P_{1/2}-^2P_{3/2}$	[86.37]	81.863	77.545	[73.45]
$^2P_{1/2}-^2S_{1/2}$	91.028	86.266	81.783	77.515 bl
$^2D_{3/2}-^2D_{3/2}$	92.695 B	87.700 B	[83.07]	78.701
$^2D_{5/2}-^2D_{5/2}$	94.847 B	89.490 A,B	84.403	79.641
$^4S_{3/2}-^4P_{1/2}$	96.457	90.080	84.102	[74.49]
$^4S_{3/2}-^4P_{3/2}$	98.892	92.225 bl	85.927	80.084
$^4S_{3/2}-^4P_{5/2}$	[111.05]	104.556	98.341 bl	92.637 bl
$2s\,2p^4 - 2p^5$				
$^2D_{3/2}-^2P_{3/2}$	[93.63]	89.040	84.724	80.719
$^2D_{5/2}-^2P_{3/2}$	96.762 bl	92.632	88.756	85.190
$^2P_{1/2}-^2P_{1/2}$	[118.11]	112.428 bl		

A. Transitions previously identified by Behring, Cohen, Doschek, and Feldman (1976).

B. Transitions previously identified by Kononov, Kovalev, Ryabtsev, and Churilov (1977).

bl. Blend

[ ]. Interpolated

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Table II. Energy levels isoelectronic with N I.

Level		Cu XXIII	Zn XXIV	Ga XXV	Ge XXVI
$2s^2 2p^3$	$^4S_{3/2}$	0	0	0	0
	$^2D_{3/2}$	170900+x	188200	208500+x	233200+x
	$^2D_{5/2}$	230000+y	254500	281200+x	313200+y
	$^2P_{1/2}$	328100+x	357400	389700+x	426400+x
	$^2P_{3/2}$	446800+t	500100+t	560700+z	629100+t
$2s\,2p^4$	$^4P_{5/2}$		956400	1016900	1079500
	$^4P_{3/2}$	1011200	1084300	1163800	1248700
	$^4P_{1/2}$	1036700	1110000	1189000	
	$^2D_{3/2}$	1249700+x	1328500	1412400+x	1503800+x
	$^2D_{5/2}$	1284300+y	1372000	1466000+x	1568900+y
	$^2S_{1/2}$	1426700+x	1516600	1612800+x	1716600+x
	$^2P_{3/2}$	1485700+y	1579000	1678900+x	1787500+y
	$^2P_{1/2}$	1646800+t	1766200	1896200+z	2037800+t
$2p^5$	$^2P_{3/2}$	2317800+y	2451500	2592700+x	2742700+y

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