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Electromagnetic properties of states in ^{63}Zn through the ^{63}Cu$(p,n\gamma)^{63}$Zn reaction

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The level structure and the decay properties of levels in ^{63}Zn up to 2750 keV excitation have been studied through the ^{63}Cu$(p,n\gamma)$ reaction at incident proton energy between 5 and 7.8 MeV. Singles γ-ray spectra at angles of observation $\theta_\gamma=0°$, 20°, 40°, 55°, 70°, and 90° and $\gamma\gamma$-coincidence spectra were obtained with high resolution Ge(Li) detectors. From these experiments a decay scheme of ^{63}Zn has been obtained which includes 33 levels. The lifetimes or limits on the lifetimes of 24 levels were determined through the Doppler shift attenuation method by studying the systematic energy shift of γ-ray peaks in the angular distribution data. The analysis of angular distributions yielded multipole mixing ratios and J^π values for several states. The experimental information, wherever complete, was employed to calculate reduced transition probabilities.

[NUCLEAR REACTIONS ^{63}Cu$(p,n)^{63}$Zn$^*(\gamma)$, $E=5.0-7.8$ MeV; measured E_γ, $I_\gamma(\theta)$, $\Delta E_\gamma(\theta)$, $\gamma\gamma$ coincidences; deduced ^{63}Zn levels, J, π, branching ratios, τ, δ, $B(\Lambda)$ values; enriched target, Ge(Li) detector.]

I. INTRODUCTION

Although the level structure of ^{63}Zn has been extensively studied experimentally,[1–12] lifetimes of excited states, and hence transition probabilities, have been reported recently only by Mustaffa *et al.*[13,14] On the other hand, despite the numerous theoretical papers on zinc and copper nuclei, only one theoretical investigation[15] has been devoted to the ^{63}Zn isotope. The fundamental assumptions in this shell-model calculation were that ^{56}Ni forms an inert core and the active particles are restricted to the $2p_{3/2}$, $1f_{5/2}$, and $2p_{1/2}$ orbits. In a recent comparison between the thus predicted and the experimental levels a reasonably good agreement was observed.[14] A more decisive test of the theory, however, should include the comparison of electromagnetic properties.

In the present work the level structure and decay properties in ^{63}Zn were investigated by detailed in-beam γ-ray spectrometry using the reaction ^{63}Cu$(p,n\gamma)^{63}$Zn in order to obtain the necessary experimental information on ^{63}Zn which would render a comparison with theory more meaningful. Thus, a consistent decay scheme was constructed in which several new levels and transitions were added on the evidence of $\gamma\gamma$-coincidence data. Spin and mixing ratio values for most of the observed states and transitions were determined from directional correlation measurements of singles γ-ray spectra. Lifetimes for 11 states in ^{63}Zn and lower limits for 13 others were obtained from Doppler-shift-attenuation measurements. $B(\Lambda)$ values for many transitions were thus obtained.

II. EXPERIMENTAL PROCEDURE AND ANALYSIS OF THE DATA

States in ^{63}Zn up to an excitation energy of 2.8 MeV were studied via the ^{63}Cu$(p,n\gamma)$ reaction

($Q = -4.1$ MeV) between 5.0 and 7.8 MeV incident proton energies. The beam was supplied by the high intensity T11/25 tandem Van de Graaff accelerator of the Nuclear Research Center Demokritos. The targets employed were self-supporting foils, 3.8 mg/cm^2 thick, of copper metal enriched to 99.7% in mass 63. For γ ray counting a high-resolution 65 cm^3 Ge(Li) detector was used. The detector resolution at 1332 keV was better than 1.9 keV FWHM. Standard electronics were employed for the accumulation of spectra over 4096 channels in a PDP-11/15 on-line computer.

The experimental setup and procedure for in-beam γ-ray spectroscopy at the Tandem Laboratory of the N.R.C. Democritos is presented in greater detail elsewhere.[16] A typical singles spectrum obtained in this way from the bombardment of ^{63}Cu with 7 MeV protons is shown in Fig. 1. In this spectrum the γ rays assigned in the ^{63}Zn decay scheme are simply indicated by their energy in keV. Peaks due to inelastic scattering, background, or unidentified radiations are labeled as *p*, *b*, or *u*, respectively. The γ-ray energies measured are given in the fifth column of Table I. In the present study three types of experiments, namely, $\gamma\gamma$-coincidence, angular distribution, and Doppler-shift attenuation measurements, were performed.

A. $\gamma\gamma$-coincidence relationships

The coincidence relationships for the γ-ray cascades in ^{63}Zn were established in an experiment

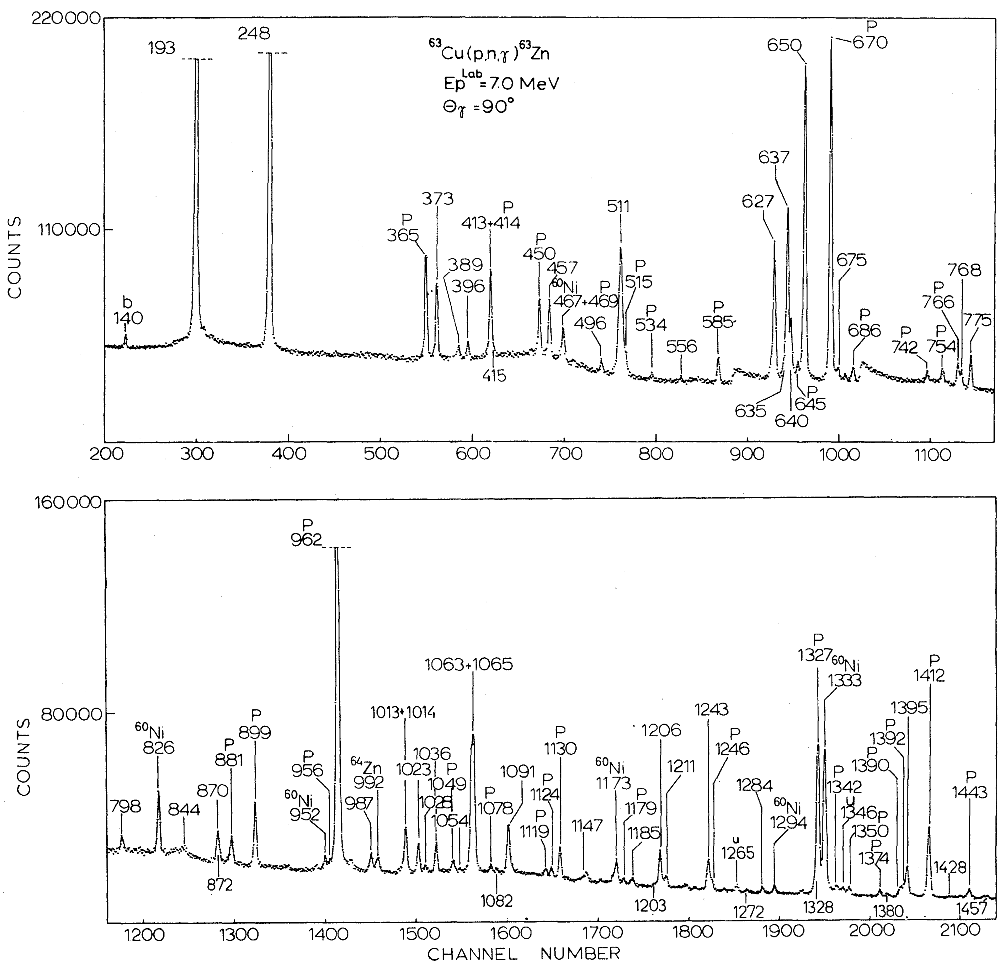

FIG. 1. Gamma-ray spectrum from the ^{63}Cu($p,n\gamma$)^{63}Zn reaction at 7.0 MeV taken at 90° to the beam direction. The γ rays labeled only by energy have been assigned to ^{63}Zn. Peaks labeled as *p* are associated with ($p,p'\gamma$); peaks labeled by *b* are due to background radiation; peaks labeled by *u* are unassigned.

with the $(p,n\gamma)$ reaction at 7.8 MeV. In this experiment the previously described 65 cm^3 detector was used in conjunction with a 45 cm^3 Ge(Li) detector which had FWHM of 1.8 keV at 1332 keV. The Ge(Li) detectors were positioned at 55° on each side of the beam. The coincidence resolving time was better than 10 nsec.

The data were recorded on magnetic tape event by event in a related address format of a 256 $\times$2048$\times$2048 channel three-parameter configuration. They were subsequently analyzed off line by placing proper gates on peaks of interest and nearby Compton background. The $\gamma\gamma$-coincidence relationships established from this experiment are summarized in Table II. The first column in this table gives the γ-ray energy in the gated detector, and the second column lists the energy of the γ rays observed in the corresponding coincidence gate. Some coincidence spectra after background subtraction are shown in Fig. 2.

B. Angular distributions

Spins of level and multipole mixing ratios of electromagnetic transitions were obtained from singles angular distribution measurements at 5 and 7 MeV incident proton energies. Singles γ-ray spectra were taken at six detector angles, $\theta_d = 0°$, 20°, 40°, 55°, 70°, and 90°, with respect to the proton beam. The normalization of the spectra was carried out with the help of high intensity peaks in the associated spectra of a fixed Ge(Li) monitor.

The experimental angular distributions were first

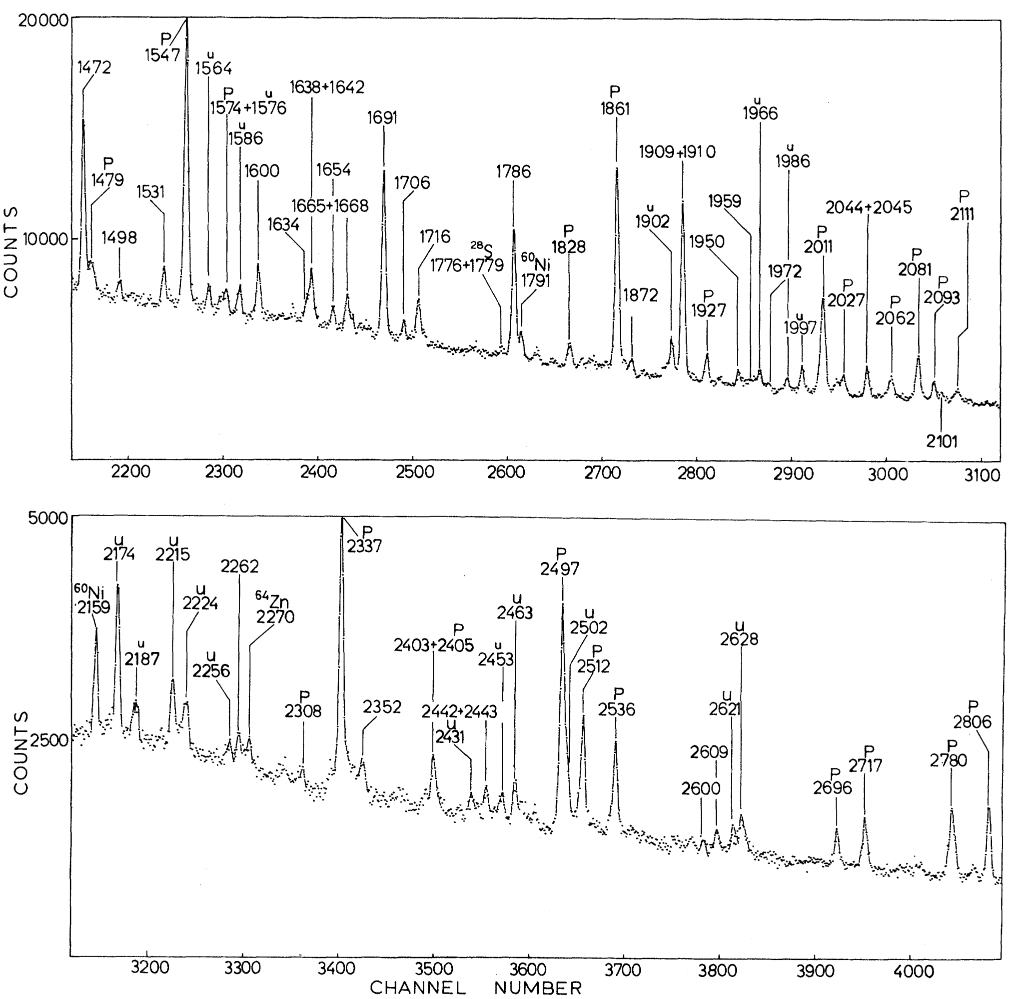

FIG. 1. *(Continued.)*

TABLE I. Summary of level energies, J^{π} values, γ-ray energies, and branching fractions for transitions in ^{63}Zn determined in this work.

Level no.	Level energy (keV)[a]	J^{π}	Transition	γ-ray (keV)	Branching % Present work	Branching % Mustaffa *et al.* (Refs. 13 and 14)	Branching % Metford *et al.* (Ref. 12)
0	0	$\frac{3}{2}^-$					
1	192.94(6)	$\frac{5}{2}^-$	1→0	192.94(6)	100	100	100
2	247.84(7)	$\frac{1}{2}^-$	2→0	247.84(7)	100	100	100
3	627.10(7)	$\frac{1}{2}^-$	3→0	627.10(7)	100	100	100
4	637.06(6)	$\frac{3}{2}^-$	4→0	637.04(7)	96.0(4)	95.8(4)	95
			4→2	389.26(9)	4.0(4)	4.2(4)	5
5	650.14(5)	$\frac{5}{2}^-$	5→0	650.14(6)	86.6(9)	85.4(12)	90
			5→1	457.19(6)	13.4(9)	14.6(12)	10
6	1023.22(5)	$\frac{3}{2}^-$	6→0	1023.22(8)	27.0(13)	30.6(16)	30
			6→2	775.43(8)	27.7(14)	27.0(20)	25
			6→3	396.1(1)	6.5(5)	5.8(4)	5
			6→5	373.06(8)	38.8(19)	36.6(16)	40
7	1063.26(7)	$\frac{7}{2}^-$	7→0	1063.2 (2)	65.6(16)		60
			7→1	870.25(10)	15.9(9)		15
			7→5	413.2(1)	18.5(13)		25
8	1065.3(1)	$\frac{5}{2}^-$	8→0	1065.2(2)	91.4(6)		
			8→1	872.4 (2)	4.8(4)		
			8→5	415.2 (2)	3.8(4)		
9	1206.38(7)	$\frac{7}{2}^-$	9→0	1206.34(11)	50.9(22)	46.4(22)	50
			9→1	1013.45(10)	46.9(20)	50.6(22)	50
			9→5	556.3(2)	2.2(2)	3.0(3)	
10	1284.27(6)	$\frac{5}{2}^-$	10→0	1284.21(15)	6.6(5)	6.1(6)	5
			10→1	1091.40(8)	58.1(15)	59.4(20)	70
			10→2	1036.34(8)	27.6(13)	34.5(19)	25
			10→5	634.5(5)	7.7(6)		
11	1395.4(1)	$\frac{3}{2}^-$	11→0	1395.39(15)	70.0(13)	48(1)	
			11→1	1202.8 (5)	4.0(5)	4(3)	
			11→2	1147.3 (4)	6.7(8)	5(2)	
			11→3	768.36(12)	19.3(12)	43(2)	
12	1436.22(12)	$\frac{9}{2}^-$	12→1	1243.28(10)	100	100	95
13	1664.9(1)		13→0	1664.8(2)	14.9(10)	25(1)	
			13→1	1472.0(1)	59.8(25)	75(1)	
			13→4	1027.8(2)	12.1(8)		
			13→5	1014 (1)	13.2(12)		
14	1691.2(1)	$\frac{5}{2}^-$	14→0	1691.2 (1)	84.7(1)	88(1)	100
			14→1	1498.3(2)	10.0(7)	6(3)	
			14→4	1054.1(3)	5.3(7)	6(3)	
15	1702.9(1)	$\frac{9}{2}^+$	15→7	639.64(10)	84.9(13)	85(1)	85
			15→9	496.56(12)	15.1(13)	15(1)	15

TABLE I. (*Continued.*)

Level no.	Level energy (keV)[a]	J^π	Transition	γ-ray energy (keV)	Branching % Present work	Mustaffa *et al.* (Refs. 13 and 14)	Metford *et al.* (Ref. 12)
16	1860.8(1)	$\frac{9}{2}^-$	16→1	1668.0(4)	15.3(20)	4(2)	11
			16→5	1210.7(2)	61.3(20)	70(3)	56
			16→7	797.5(2)	23.4(14)	26(3)	33
17	1909.2(2)	$\frac{5}{2}^-$	17→0	1909.0(3)	70.5(14)		
			17→1	1716.3(2)	22.7(14)		
			17→4	1272.3(2)	6.8(5)		
18	1978.5(2)	$\frac{3}{2}^-,\frac{5}{2}^-,\frac{7}{2}$	18→1	1785.5(2)	73.7(24)	77(2)	
			18→5	1328.0(5)	26.3(24)	23(2)	
19	2050.4(2)	$\frac{9}{2}^-$	19→7	987.1(2)	61(3)	70(2)	
			19→9	844.1(4)	39(3)	30(2)	
20	2158.1(2)	$\frac{3}{2}^-$	20→2	1910.4(3)	60(2)	90(1)	
			20→3	1530.8(3)	40(2)	10(1)	
21	2250.0(2)	$\frac{3}{2}^-,\frac{5}{2}^-,\frac{7}{2}^-$	21→5	1599.8(2)	50(2)	29(2)	
			21→8	1184.8(2)	50(2)	71(2)	
22	2261.5(2)	$\frac{3}{2}^-$	22→0	2261.5(3)	26(2)		
			22→3	1634.4(2)	74(2)		
23	2288.3(2)	$\frac{7}{2}^-$	23→5	1638.2(2)	68(2)		
			23→9	1081.9(3)	32(2)		
24	2291.5(2)	$\frac{3}{2}^-$	24→2	2043.6(3)	27(2)		
			24→4	1654.2(2)	39(2)		
			24→5	1641.7(3)	34(2)		
25	2292.9(3)	$(\frac{3}{2}^-)$	25→2	2045.1(3)	100		
26	2377.8(2)	$\frac{9}{2}^+$	26→15	674.9(2)	100	100	
27	2403.3(2)	$\leq\frac{5}{2}$	27→3	1776.4(5)	35(5)		
			27→6	1380.0(2)	65(5)		
28	2520.1(2)	$\frac{3}{2}^-$	28→5	1871.9(2)	49(4)		
			28→7	1456.9(2)	51(4)		
29	2600.0(4)	$\leq\frac{5}{2}$	29→0	2599.8(8)	13(3)		
			29→2	2351.7(4)	44(4)		
			29→5	1950.5(4)	43(4)		
30	2609.1(4)		30→0	2609.1 (5)	38(5)		
			30→4	1971.9(8)	17(5)		
			30→5	1959.0(7)	45(5)		
31	2634.5(2)		31→1	2441.6(3)	55(3)	30(2)	
			31→9	1428.1(3)	45(3)	70(2)	
32	2691 (1)		32→2	2443 (1)	100		
33	2750.7(3)		33→1	2557.7(6)	46(8)		
			33→5	2100.6(4)	54(8)		

[a]Level energy obtained as a weighted average of the energy sums of γ rays deexciting each level. The numbers in parentheses in all columns are the estimated uncertainties referring to the last quoted significant figure.

analyzed by a least-squares fit to the function

$$W(\theta_d)=A_0[1+A_2P_2(\cos\theta_d)+A_4P_4(\cos\theta_d)] . \quad (1)$$

The coefficients of the Legendre polynomials obtained in this way were not corrected for solid angle due to the large distance of the detector from the target, which essentially reduced the corresponding geometrical attenuation coefficients to unity.

The A_0 values give the branching ratios reported

TABLE II. Summary of the observed $\gamma\gamma$-coincidence relationships in the decay of levels in ^{63}Zn populated in the ^{63}Cu$(p,n\gamma)$ reaction at $E_p=7.8$ MeV.

γ-ray energy in the Ge(Li) gate (keV)	γ ray seen in the Ge(Li) coincidence spectrum (keV)
193	373, 413, 457, 640, 870, 1013, 1091, 1211, 1243, 1472, 1498, 1716, 1786, 2442, 2558
248	389, 775, 1036, 1147, 1910, 2043, 2045, 2352, 2443,
627	396, 768, 1531, 1634, 1776
650	373, 413, 556, 635, 640 1014, 1211, 1328, 1600, 1638 1872, 1950, 1959, 2101
413	457, 640, 650, 797, 987
1064+1065	640, 797, 987, 1185
1013+1014	193, (496), 650, 844, 1082
768	627
640	193, 413, 650, 675, 1063
987	413, 650, 1063

in the sixth column of Table I. Measurements at 55° to the beam were used for the determination of the branching ratios for these levels for which angular distribution of deexciting transitions was not feasible to obtain. Coincidence intensities were also used to extract branching ratios, especially in cases of overlapping multiplets. The experimentally obtained A_2 and A_4 coefficients for each transition are given in Table III.

The theoretical angular distributions were calculated in the framework of the Hauser-Feshbach theory of nuclear reactions with a modified version of the program MANDY originally written by Sheldon and Strang.[17] Transmission coefficients for the proton channels were obtained from the tables of Mani *et al.*,[18] while the coefficients for the neutron channels were obtained from the tables of Auerbach and Perey.[19] The theoretical A_2 and A_4 coefficients from these calculations for various assumptions on the spin of the decaying state are given in Table III below the corresponding experimental quantities. Initial spin values were considered in a range permitted by the mode of decay of the state under consideration. The minimum χ^2 value divided by the degrees of freedom and the corresponding δ value at the minimum are contained in the fourth and fifth columns of Table III. The uncertainties quoted with the present δ values refer to the 95.5% confidence limit and are evaluated according to the procedure prescribed by Rogers.[20] The mixing ratio δ is defined in terms of emission matrix elements according to Krane and Steffen.[21] In several instances the present results are compared with the δ values of Metford *et al.*[12] and Mustaffa *et al.*,[13,14] shown in the sixth and seventh columns, obtained via the ^{60}Ni$(\alpha,n\gamma)$ reaction. Since these authors employ a different convention, the signs of δ given in Refs. 12–14 have been reversed here.

C. Lifetime measurements

The lifetimes of 11 states in ^{63}Zn and lower limits for 13 others were determined from γ-ray photopeaks exhibiting an energy shift as a function of detector angle. Singles spectra were measured at six angles $\theta_d=0°$, 20°, 40°, 55°, 70°, and 90° with respect to the beam at 7 MeV bombarding energy. According to the particular variant[22,23] of the Doppler shift attenuation method employed here, the energy of the emitted γ ray E_γ, observed at an angle θ_γ with respect to the beam, is given by

$$E_\gamma=E_0[1+\widetilde{F}(\tau)\beta_{\text{c.m.}}\cos\theta_\gamma] , \qquad (2)$$

where E_0 is the energy of the transition (observed at $\theta_\gamma=90°$), $\beta_{\text{c.m.}}$ is the center of mass velocity, and $\widetilde{F}(\tau)$ is the attenuation factor averaged over all initial velocities of the recoil nucleus by employing the angular correlation function as a weighting factor.

As indicated in Eq. (2), experimental values of $\widetilde{F}(\tau)$ may be obtained through a linear fit of the energy E_γ observed in the angular distribution spectra versus $\cos\theta_\gamma$. For some of the cases examined here this procedure is shown in Fig. 3. These values were compared with theoretical calculations of $\widetilde{F}(\tau)$ as described in Ref. 22. In the calculation of the attenuation factor the slowing-down theory of Lindhard, Scharff, and Schiøtt[24] (LSS) and the average scattering in the stopping material estimated by Blaugrund[25] were used.

The functional form of the nuclear stopping power was approximated by the expression

$$\left[\frac{d\epsilon}{d\rho}\right]_n=\frac{\epsilon^{1/2}}{0.67+2.07\epsilon+0.03\epsilon^2} , \qquad (3)$$

where ϵ and ρ denote the dimensionless energy and length parameters introduced by LSS. Since the applicability of the statistical theory of nuclear reactions was ensured by the experimental condi-

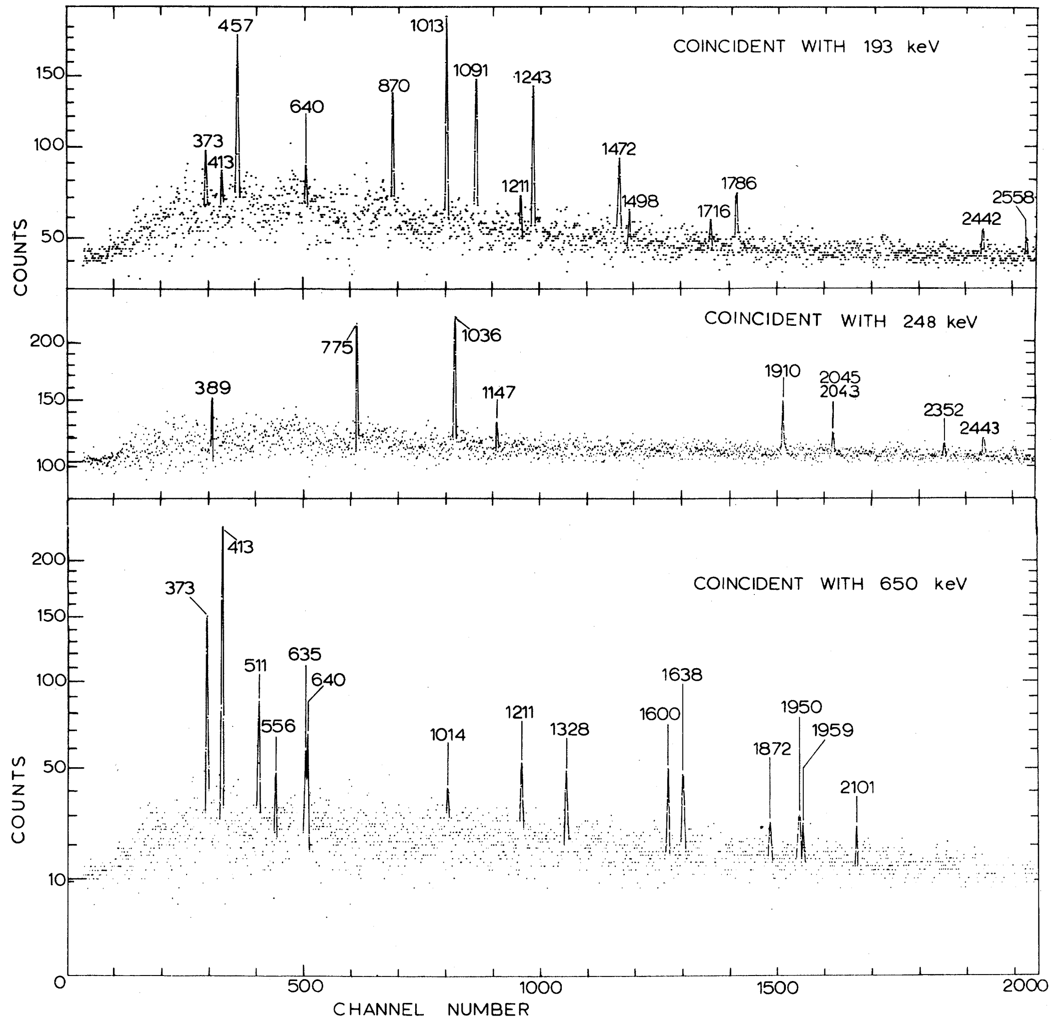

FIG. 2. Gamma-ray spectra from the ^{63}Cu($p,n\gamma$)^{63}Zn reaction at 7.8 MeV in coincidence with the indicated γ ray peaks. The contribution from the underlying Compton events has been subtracted.

tions, the averaging of the attenuation factor was performed by considering an expression[22,26] for the angular correlation function $W(\theta_\gamma,\theta_N,\phi_N)$ symmetric about the recoil c.m. angle $\theta_N=\frac{1}{2}\pi$ and almost independent of the azimuthal recoil angle ϕ_N.

Table IV contains the averaged attenuation factors measured in this experiment for transitions emanating from 23 levels in ^{63}Zn. The lifetimes of these states, extracted from the comparison with the theoretical $\widetilde{F}(\tau)$, are given in the fifth column of Table IV. The experimental error associated with the extracted values of the lifetime contains a 20% uncertainty in the LSS prediction for the stopping power and a 6% estimated error arising from realistic variations in the expression employed for the angular correlation function. The lifetimes obtained here are compared in the adjacent column of Table IV with the results for 11 states of Mustaffa *et al.*[13,14] With the exception of levels 20 and 21 the two sets of results are seen to agree within the experimental error. For these cases of agreement the next column of Table IV contains the weighted average of lifetimes obtained here and in Refs. 13 and 14. The averaged lifetimes are subsequently adopted for the calculation of reduced transition probabilities.

D. Proposed decay scheme and assignment of J^π values

On the basis of the evidence obtained in this work, a detailed scheme for the decay of 33 levels up to 2750 keV in ^{63}Zn was constructed and is

TABLE III. Summary of angular distribution analysis.

Transition (keV) $J_i \rightarrow J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
192.9→0	−0.12(1)	0.003(1)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.05	0.00	4.5				
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.11	0.00	0.8	$-0.08^{+0.03}_{-0.04}$ or $-2.5^{+0.2}_{-0.3}$	$+0.07^{+0.02}_{-0.03}$	0.3±0.02	0.01±0.04[c]
247.8→0	−0.01(1)	0.03(1)					
$\frac{1}{2}\rightarrow\frac{3}{2}$	0.00	0.00	1.4	indeterminate			$M1+E2$
$\frac{3}{2}\rightarrow\frac{3}{2}$	0.01	0.00	1.2	−0.14±0.10 or $9.5^{+\infty}_{-4.8}$			
$\frac{5}{2}\rightarrow\frac{3}{2}$	0.02	0.00	1.4	$0.24^{+0.04}_{-0.06}$ or pure $E2$			
627.1→0	0.01(1)	0.01(1)					
$\frac{1}{2}\rightarrow\frac{3}{2}$	0.00	0.00	0.4	indeterminate			$M1+E2$
$\frac{3}{2}\rightarrow\frac{3}{2}$	0.01	0.00	0.3	$-0.12^{+0.13}_{-0.10}$			
$\frac{5}{2}\rightarrow\frac{3}{2}$	0.00	0.00	0.4	0.22±0.04			
637.1→0	0.02(1)	0.00(1)					
$\frac{1}{2}\rightarrow\frac{3}{2}$	0.00	0.00	1.2	indeterminate			
$\frac{3}{2}\rightarrow\frac{3}{2}$	0.01	0.00	1.0	−0.09±0.18	0.04±0.02	0.02±0.03 or 3.6±0.6	0.03±0.02
$\frac{5}{2}\rightarrow\frac{3}{2}$	0.00	0.00	1.1	0.20±0.03			
637.1→247.8	0.00(4)	−0.10(5)					
$\frac{1}{2}\rightarrow\frac{1}{2}$	0.00	0.00	0.5	indeterminate			
$\frac{3}{2}\rightarrow\frac{1}{2}$	−0.04	0.00	0.8	$0.0^{+0.2}_{-0.3}$ or $1.8^{+0.8}_{-1.7}$	$-0.05^{+0.03}_{-0.04}$		$-0.05^{+0.03}_{-0.04}$
650.1→0	−0.25(2)	0.00(2)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.06	0.00	50				
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.24	0.00	0.4	−0.75±0.18	0.57±0.03	−0.29±0.03	−0.43±0.10
$\frac{7}{2}\rightarrow\frac{3}{2}$	0.00	−0.05	70				

TABLE III. (*Continued.*)

Transition (keV) $J_i \to J_f$	A_2 Experimental[a] Theoretical	A_4 Experimental[a] Theoretical	χ^2	Mixing ratio δ Present work	Mixing ratio δ Mustaffa *et al.* (Ref. 14)	Mixing ratio δ Metford *et al.* (Ref. 12)	Proposed[b]
650.1→192.9	0.09(2)	0.02(2)					
$\frac{3}{2}\to\frac{5}{2}$	0.03	0.00	5.7				
$\frac{5}{2}\to\frac{5}{2}$	0.09	0.00	0.2	0.07 ± 0.06 or $1.5^{+0.3}_{-0.2}$	$-0.08^{+0.01}_{-0.02}$	0.00 ± 0.04 or -1.7 ± 0.2	-0.06 ± 0.02
1023.2→0	0.09(2)	0.00(2)					
$\frac{3}{2}\to\frac{3}{2}$	0.09	0.00	1.2	$0.8^{+0.9}_{-0.7}$	1.9 ± 0.2	0.4 ± 0.2 or 1.5 ± 0.5	$M1+E2$
$\frac{5}{2}\to\frac{3}{2}$	0.09	0.00	1.2	$0.43^{+0.07}_{-0.05}$ or $8.6^{+3.8}_{-2.4}$			
$\frac{7}{2}\to\frac{3}{2}$	0.10	-0.03	1.9	-0.20 ± 0.05			
1023.2→247.8	$-0.05(2)$	0.00(2)					
$\frac{1}{2}\to\frac{1}{2}$	0.00	0.00	4.1				
$\frac{3}{2}\to\frac{1}{2}$	-0.05	0.00	0.7	0.00 ± 0.08 or $-1.7^{+0.3}_{-0.4}$	$-0.91^{+0.24}_{-0.06}$	-0.2 ± 0.1 or -1.3 ± 0.3	$M1+E2$
$\frac{5}{2}\to\frac{1}{2}$	0.06	-0.01	15				
1023.2→650.1	$-0.01(2)$	0.04(2)					
$\frac{3}{2}\to\frac{5}{2}$	0.02	0.00	1.6	$-0.32^{+0.21}_{-0.28}$ or $1.7^{+0.6}_{-0.8}$	$-0.82^{+0.04}_{-0.05}$	-0.4 ± 0.1 or -1.5 ± 0.5	$M1+E2$
1063.3→0	0.19(2)	$-0.02(2)$					
$\frac{3}{2}\to\frac{3}{2}$	0.10	0.00	9.6				
$\frac{5}{2}\to\frac{3}{2}$	0.18	0.00	0.5	0.88 ± 0.15 or 2.3 ± 0.5			
$\frac{7}{2}\to\frac{3}{2}$	0.19	-0.02	0.3	0.00 ± 0.03			
1063.3→192.9	0.24(2)	0.01(2)					
$\frac{3}{2}\to\frac{5}{2}$	0.04	0.00	56				
$\frac{5}{2}\to\frac{5}{2}$	0.16	0.00	10				
$\frac{7}{2}\to\frac{5}{2}$	0.24	0.01	0.5	0.58 ± 0.04 or 3.5 ± 0.3		0.51 ± 0.05	0.55 ± 0.03

TABLE III. (*Continued.*)

Transition (keV) $J_i \to J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
1063.3→650.1	−0.26(2)	0.02(2)					
$\frac{3}{2}\to\frac{5}{2}$	−0.09	0.00	39				
$\frac{5}{2}\to\frac{5}{2}$	−0.11	0.00	29				
$\frac{7}{2}\to\frac{5}{2}$	−0.26	0.03	0.8	-0.17 ± 0.03 or -2.5 ± 0.2		-0.08 ± 0.03	-0.12 ± 0.05
1065.3→0	−0.19(2)	0.02(2)					
$\frac{3}{2}\to\frac{3}{2}$	−0.06	0.00	21				
$\frac{5}{2}\to\frac{3}{2}$	−0.19	0.00	0.3	-0.30 ± 0.07 or -1.6 ± 0.2			-0.30 ± 0.07 or -1.6 ± 0.2
$\frac{7}{2}\to\frac{3}{2}$	0.00	−0.05	36				
1065.3→650.1	−0.04(5)	0.02(6)					
$\frac{3}{2}\to\frac{5}{2}$	−0.03	0.00	2.6	0.2 ± 0.5 or $E2$			
$\frac{5}{2}\to\frac{5}{2}$	−0.03	0.00	2.6	-0.6 ± 0.4			-0.6 ± 0.4 or $E2$
$\frac{7}{2}\to\frac{5}{2}$	−0.03	0.00	2.6	0.14 ± 0.08			
1206.4→0	0.19(2)	−0.01(2)					
$\frac{3}{2}\to\frac{3}{2}$	0.10	0.00	27				
$\frac{5}{2}\to\frac{3}{2}$	0.19	0.00	1.5	0.87 ± 0.06 or 2.3 ± 0.3			
$\frac{7}{2}\to\frac{3}{2}$	0.19	−0.02	1.3	0.01 ± 0.02	-0.03 ± 0.02		$E2$
1206.4→650.1	−0.35(11)	0.03(14)					
$\frac{5}{2}\to\frac{5}{2}$	−0.11	0.00	1.3	$-1.8^{+0.8}_{-2.8}$			
$\frac{7}{2}\to\frac{5}{2}$	−0.35	0.02	0.1	-0.32 ± 0.06 or -1.8 ± 0.2	-1.24 ± 0.09		-1.3 ± 0.2
1284.3→0	−0.34(8)	0.04(9)					
$\frac{3}{2}\to\frac{3}{2}$	−0.06	0.00	5.6				
$\frac{5}{2}\to\frac{3}{2}$	−0.25	0.00	0.9	$-0.75^{+0.30}_{-0.20}$	-0.70 ± 0.20	-0.8 ± 0.3	-0.74 ± 0.14
$\frac{7}{2}\to\frac{3}{2}$	0.00	−0.06	7.0				

TABLE III. (*Continued.*)

Transition (keV) $J_i \rightarrow J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
1284.3→192.9	−0.02(2)	−0.02(2)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.02	0.00	1.6	$0.11^{+0.13}_{-0.10}$			
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.02	0.00	1.6	-0.50 ± 0.08 or 10^{+19}_{-4}		-0.39 ± 0.05 or 4.3 ± 1.2	-0.42 ± 0.05 or 4.5 ± 1.6
1284.3→247.8	0.13(2)	0.03(2)					
$\frac{3}{2}\rightarrow\frac{1}{2}$	0.10	0.00	2.8				
$\frac{5}{2}\rightarrow\frac{1}{2}$	0.13	0.00	1.3	0.02 ± 0.05	-0.01 ± 0.01		$E2$
1395.4→0	0.10(2)	−0.02(2)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	0.10	0.00	1.0	$0.78^{+0.45}_{-0.33}$	$0.36^{+0.14}_{-0.10}$		$0.40^{+0.14}_{-0.12}$
$\frac{5}{2}\rightarrow\frac{3}{2}$	0.11	0.00	1.0	0.50 ± 0.09			
1395.4→627.1	0.02(4)	−0.01(4)					
$\frac{3}{2}\rightarrow\frac{1}{2}$	0.02	0.00	0.2	$0.37^{+0.25}_{-0.18}$ or $\delta\geq3$			$0.37^{+0.25}_{-0.18}$ or $\delta\geq3$
$\frac{5}{2}\rightarrow\frac{1}{2}$	0.06	−0.01	0.5	$-0.7^{+0.4}_{-0.5}$			
1436.2→192.9	0.25(2)	−0.06(2)					
$\frac{3}{2}\rightarrow\frac{5}{2}$	0.04	0.00	46				
$\frac{5}{2}\rightarrow\frac{5}{2}$	0.17	0.00	6.5				
$\frac{7}{2}\rightarrow\frac{5}{2}$	0.21	0.01	4	0.47 ± 0.05			
$\frac{9}{2}\rightarrow\frac{5}{2}$	0.25	−0.04	0.4	-0.02 ± 0.03	0.01 ± 0.02		$E2$
1664.9→0	−0.07(4)	0.09(5)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.04	0.00	1.3	$\delta\leq0.2$			
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.04	0.00	1.3	0.10 ± 0.09			
$\frac{7}{2}\rightarrow\frac{3}{2}$	0.01	−0.06	2.6	$-1.9\leq\delta\leq-0.05$	0.03 ± 0.03		

TABLE III. (*Continued.*)

Transition (keV) $J_i \rightarrow J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
1664.9→192.9	−0.04(2)	0.01(2)					
$\frac{3}{2}\rightarrow\frac{5}{2}$	−0.04	0.00	0.2	$0.30^{+0.23}_{-0.11}$ or $E2$			
$\frac{5}{2}\rightarrow\frac{5}{2}$	−0.04	0.00	0.2	-0.64 ± 0.09 or $E2$			
$\frac{7}{2}\rightarrow\frac{5}{2}$	−0.04	0.00	0.2	0.11 ± 0.03	0.18 ± 0.03		
1664.9→637.1	0.11(5)	0.01(5)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	0.10	0.00	0.6	$0.7^{+1.3}_{-0.5}$			
$\frac{5}{2}\rightarrow\frac{3}{2}$	0.12	0.00	0.6	0.50 ± 0.14 or 7^{+10}_{-3}			
$\frac{7}{2}\rightarrow\frac{3}{2}$	0.13	−0.04	0.8	-0.18 ± 0.10 or $-3.7^{+1.0}_{-2.0}$			
1691.2→0	−0.17(2)	0.01(2)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.06	0.00	10				
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.17	0.00	0.7	-0.19 ± 0.06 or -2.0 ± 0.3	-0.10 ± 0.03		-0.12 ± 0.04
$\frac{7}{2}\rightarrow\frac{3}{2}$	0.00	−0.06	23				
1691.2→192.9	0.09(7)	0.09(8)					
$\frac{3}{2}\rightarrow\frac{5}{2}$	0.04	0.00	1.2				
$\frac{5}{2}\rightarrow\frac{5}{2}$	0.11	0.00	0.9	$-0.2\leq\delta\leq2.8$			$-0.2\leq\delta\leq2.8$
1702.9→1063.3	−0.17(2)	−0.01(2)					
$\frac{3}{2}\rightarrow\frac{7}{2}$	−0.07	0.00	8				
$\frac{5}{2}\rightarrow\frac{7}{2}$	−0.18	0.00	0.5	$0.54^{+0.13}_{-0.10}$ or 2.7 ± 0.8			
$\frac{7}{2}\rightarrow\frac{7}{2}$	−0.17	−0.03	0.7	$-9.2\leq\delta\leq-1.2$			
$\frac{9}{2}\rightarrow\frac{7}{2}$	−0.18	0.00	0.5	0.00 ± 0.02		0.00 ± 0.02	$E1$
$\frac{11}{2}\rightarrow\frac{7}{2}$	−0.03	−0.18	12				

TABLE III. (*Continued.*)

Transition (keV) $J_i \rightarrow J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
1702.9→1206.4	−0.24(3)	0.02(4)					
$\frac{3}{2}\rightarrow\frac{7}{2}$	−0.07	0.00	7				
$\frac{5}{2}\rightarrow\frac{7}{2}$	−0.23	0.00	0.8	$1.2^{+0.9}_{-0.5}$			
$\frac{7}{2}\rightarrow\frac{7}{2}$	−0.19	−0.02	1.3	$-2.3^{+0.8}_{-1.5}$			
$\frac{9}{2}\rightarrow\frac{7}{2}$	−0.24	0.00	0.8	−0.01±0.03	0.02±0.02	0.02±0.03	$E1$
$\frac{11}{2}\rightarrow\frac{7}{2}$	−0.08	−0.02	9				
1860.8→650.1	0.30(2)	0.01(2)					
$\frac{3}{2}\rightarrow\frac{5}{2}$	0.04	0.00	35				
$\frac{5}{2}\rightarrow\frac{5}{2}$	0.18	0.00	8				
$\frac{7}{2}\rightarrow\frac{5}{2}$	0.30	0.01	0.4	0.64±0.07 or $2.9^{+0.6}_{-0.4}$		0.5±0.1	
$\frac{9}{2}\rightarrow\frac{5}{2}$	0.31	−0.03	0.4	0.02±0.05	0.01±0.02		$E2$
1860.8→1063.3	−0.25(4)	−0.06(5)					
$\frac{3}{2}\rightarrow\frac{7}{2}$	−0.07	0.00	15				
$\frac{5}{2}\rightarrow\frac{7}{2}$	−0.23	0.00	1.7	1.2±0.4			
$\frac{7}{2}\rightarrow\frac{7}{2}$	−0.20	−0.03	2.0	−2.5±0.8		−0.8±0.1	
$\frac{9}{2}\rightarrow\frac{7}{2}$	−0.26	0.00	0.9	−0.07±0.04	−0.03±0.02		−0.04±0.02
1909.2→0	−0.17(2)	0.02(2)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.05	0.00	12				
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.17	0.00	1.7	−0.18±0.05 or −2.1±0.2			−0.18±0.05 or −2.1±0.2
$\frac{7}{2}\rightarrow\frac{3}{2}$	0.00	−0.07	20				
1909.2→192.9	0.06(3)	0.02(4)					
$\frac{3}{2}\rightarrow\frac{5}{2}$	0.03	0.00	0.8	$-0.8^{+0.5}_{-0.9}$			
$\frac{5}{2}\rightarrow\frac{5}{2}$	0.06	0.00	0.6	−0.15±0.11 or 2.5±0.7			−0.15±0.11 or 2.5±0.7
$\frac{7}{2}\rightarrow\frac{5}{2}$	0.06	0.00	0.6	0.25±0.04 or $E2$			

TABLE III. (*Continued.*)

Transition (keV) $J_i \rightarrow J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
1909.2→637.1	−0.08(8)	0.00(10)					
$\frac{3}{2}\rightarrow\frac{3}{2}$	−0.06	0.00	0.2	$\delta \leq -0.3$			
$\frac{5}{2}\rightarrow\frac{3}{2}$	−0.09	0.00	0.2	0.0 ± 0.2 or $-3.6^{+1.7}_{-6.0}$			-0.0 ± 0.2 or $-3.6^{+1.7}_{-6.0}$
1978.5→192.9	−0.08(2)	0.01(2)					
$\frac{3}{2}\rightarrow\frac{5}{2}$	−0.07	0.00	0.4	$0.6 \leq \delta \leq 3.2$			
$\frac{5}{2}\rightarrow\frac{5}{2}$	−0.08	0.00	0.3	-0.8 ± 0.1 or -9^{+4}_{-10}			
$\frac{7}{2}\rightarrow\frac{5}{2}$	−0.08	0.00	0.3	$0.12^{+0.05}_{-0.03}$			
$\frac{9}{2}\rightarrow\frac{5}{2}$	0.02	−0.12	15	$-2.4^{+1.4}_{-2.3}$	-0.10 ± 0.05		
2050.4→1063.3	−0.50(4)	0.07(4)					
$\frac{3}{2}\rightarrow\frac{7}{2}$	−0.06	0.00	79				
$\frac{5}{2}\rightarrow\frac{7}{2}$	−0.24	0.00	23				
$\frac{7}{2}\rightarrow\frac{7}{2}$	−0.22	−0.03	23				
$\frac{9}{2}\rightarrow\frac{7}{2}$	−0.47	0.01	0.5	-0.20 ± 0.04 or -2.2 ± 0.2		-0.40 ± 0.05	$-(0.28\pm0.10)$
$\frac{11}{2}\rightarrow\frac{7}{2}$	−0.15	−0.33	22				
2158.1→247.8	0.16(5)	−0.01(6)					
$\frac{3}{2}\rightarrow\frac{1}{2}$	0.09	0.00	0.9	$1.7^{+2.6}_{-0.8}$	-2.3 ± 0.2		$1.7^{+2.6}_{-0.8}$
$\frac{5}{2}\rightarrow\frac{1}{2}$	0.16	0.01	0.1	0.10 ± 0.26 or ≤ -1.8			
2158.1→650.1	0.08(4)	−0.09(5)					
$\frac{3}{2}\rightarrow\frac{1}{2}$	0.06	0.00	1.1	$\delta \geq 0.4$	-2.0 ± 0.2		$\delta \geq 0.4$
$\frac{5}{2}\rightarrow\frac{1}{2}$	0.07	0.03	2.2	$-0.7^{+0.5}_{-0.9}$			

TABLE III. (*Continued.*)

Transition (keV) $J_i \to J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
2250.0→650.1	−0.13(7)	−0.10(8)					
$\frac{3}{2}\to\frac{5}{2}$	−0.07	0.00	0.6	$2.2^{+3.2}_{-0.8}$ or $E2$			
$\frac{5}{2}\to\frac{5}{2}$	−0.13	0.01	0.3	-2^{+1}_{-8} or $E2$			
$\frac{7}{2}\to\frac{5}{2}$	−0.13	0.00	0.3	0.05 ± 0.06 or -5^{+1}_{-2}			
$\frac{9}{2}\to\frac{5}{2}$	0.00	−0.17	1.6	$-2.1^{+0.4}_{-0.6}$	-0.04 ± 0.03		
2250.0→1065.3	0.14(7)	−0.06(8)					
$\frac{3}{2}\to\frac{5}{2}$	0.03	0.00	1.3	$-0.8^{+1.4}_{-0.6}$			
$\frac{5}{2}\to\frac{5}{2}$	0.12	0.00	0.8	$0.1^{+0.5}_{-0.2}$ or $1.5^{+1.1}_{-0.8}$			
$\frac{7}{2}\to\frac{5}{2}$	0.12	0.00	0.8	0.3 ± 0.1			
$\frac{9}{2}\to\frac{5}{2}$	0.15	−0.10	0.8	-0.18 ± 0.08			
2261.5→0	−0.19(13)	0.22(17)					
$\frac{1}{2}\to\frac{3}{2}$	0.00	0.00	0.6	indeterminate			
$\frac{3}{2}\to\frac{3}{2}$	−0.05	0.00	0.5	any δ			$M1+E2$
$\frac{5}{2}\to\frac{3}{2}$	−0.10	0.00	0.4	-0.0 ± 0.3			
2261.5→627.1	−0.21(5)	0.05(6)					
$\frac{1}{2}\to\frac{1}{2}$	0.00	0.00	4.3	indeterminate			
$\frac{3}{2}\to\frac{1}{2}$	−0.08	0.00	1.9	$-0.5^{+0.3}_{-0.4}$			$-0.5^{+0.3}_{-0.4}$
$\frac{5}{2}\to\frac{1}{2}$	0.07	0.04	9				
2288.3→650.1	−0.42(4)	−0.03(3)					
$\frac{3}{2}\to\frac{5}{2}$	−0.07	0.00	54				
$\frac{5}{2}\to\frac{5}{2}$	−0.12	0.01	38				
$\frac{7}{2}\to\frac{5}{2}$	−0.42	0.04	0.6	-2.0 ± 0.2 or -0.25 ± 0.04			-2.0 ± 0.2 or -0.25 ± 0.04
$\frac{9}{2}\to\frac{5}{2}$	−0.09	−0.24	36				

TABLE III. (*Continued.*)

Transition (keV) $J_i \to J_f$	A_2 Experimental[a] Theoretical	A_4	χ^2	Mixing ratio δ Present work	Mustaffa *et al.* (Ref. 14)	Metford *et al.* (Ref. 12)	Proposed[b]
2291.5→247.8	−0.31(10)	0.11(10)					
$\frac{3}{2}\to\frac{1}{2}$	−0.08	0.00	2.5	$-0.5^{+0.3}_{-0.5}$			$-0.5^{+0.3}_{-0.5}$
$\frac{5}{2}\to\frac{1}{2}$	−0.07	0.05	7.5				
2291.5→637.1	−0.01(6)	0.04(8)					
$\frac{3}{2}\to\frac{3}{2}$	0.04	0.00	1.8	$-0.5\leq\delta$			$-0.5\lesssim\delta$
$\frac{5}{2}\to\frac{3}{2}$	0.05	0.00	1.8	0.27 ± 0.14			
$\frac{7}{2}\to\frac{3}{2}$	0.07	−0.07	2.0	$-2.1^{+0.7}_{-0.9}$			
2292.9→247.8	0.33(10)	−0.11(11)					
$\frac{3}{2}\to\frac{1}{2}$	0.08	0.00	2.6	$1.7^{+7.8}_{-1.0}$			$1.7^{+7.8}_{-1.0}$
$\frac{5}{2}\to\frac{1}{2}$	0.28	−0.03	1.1	$1.5^{+17.6}_{-1.1}$			
2377.8→1702.9	0.02(2)	−0.02(2)					
$\frac{5}{2}\to\frac{9}{2}$	0.02	0.00	3.0	0.14 ± 0.05 or -2.5 ± 0.5			
$\frac{7}{2}\to\frac{9}{2}$	0.00	0.00	3.0	-0.11 ± 0.04 or $-5.1^{+0.8}_{-1.2}$			
$\frac{9}{2}\to\frac{9}{2}$	0.03	−0.03	2.8	-0.53 ± 0.05	$-2.5^{+0.5}_{-1.2}$		
$\frac{11}{2}\to\frac{9}{2}$	0.06	0.01	7				
$\frac{13}{2}\to\frac{9}{2}$	0.15	−0.14	20				
2403.3→1023.2	−0.06(7)	0.04(9)					
$\frac{1}{2}\to\frac{3}{2}$	0.00	0.00	0.2	indeterminate			
$\frac{3}{2}\to\frac{3}{2}$	−0.04	0.00	0.1	$\delta<0$			
$\frac{5}{2}\to\frac{3}{2}$	−0.05	0.00	0.1	$0.09^{+0.15}_{-0.12}$			
$\frac{7}{2}\to\frac{3}{2}$	0.01	−0.10	0.5	-1.2 ± 0.8			

[a]The numbers in parentheses are estimated uncertainties to the last quoted significant figure.
[b]The proposed δ value marks the most probable spin assignment.
[c]Average includes also value from Ref. 5.

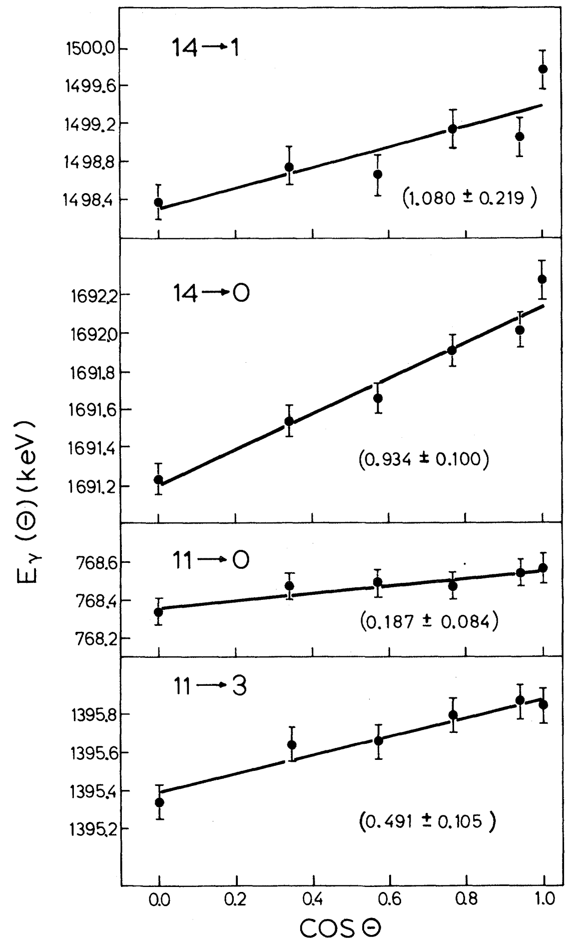

FIG. 3. Linear fit to the γ ray energies observed in the angular distribution spectra vs $\cos\theta_\gamma$. The levels involved in the transitions are indicated according to the numbering in Fig. 4. The numbers (in parentheses) indicate the slope of the curve.

shown in Fig. 4. Many of the low-lying levels in ^{63}Zn have been well established in the work of Ref. 12 and more recently by Mustaffa *et al.*[13,14] In what follows alternative or additional assignments to the ^{63}Zn levels will be discussed.

The $\frac{5}{2}^-$ assignment to the *192.9 keV* first excited state is well established.[5,13] The δ values for the 192.9 keV transition reported in Refs. 5 and 13, however, as -0.07 ± 0.03 and $0.07^{+0.03}_{-0.02}$, respectively, are in poor agreement. The δ value determined here, $\delta=-0.08^{+0.03}_{-0.04}$, is in agreement with the former.

Angular correlation results obtained here for the deexcitation of levels at *247.8, 627.1, 637.1, and 650.1 keV* are consistent with J^π values previously assigned[12,13] to these states.

The angular distribution of the 775.4 keV γ ray deexciting the *1023.2 keV* level uniquely selects a $\frac{3}{2}$ J assignment to this level, in agreement with previous results.[13] A negative parity is indicated by an $l_n=1$ pickup to this level observed in the ^{64}Zn(p,d) reaction.[12] Some discrepancies in the δ values of the transitions deexciting the 1023.2 keV level currently or previously[12,13] determined are observed, as it can be seen in Table III. Our results, nevertheless, seem to be closer to those of Metford *et al.*[12]

A doublet at 1065 keV with $\frac{3}{2}^-$ and $\frac{7}{2}^-$ J^π values has been proposed by Mustaffa *et al.*,[13] while a $\frac{1}{2}^-$ assignment to one of its components was made by Metford *et al.*[12] In the present study the two components of this doublet were explicitly assigned at *1063.3* and *1065.3 keV*. The angular distribution of the 1063.2, 870.3, and 413.2 keV γ rays deexciting the former state uniquely select a $\frac{7}{2}$ J value. The angular distribution of the 1065.2 and 415.2 keV γ rays deexciting the 1065.3 keV level uniquely select a $\frac{5}{2}$ assignment to this level. A negative parity assignment to both levels is suggested by the large δ values obtained, which otherwise would require considerable $M2$ contributions.

Our results confirm those of Mustaffa *et al.*[13] with respect to the *1206.4 keV* level. We did not see any evidence for a 569 keV transition assigned by Metford *et al.*[12] to deexcite this level.

A new transition at 634.5 keV was assigned for the deexcitation of the *1284.3 keV* level to the 650.1 keV state, in addition to those previously observed.[13] The δ values of three transitions deexciting this level were found in very good agreement with previous results.[12,13]

The *1395.4 keV* level has been well established.[9,13] Of the rather different branching ratio values previously proposed for this level,[9,13] our results are closer to those of Giesler.[9] The present angular distribution results are in agreement with the $\frac{3}{2}^-$ assignment of Ref. 13. The mixing ratio of the 768.4 keV transition is determined here for the first time.

The angular distribution of a 1243.3 keV γ ray deexciting the *1436.2 keV* level uniquely selects a $\frac{9}{2}$ J assignment to this level. The $\frac{9}{2}^+$ J^π value can be rejected since it gives $B(M2)=960\pm290$ Weisskopf units (W.u.). The assignment $J^\pi=\frac{9}{2}^-$ to the 1436.2 keV level confirms a previous similar assignment of Mustaffa *et al.*[13]

A *1664.8 keV* level which has been proposed pre-

TABLE IV. The experimental averaged attenuation factors and lifetimes deduced for states in ^{63}Zn.

Level no.	Level energy (keV)	Transition energy (keV)	$\tilde{F}(\tau)$	$\langle \tilde{F}(\tau) \rangle$	Lifetime τ(fsec) Present experiment	Lifetime τ(fsec) Mustaffa *et al.* (Ref. 14)	Lifetime τ(fsec) Adopted value
4	637.1	389.3	0.084 ± 0.128	0.009 ± 0.037	>760		>760
		637.1	0.002 ± 0.047				
5	650.1	457.2	0.028 ± 0.047	0.053 ± 0.026	>400		>400
		650.1	0.073 ± 0.037				
6	1023.2	373.1	0.039 ± 0.052	0.045 ± 0.022	>500	>1500	>1500
		396.1	0.022 ± 0.102				
		775.4	0.072 ± 0.056				
		1023.2	0.047 ± 0.033				
7	1063.3	413.2	0.068 ± 0.060	0.050 ± 0.029	>420		>420
		870.3	0.040 ± 0.035				
		1063.2	0.090 ± 0.122				
8	1065.3	872.4	0.023 ± 0.070	0.057 ± 0.045	>320		>320
		1065.2	0.081 ± 0.058				
9	1206.4	556.3	0.182 ± 0.223	0.022 ± 0.031	>600		>600
		1206.3	0.019 ± 0.031				
10	1284.3	1036.3	0.056 ± 0.029	0.038 ± 0.019	>580		>580
		1091.4	0.026 ± 0.028				
		1284.2	0.014 ± 0.066				
11	1395.4	768.4	0.128 ± 0.058	0.166 ± 0.033	190^{+80}_{-50}	125 ± 35	140 ± 30
		1395.4	0.184 ± 0.040				
12	1436.2	1243.3	0.042 ± 0.030	0.042 ± 0.030	>440	1000 ± 300	1000 ± 300
13	1664.9	1027.8	0.061 ± 0.065	0.089 ± 0.024	370^{+180}_{-110}	335 ± 90	346^{+80}_{-70}
		1472.0	0.105 ± 0.029				
		1664.8	0.037 ± 0.064				
14	1691.2	1054.1	0.253 ± 0.130	0.299 ± 0.029	90^{+27}_{-20}	120 ± 30	100^{+20}_{-17}
		1498.3	0.378 ± 0.079				
		1691.2	0.289 ± 0.032				
15	1702.9	496.6	0.153 ± 0.098	0.046 ± 0.043	>360	46 ± 6 psec	46 ± 6 psec
		639.6	0.020 ± 0.039				
16	1860.8	1210.7	0.070 ± 0.046	0.070 ± 0.046	480^{+1000}_{-220}	710 ± 230	625^{+225}_{-160}
17	1909.2	1272.3	0.074 ± 0.112	0.042 ± 0.041	>400		>400
		1716.3	0.026 ± 0.053				
		1909.0	0.071 ± 0.076				
18	1978.5	1272.3	0.121 ± 0.024	0.121 ± 0.024	270^{+100}_{-70}	<400	270^{+100}_{-70}
19	2050.4	987.1	0.017 ± 0.050	0.017 ± 0.050	>450		>450
20	2158.1	1530.8	0.497 ± 0.148	0.496 ± 0.084	40^{+20}_{-14}	260 ± 70	40^{+20}_{-14}
		1910.4	0.495 ± 0.102				
21	2250.0	1184.8	0.144 ± 0.046	0.134 ± 0.033	240^{+100}_{-70}	150 ± 40	170 ± 40
		1599.8	0.124 ± 0.047				
22	2261.5	1634.4	0.282 ± 0.076	0.284 ± 0.062	95^{+45}_{-30}		95^{+45}_{-30}
		2261.5	0.287 ± 0.105				
23	2288.3	1638.2	0.046 ± 0.056	0.046 ± 0.056	>300		>300
24	2291.5	1641.7	0.261 ± 0.106	0.290 ± 0.053	93^{+37}_{-27}		93^{+37}_{-27}
		1654.2	0.352 ± 0.080				
		2043.6	0.224 ± 0.095				
25	2292.9	2045.1	0.480 ± 0.099	0.480 ± 0.099	43^{+22}_{-15}		43^{+22}_{-15}
26	2377.8	674.9	0.012 ± 0.091	0.012 ± 0.091	>300	>2000	>2000
27	2403.3	1380.2	0.197 ± 0.067	0.197 ± 0.067	160^{+100}_{-60}		160^{+100}_{-60}

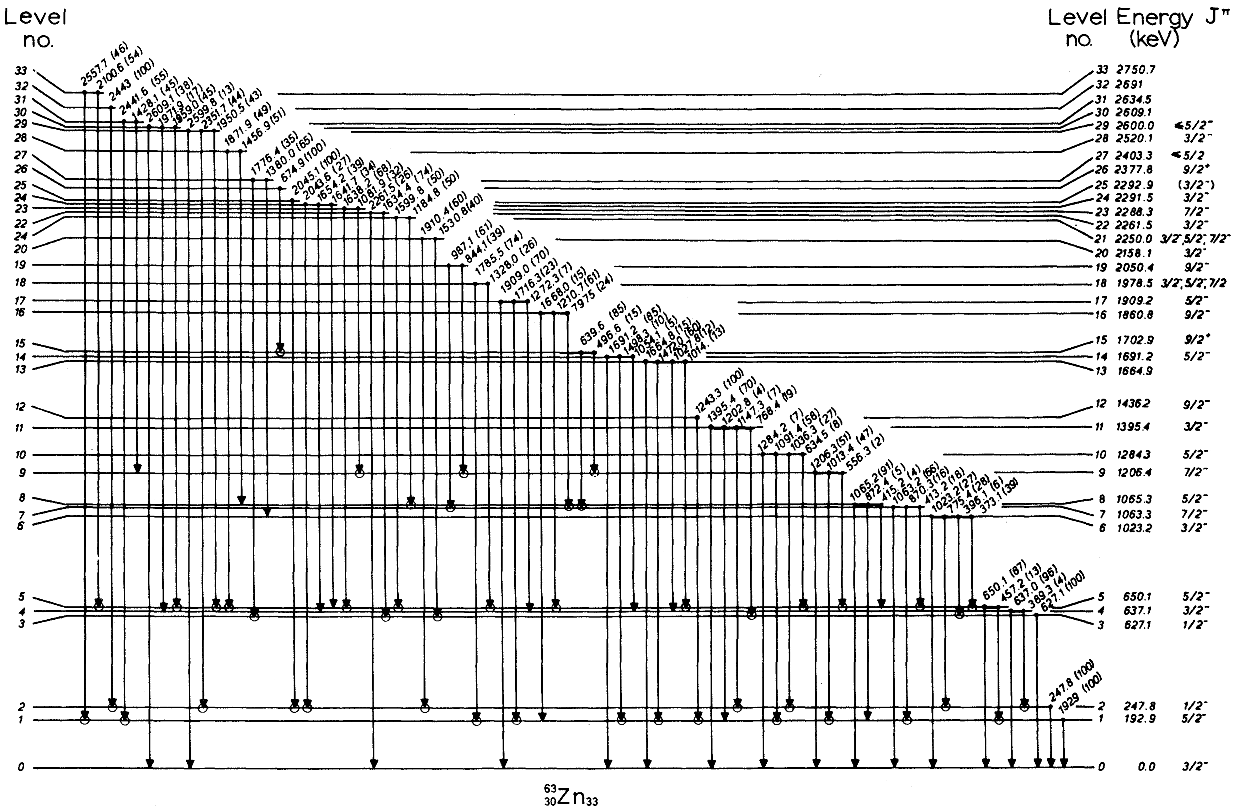

FIG. 4. Decay scheme of ^{63}Zn excited through the ^{63}Cu($p,n\gamma$) reaction. The energies are in keV. The energies of individual γ rays and percent branching ratios (in parentheses) are also indicated. A circle at the end of a transition denotes that the corresponding γ ray was identified in the coincidence spectrum.

viously[14] has been reassigned in the present study with the additional evidence of two γ-ray transitions at 1014 and 1027.8 keV which were assigned to the deexcitation of this level to the 650.1 and 637.1 keV states, respectively. The angular distribution results cannot distinguish between $\frac{3}{2}$, $\frac{5}{2}$, or $\frac{7}{2}$ J values on the basis of minimum χ^2. The $\frac{7}{2}^-$ J^π value assigned by Mustaffa *et al.*[14] to the 1664.8 keV level is not, however, adopted since the δ value for the 1664.9 keV transition determined here does not indicate $E2$ character. The positive parity alternatives can be rejected because they would require unrealistically high $M2$ contributions.

A level at *1909.2 keV* which has not been previously observed via γ-ray spectrometry is proposed here on the basis of an observed coincidence of a γ ray at 1716.3 keV with the 192.9 keV γ ray that deexcites the first excited state. Two more γ rays at 1272.3 and 1909.0 keV were assigned with good energy agreement to deexcite these levels to the 637.1 keV and the ground states, respectively. It should be noted that the 1909.0 keV γ photopeak is a doublet since it is observed in coincidence with the 247.8 keV transition and accordingly was also assigned to deexcite a 2158.1 keV level (see below). The coincidence data, however, indicated that the transition from the 2158.1 keV level was the 30% of the total intensity of the 1909.0 keV photopeak. The angular distribution of the 1909.0 keV γ ray, which was obtained from a careful stripping of the (1909.0, 1910.4) keV doublet, uniquely selects a $\frac{5}{2}^-$ J^π assignment to the 1909.2 keV level. The angular distributions of the 1272.3 and 1716.3 keV γ rays which deexcite the 1909.2 keV level were compatible with this J^π assignment.

A level at *1978.5 keV* has been assigned previously by Mustaffa *et al.*[14] to deexcite to the 650.1 and 192.9 keV levels. The present $\gamma\gamma$-coincidence results confirm this assignment. From the analysis of the Doppler-shift data, a lifetime of 270^{+100}_{-70} fsec was deduced for the 1978.5 keV level. The only previous value[14] was an upper limit of 400 fsec. A J^π value of $\frac{9}{2}^-$ has been previously assigned[14] to this level. This value, however, is not adopted in the present study since the angular distribution of the 1785.5 keV γ ray emanating from the 1978.5 keV level is not compatible with such a spin value (see Table III), but instead is consistent with $\frac{3}{2}$, $\frac{5}{2}$, and $\frac{7}{2}$. The $\frac{3}{2}^+$ and $\frac{5}{2}^+$ alternatives can be rejected since they would result to unrealistically high $M2$ contributions.

A level at *2050.4 keV* was previously assigned $J=\frac{9}{2}$ by Metford *et al.*[12] and $J^\pi \geq \frac{5}{2}^-$ by Mustaffa *et al.*[14] The decay mode of this level as reported by Mustaffa *et al.*[14] has been confirmed here, while a transition at 1857.6 keV assigned by Metford *et al.*[12] to deexcite this level to the 192.9 keV level was not observed. The angular distribution of the 987.1 keV transition from this to the 1063.3 keV level uniquely selects a $\frac{9}{2}^-$ J^π assignment. The positive parity was rejected because the nonzero δ value obtained indicates an $M1+E2$ transition.

A level at *2157 keV* was assigned by Mustaffa *et al.*[14] to deexcite to the 247.8 and 627.1 keV levels via the 1909 and 1530 keV γ rays, with a branching of 90% and 10%, respectively. The level position and its decay modes were confirmed here, with the exception of the branching ratio: 60% and 40% for the 1910.4 and 1530.8 keV transitions, respectively. It should be noted that the 1910 keV γ photopeak was observed here to be a doublet (see the level at 1909.2 keV) with only 30% of its total intensity emanating from the 2158.1 keV level. If the total intensity of the 1910 keV photopeak were assigned to the decay of the 2158.1 keV level, the branching fraction (85% and 15%) would be very close to the one reported by Mustaffa *et al.*[14] A $\frac{3}{2}^-$ J^π value for the 2158.1 keV level was proposed by Mustaffa *et al.*[14] The present results of the angular distribution of the two γ rays deexciting this level confirm this assignment. A lifetime of 40^{+20}_{-14} fsec was deduced by averaging the results from the Doppler shifts of the two γ rays. This lifetime value is significantly different from the lifetime, 260 ± 70 fsec, proposed in Ref. 14. The difference may stem from the fact that the 1910 keV photopeak was not recognized as a doublet in the previous study. The mixing ratios for the two transitions deexciting the 2158.1 keV level determined here also deviate significantly from those previously reported.[14]

A level at *2250.0 keV* was assigned by Mustaffa *et al.*[14] to decay via the 1599.5 and 1185.4 keV γ rays to the 650.1 keV level and to the $\frac{7}{2}^-$ component of the 1065 keV doublet. The existence of this level was confirmed here on the evidence of observed $\gamma\gamma$ coincidences. The 1184.8 keV γ ray, however, has been assigned here to proceed to the $\frac{5}{2}^-$ 1065.3 keV component of the doublet level on the evidence of energy agreement. The $\frac{9}{2}^-$ J^π assignment to this level proposed by Mustaffa *et al.*[14] was found incompatible with the distribution of the 1599.8 keV transition to the $\frac{5}{2}^-$ 650.1 keV level since the mixing ratio value resulting from the $\frac{9}{2}^-$ hypothesis was significantly different from zero. The $\frac{3}{2}^-$, $\frac{5}{2}^-$, and $\frac{7}{2}^-$ J^π values remain equally probable. The positive parity alternatives were rejected since the nonzero δ values obtained indicate an $M1+E2$ character of the transitions deexciting the 2250.0 keV level. The lifetime of this level obtained here, 240^{+100}_{-70} fsec, was longer than, but not incompatible with, the value 150 ± 40 fsec determined previously.[14]

A new level at *2261.5 keV* was established from the observed coincidences between the 1634.4 and the 627.1 keV γ rays. The crossover transition to the ground state was also observed at 2261.5 keV. The angular distribution of the 1634.4 keV γ ray indicates a preference for the $\frac{3}{2}\rightarrow\frac{1}{2}$ sequence. The large quadrupole admixture required to fit this distribution indicates that the transition is $M1$ or $E2$ rather than $E1$ or $M2$. A $\frac{3}{2}^-$ assignment is therefore tentatively proposed for the 2261.5 keV level. The lifetime for this level of 95^{+45}_{-30} fsec was deduced by averaging the results from the Doppler shifts of the two γ rays.

A level at 2289.6 keV has previously reported by Mustaffa *et al.*,[14] with $J^\pi=\frac{3}{2}^-$ and a lifetime of 20 ± 10 fsec. In the present study, three close lying states at 2288.3, 2291.5, and 2292.9 keV have been identified, none of which can be associated on the basis of the decay mode J^π and lifetime characteristics with the one previously proposed.

The new level at *2288.3 keV* was identified in this work on the evidence of the 1081.9 and 1638.2 keV γ rays which were seen in coincidence with the 1013.4 and 650.1 keV γ rays, respectively. The angular distribution of the 1638.2 keV γ ray restricts the J^π value of the 2288.3 keV level only to $\frac{7}{2}$. The large quadrupole admixture required to fit this distribution indicates an $M1+E2$ character, and therefore a $\frac{7}{2}^-$ assignment.

The new level at *2291.5 keV* was identified from the observed $\gamma\gamma$ coincidences between three γ rays deexciting this level (Tables I and II) and γ rays below. From the J^π values suggested for this level by its mode of decay, the angular distribution of the 2043.6 keV γ ray selects $J=\frac{3}{2}$, although the fit to the angular distribution is not very satisfactory.

The nonzero δ value obtained favors the negative parity alternative. Therefore, we suggest a $\frac{3}{2}^-$ assignment to this level. The lifetime of the 2291.5 keV level was obtained as 93^{+37}_{-27} fsec by averaging the Doppler shifts of the three γ rays deexciting this level.

The new level at *2292.9 keV* was identified on the evidence of a 2045.1 keV γ ray which forms a doublet with the 2043.6 keV γ ray deexciting the previously mentioned level at 2291.5 keV. This composite photopeak, (2043.6, 2045.1) keV, was observed in coincidence with the 247.8 keV gate. After careful stripping of the doublet the Doppler shifts of both 2043.6 and 2045.1 keV γ rays were obtained and were found significantly different. A lifetime of 43^{+22}_{-15} fsec was determined for the 2292.9 keV level. The angular distribution of the 2045.1 keV γ ray indicates a preference for the $\frac{5}{2}\rightarrow\frac{1}{2}$ spin sequence. This value, however, leads to an unrealistically high $M3$ contribution and can be rejected. The large quadrupole admixture $1.7^{+7.8}_{-1.0}$ required to fit the 2045.1 keV correlation for the $\frac{3}{2}\rightarrow\frac{1}{2}$ sequence requires a character of $M1$ or $E2$ rather than $E1$ or $M2$. A $\frac{3}{2}^-$ assignment is therefore proposed for the 2292.9 keV level although the corresponding fit is rather poor.

A level at 2380.2 keV has been previously observed by Mustaffa *et al.*[14] to deexcite via a 676.1 keV γ ray. In the present study a level at *2377.8 keV* was assigned on the evidence of observed coincidences between a 674.9 and the 640 keV γ ray. The angular distribution of the 674.9 keV γ ray was found compatible with the $J^\pi=\frac{9}{2}^{(+)}$ value assigned[14] to this level previously.

The level at *2403.3 keV* has not been previously reported. In this work it was established on the evidence that a 1380.0 and 1776.4 keV γ ray were observed in coincidence with the 775.4 and 627.1 keV γ ray, respectively. The angular distribution of the 1380.0 keV γ ray was found compatible with $J\leq\frac{5}{2}$. The lifetime of this state has been deduced from the Doppler shift of the 1380.0 keV γ ray as 160^{+100}_{-60} fsec.

A level at *2520.1 keV* was established from the observed coincidences between the 1871.9 and the 650.1 keV γ rays. A second 1456.9 keV γ ray was assigned to deexcite this level to the 1063.3 keV level. The level at 2520.1 keV has not been previously observed in γ-ray spectrometry studies of ^{63}Zn. A level at 2.52 keV, however, has been observed previously in particle reaction studies[3,4] to be populated by an $l=1$ transition. The decay mode of the 2520.1 keV level indicates a spin value between $\frac{3}{2}^-$ and $\frac{9}{2}^-$. The present and previous evidence suggests a $\frac{3}{2}^-$ assignment to this level.

A new level at *2600.0 keV* was established on the evidence that the 1950.5 and the 2351.7 keV γ rays were observed in coincidence with the 650.1 and 247.8 keV γ rays, respectively. The cross-over transition to the ground state was also observed at 2599.8 keV.

A new level at *2609.1 keV* was assigned on the evidence of an observed coincidence between the 1959.0 and the 650.1 keV γ rays. Two other γ rays at 2609.1 and 1971.9 keV were assigned to deexcite this level to the ground and 637.1 keV levels, respectively.

A level at 2635 keV was observed by Mustaffa *et al.*[14] to deexcite via the 2442.7 and 1428.5 keV γ rays. This assignment was confirmed here. It should be noted, however, that the 2442 keV photopeak was observed here to be a composite of the 2441.6 and 2443 keV γ rays. Accordingly, the branching ratio reported here for the *2634.5 keV* level is significantly different from the previous[14] value.

A new level at *2691 keV* was established from the observed coincidence between the 2443 and 247.8 keV γ rays. A level at *2750.7 keV* has not been previously observed in γ-ray spectroscopy studies. In this work it was established on the evidence that the 2557.7 and 2100.6 keV γ rays were observed in coincidence with the 192.9 and 650.1 keV γ rays, respectively. A level at 2.76 MeV has been previously observed by spectroscopy of particles emitted in nuclear reactions,[3,4] in which a spin of $\frac{7}{2}^-$ was determined. This 2.76 MeV and the 2750.7 keV level observed here should be associated in all likelihood.

E. Reduced transition probabilities

Reduced transition probabilities $B(\Lambda)$ have been calculated for transitions where the level spin sequence has been established and the required parameters (branching ratio, lifetime, and mixing ratio) are known from the present or previous work. These values are summarized in Table V. All transition energies and branching ratios are taken from the results of the work reported here. The lifetimes employed in the calculations are taken from column 8 of Table IV, which contains the average value of the results obtained here and in Ref. 14. An exception is made in the case of the 2158.1 keV level where the measured lifetimes

TABLE V. Electromagnetic transition rates ^{63}Zn.

Transition	$J_i \to J_f$	Transition energy (keV)	Branch (%)	τ[a] (fsec)	δ[b]	$B(E2)$ (W.u.)	$B(M1)$ (W.u.$\times 10^{-3}$)
$1\to 0$	$\frac{5}{2}^- \to \frac{3}{2}^-$	129.9	100	760 ± 170 psec[c]	0.01 ± 0.04	$0.03^{+0.22}_{-0.03}$	5.8 ± 1.3
$2\to 0$	$\frac{1}{2}^- \to \frac{3}{2}^-$	247.8	100	48 ± 11 psec[c]			43 ± 10[d]
$4\to 0$	$\frac{3}{2}^- \to \frac{3}{2}^-$	637.1	96.0 ± 0.4	>760	0.03 ± 0.01	<1.4	
$4\to 2$	$\frac{3}{2}^- \to \frac{1}{2}^-$	389.3	4.0 ± 0.4		$-0.05^{+0.03}_{-0.04}$	<2.1	
$5\to 0$	$\frac{5}{2}^- \to \frac{3}{2}^-$	650.1	86.6 ± 0.9	>400	-0.43 ± 0.10		
$5\to 1$	$\frac{5}{2}^- \to \frac{5}{2}^-$	457.1	13.4 ± 0.9		-0.06 ± 0.02	<5.5	
$7\to 0$	$\frac{7}{2}^- \to \frac{3}{2}^-$	1063.3	65.6 ± 1.6	>420	$E2$	<65	
$7\to 1$	$\frac{7}{2}^- \to \frac{5}{2}^-$	870.2	15.9 ± 0.9		0.55 ± 0.03	<11	
$7\to 5$	$\frac{7}{2}^- \to \frac{5}{2}^-$	413.2	18.5 ± 1.3		-0.12 ± 0.05	<52	
$8\to 0$	$\frac{5}{2}^- \to \frac{3}{2}^-$	1065.2	91.4 ± 0.6	>320	-0.30 ± 0.07	<13	
					or -1.6 ± 0.2	<88	
$9\to 0$	$\frac{7}{2}^- \to \frac{3}{2}^-$	1206.3	50.9 ± 2.2	>600	$E2$	<19	
$9\to 5$	$\frac{7}{2}^- \to \frac{5}{2}^-$	556.3	2.2 ± 0.2		-1.3 ± 0.2	<27	
$10\to 0$	$\frac{5}{2}^- \to \frac{3}{2}^-$	1284.2	6.6 ± 0.5	>580	-0.74 ± 0.14	<0.9	
$10\to 1$	$\frac{5}{2}^- \to \frac{5}{2}^-$	1091.4	58.1 ± 1.5		-0.42 ± 0.05	<6.4	
					or 4.5 ± 1.6	<35	
$10\to 5$	$\frac{5}{2}^- \to \frac{1}{2}^-$	1036.3	27.6 ± 1.3		$E2$	<23	
$11\to 0$	$\frac{3}{2}^- \to \frac{3}{2}^-$	1395.4	70.0 ± 1.3	140 ± 30	$0.40^{+0.14}_{-0.12}$	$7.1^{+4.6}_{-4.0}$	50 ± 12
$11\to 3$	$\frac{3}{2} \to \frac{1}{2}$	768.4	19.3 ± 1.2		$0.37^{+0.14}_{-0.18}$		
					or ≥ 3		
$12\to 1$	$\frac{9}{2}^- \to \frac{5}{2}^-$	1243.3	100	1000 ± 300	$E2$	18.4 ± 5	
$14\to 0$	$\frac{5}{2}^- \to \frac{3}{2}^-$	1691.2	84.7 ± 1.0	100^{+20}_{-17}	-0.12 ± 0.04	0.5 ± 0.3	55^{+9}_{-11}
$14\to 1$	$\frac{5}{2}^- \to \frac{5}{2}^-$	1498.3	10.0 ± 0.7		$-0.2 \lesssim \delta \lesssim 2.8$	$0.2 \lesssim B(E2) \lesssim 8.3$	$0.8 \lesssim B(M1) \lesssim 10.8$
$15\to 7$	$\frac{9}{2}^+ \to \frac{7}{2}^-$	639.6	84.9 ± 1.3	46 ± 6 psec	$E1$	$(4.3\pm 0.6)10^{-5}$	
$15\to 9$	$\frac{9}{2}^+ \to \frac{7}{2}^-$	496.6	15.1 ± 1.3		$E1$	$(1.6\pm 0.3)10^{-5}$	
$16\to 5$	$\frac{9}{2}^- \to \frac{5}{2}^-$	1210.7	61.3 ± 2.0	625^{+225}_{-160}	$E2$	21^{+5}_{-8}	

TABLE V. (*Continued.*)

Transition	$J_i \to J_f$	Transition energy (keV)	Branch (%)	τ^a (fsec)	δ^b	$B(E2)$ (W.u.)	$B(M1)$ (W.u.$\times 10^{-3}$)
16→7	$\frac{9}{2}^- \to \frac{7}{2}^-$	797.5	23.4±1.4		-0.04 ± 0.02	0.1±0.1	24^{+6}_{-9}
17→0	$\frac{5}{2}^- \to \frac{3}{2}^-$	1909.2	70.5±1.4	>400	-0.18 ± 0.05 or	<0.2	<8
					-2.1 ± 0.2	<3.2	<1.7
17→1	$\frac{5}{2}^- \to \frac{5}{2}^-$	1716.3	22.7±1.4		-0.15 ± 0.11 or	<0.1	<3.8
					2.5±0.7	<2	<0.7
17→4	$\frac{5}{2}^- \to \frac{3}{2}^-$	1272.3	6.8±0.5		0.0±0.2 or		
					$-3.6^{+1.7}_{-6.0}$	<3.3	<0.4
19→7	$\frac{9}{2}^- \to \frac{7}{2}^-$	987.3	61±3	>450	-0.28 ± 0.10	<10	<45
20→2	$\frac{3}{2}^- \to \frac{1}{2}^-$	1910.4	60±2	40^{+20}_{-14}	$1.7^{+2.6}_{-0.8}$	24^{+21}_{-13}	27^{+14}_{-17}
20→3	$\frac{3}{2}^- \to \frac{1}{2}^-$	1530.8	40±2		≥ 0.4	≥ 4.5	≤ 100
22→0	$\frac{3}{2}^- \to \frac{3}{2}^-$	2261.5	26±2	95^{+45}_{-30}	if $E2$	$2.5^{+0.8}_{-1.2}$	
22→3	$\frac{3}{2}^- \to \frac{1}{2}^-$	1634.4	74±2		$-0.5^{+0.3}_{-0.4}$	$7.3^{+9.6}_{-7.3}$	45^{+18}_{-26}
23→5	$\frac{7}{2}^- \to \frac{5}{2}^-$	1638.2	68±2	>300	-2.0 ± 0.2 or	<8.8	<3.8
					-0.25 ± 0.04	<0.8	<16
24→2	$\frac{3}{2}^- \to \frac{1}{2}^-$	2043.6	27±2	93^{+37}_{-27}	$-0.5^{+0.3}_{-0.5}$	$0.9^{+1.4}_{-0.9}$	$8.6^{+3.3}_{-4.9}$
24→4	$\frac{3}{2}^- \to \frac{3}{2}^-$	1654.2	39±2		$0.5 \lesssim \delta$	≥ 2.2	≤ 30
25→2	$\frac{3}{2}^- \to \frac{1}{2}^-$	2045.1	100	43^{+22}_{-15}	$1.7^{+7.8}_{-1.0}$	26^{+63}_{-16}	22±22

[a]Adopted values shown in Table IV.
[b]Adopted values shown in Table III.
[c]From Ref. 14.
[d]Calculated assuming a pure $M1$ transition.

differ by several standard deviations. In this case the result of the present experiment has been employed for the calculation of reduced transition probabilities. Similarly, the mixing ratio employed in the calculations are taken from column 8 of Table III, which contains the average value of the results obtained here and in Ref. 14. The resulting $B(\Lambda)$ values are given in Weisskopf single particle units in the last two columns of Table V.

III. DISCUSSION AND CONCLUSIONS

There is a reasonably good agreement between experimentally established and predicted[15] levels in ^{63}Zn below 3 MeV of excitation. Owing, however, to the large number of closely spaced states, the association between experimental and theoretical states cannot be safely attempted on the basis of excitation energy only. In particular, electromagnetic lifetime and transition properties should be taken into account. However, theoretical transition rates have been reported[15] only for two electromagnetic transitions in ^{63}Zn. The unavailibility for a detailed theoretical investigation of ^{63}Zn may be understandable in view of the, until recently, lack of relevant experimental information. The present investigation, in association with recent similar studies, offers a consistent level and decay scheme of ^{63}Zn in which 11 new excited states and several previously unobserved electromagnetic transitions have been incorporated. Finally, rather detailed information about lifetimes and properties of electromagnetic transitions render ^{63}Zn an attractive choice for testing the various theoretical models which claim to be applicable in this mass region.

In the present experimental study, in which the nonselective $(p,n\gamma)$ reaction has been utilized, it is expected that the majority of states in ^{63}Zn below 2.7 MeV have been identified. There are, however, more predicted $\frac{1}{2}^-$ and $\frac{3}{2}^-$ states[15] than experimentally observed. On the other hand, multipole mixing ratios of several electromagnetic transitions are rather well established and, therefore, available for a comparison with theoretical predictions, which is a very sensitive criterion on the employed wave functions. With the exemption of the lifetimes of the first nine excited states, for which only limits were determined, the lifetimes of several states extracted here from Doppler-shift-attenuation measurements were found in good agreement with previously reported values. Accordingly, most of the proposed lifetimes represent weighted averages of previous and present results and can, therefore, be taken with increased confidence. Finally, the properties of electromagnetic transitions, summarized in Table V, have been derived by considering all present and previous information on lifetimes, branching, and multipole mixing ratios. Qualitatively, one notes that the derived $B(E2)$ values are not too large to be explained within a shell-model framework, while the $B(M1)$ values indicate strong configuration mixing. Thus, ^{63}Zn looks very attractive for the extention of shell-model and/or quasiparticle-cluster[27,28] model calculations.

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