Angular Distribution Studies for ^{65}Zn Nuclei from ^{63}Cu (α, pnγ) Reaction Using Constant Statistical Tensor, Least Square Fitting and σ/J Methods

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Abstract

Multiple mixing ratios (δ-values) have been calculated for high-spin states excited in $^{63}_{29}Cu$(α,pnγ) $^{65}_{30}Zn$ in present work using constant statistical tensor (CST), least square fitting (LSF) and σ/J methods together with experimental values reported for such γ-transition the good agreement for (δ-values) calculated in these three methods confirms its validity to calculate the (δ-values) for γ-transition.

Key Words: Least Square Fitting, Constant Statistical, Angular Distribution.

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Introduction

Structures of nuclei $^{65, 67}$ Zn have been inspected by the technicality of γ-ray spectroscopy in synchronism with the reactions $^{62, 64}$ Ni (α,n) $^{65, 67}$ Zn. gamma-gamma synchronizations measurements and measurements of the yield curve have been in order to illustrate decay planners measurements of the angular distribution of gamma ray and linear polarizations that were used to determine the mixing ratios for the decay of several levels both nuclei and to make spin to assignments the following levels in^{65}Zn: 1.958 ($\frac{7+}{2}$), 2.054 ($\frac{3+}{2}$), 2.135 ($\frac{9+}{2}$), 2.138 ($\frac{11+}{2}$) [1].

The levels of ^{65}Zn have been inspected by the ^{65}Cu(p,nγ) ^{65}Zn reaction up to 1.5 MeV and the ^{62}Ni (α,nγ) ^{65}Zn reaction up to 1.1 MeV excitation. The previously reported levels have been assured and several new transitions are suggested [2].

The ^{62}Ni (α,nγ) ^{65}Zn reaction has been studies at bombing energies (from 8 to 14) MeV. Angular distribution, linear polarizations and yield curves have been measured for transmission from individual -valence cases with excitement energies to about 2 MeV. γ-γ coincidence measurements have been done. The ages of levels, branching ratios, mixing ratios and transmission rates for gamma rays were determined by applying the attenuation method by Doppler shift. [3].

Measurements of γ-ray excitation function, γ-γ coincidence spectra and γ-ray angular apportionment have been done, following the reactions ^{61}Ni (α,n) ^{64}Zn,^{62}Ni (α,n) ^{65}Zn, ^{56}Fe(^{14}N,αnp)^{64}Zn, ^{56}Fe(^{12}C,2pn)^{65}Zn, and ^{54}Fe(^{12}C,2p)^{64}Zn [4].

Measurements of γ-ray angular distributions, γ-ray singles and Doppler shift attenuation, γ-γ coincidence spectra have been made for the following reaction ^{63}Cu (^{4}He,pn)^{65}Zn at 30 MeV. The level chart is assured until 5773 KeV.

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The spins and parities of the three cases at 3227.6, 3785.7 and 4938.0 KeV, are found to be $17/2^+$, $17/2^+$, and $21/2^+$, respectively. The rate life of these cases has been evaluated and conclude B(E2) values for the 4938 → 3227.6 ($21/2^+ \rightarrow 13/2^+$), 227.6 →2053.5 ($17/2^+ \rightarrow 13/2^+$) and 3785.7 →2053.5 ($17/2^+ \rightarrow 13/2^+$) KeV. The transformations were found to be robustly promote with respect to single-particle wisskopf appreciations mark to the collecting in the structure of the particular states. Guide is offered in corroboration of interpreting positive valence cases in ^{65}Zn with J^π value $9/2^+$ to $21/2^+$, It too results from the weak coupling of the 9/2 neutron with the quadrupole excitation of the nucleus ^{64}Zn core[5].

In the present work, the angular distribution for several γ-transitions have been used to calculate the multiple mixing rations of gamma rays for ^{65}Zn levels by using CST and LSF and σ/J methods. The CST method was suggested by [6] he calculate the magnetic sub state population parameters of levels excited in ^{92,94}Zr (n,n`γ) reaction by using computer program pop which is a miniature and modified version of computer code CINDY[7], It is found that the population parameters of levels having the same spin value do not depend on the energy of the plane nor on its parity. Based on this fact, youhana [8,9] showed that the statistical tensor, which is related to the parameters of the community must also be constant for levels having the same spin value and as a result, CST-method was suggested as a tool for calculated δ-values of mixed transitions. This method was then applied for the first time by youhana[8,10] to calculate the δ-values of γ-transitions from levels in ^{90,92,94}Zr and ^{150} Nd excited in the (n,n`γ) reactions. Abd-Alamir [11] in her Ph.D work has applied this method to calculate the δ-values of γ- transitions from levels exited in$^{173}_{70}yb$ $({}^{58}_{28}Ni, {}^{58}_{28}Ni\gamma)^{173}_{70}yb$, ${}^{59}_{27}Co({}^{28}_{27}Si,$ 2pnγ)$^{84}_{39}y$ and ${}^{58}_{28}Ni$ $({}^{35}_{28}Cl$,3Pγ) ${}^{90}_{42}Mo$ In these studies, the validity of this method as a tool as good as the computer code CINDY for calculating δ-values of γ-transitions was not confirmed only but also its capability of predicting any inaccuracy existing in the experimental data.

The LSF- method used in the present work for the first time to estimate the statistical tensors of all levels particularly those with certain spin values which have no pure transitions. More details are given in the next section.

In σ/J method, Tables of angular distribution coefficients published by Yamazaki were useful in explaining the angular distributions of the measured gamma rays in studying the cores resulting from have-ion reaction. The excited states resulting in such reactions are well aligned [13] with respect to the beam direction. Hence, gamma rays depopulating these states appear characteristic angular distributions relying on the multiple polarizations of radiation and the rotation of specific nuclear states. The base purpose of the current research was to prove rightness of these methods for calculating δ-values of γ-transition from high spin state in ^{65}Zn and their capability of predicting any inaccuracy in the experimental data.

Data Reduction and Analysis

a) CST-method

The a_2-coefficient is, in general, related to the statistical tensor, $\rho_2(J)$ by the relationship:

$$a_2\,(J_i\text{-}J_f) = \rho_2(J_i)\frac{F_2\,(J_F\,L_1\,L_1\,J_i\,)+2\delta F_2\,(J_F\,L_1\,L_2\,J_i\,)+\delta^2 F_2(J_F\,L_2\,L_2\,J_i\,)}{1+\delta^2} \quad (1)$$

for pure transitions or transitions considered to be pure, δ=0, and hence:

$$\rho_2(J_i) = \frac{a_2(J_i-J_F)}{F_2\,(J_F\,L_1\,L_1\,J_i\,)} \qquad (2)$$

Using the a_2-coefficient reported for such transition, $\rho_2(J_i)$ values can be calculated for all initial levels that have at least one pure or considered to be pure transition. The $\rho_2(J_i)$ values thus calculated are considered to be constant for all levels with the same J_i-values and can be then used in eq(1) to calculate the δ-values for the γ-transitions considered to be pure and for other mixed transitions.

b) LSF-method

In this method, the $\rho_2(J_i)$ values computed for levels with different Ji values are computer-fitted to a series polynomial of the form:

$$\rho_2(J_i) = \sum_{x=0}^{x=n} B_x J_i^x \qquad (3)$$

using the least squares fitting program that was written in present work in matlab language to determine the B_x parameters for n=1,2,3 and 4 and R^2-values for each n. the set of best R^2 was then used to calculate $\rho_2(J_i)$ values for all J_i-values. The $\rho_2(J_i)$ values thus obtained are then used to calculate the δ-values for all γ-transitions whose angular distribution have been measured.

c) σ/J Method

The yamazaki's[12] presented tables of angular distribution coefficients about total aligning and formula to find the attenuation coefficients α_2 (J) When the aligning is imperfect, yamazaki [12] showed that the partial aligning can be represented by a Gaussian distribution of the property m- states by a parameter σ which is equal to half the width of Gaussian curve.

$$P(m)=\frac{\exp(-m^2/_{2\sigma^2})}{\sum_{M_{i=J_i}}^{J_i} exp(-m^2/_{2\sigma^2})} \quad (4)$$

With this assumption, the attenuation coefficients, $\alpha_2(J)$ can be expressed as a function of J and σ/J. The values of J up to J=26 and for σ/J values range from 0.1 to 2.0 have been tabulated by Der Mateosion and Sunyor[14].

Results and Discussion

1) Results calculated by CST-method

The energy levels of ^{65}Zn and the related γ-transitions whose a_2-coefficients have been used to calculate the$\rho_2(J_i)$ values are presented in table (1) together with the $\rho_2(J_i)$ values and its weighted averages.

Table 1. Levels and γ-transitions of ^{65}Zn used to calculate $\rho_2(J_i)$

E_i (KeV)	E_γ(KeV)	$J_i^\pi - J_F^\pi$	a_2 a_4 [5]	$\rho_2(J_i)$	$\rho_2(J_i)$ w.A
1065.6	201.4	$9/2^+$-$7/2^-$	-0.21(2) 0.02(4)	-0.69360±0.06606	-0.69360±0.06606
2053.5	987.9	$13/2^+$-$9/2^+$	0.29(12) -0.22(13)	-0.73194±0.30287	-0.73194±0.30287
3227.6	1174.1	$17/2^+$- $13/2^+$	0.26(6) -0.14(8)	-0.68861±0. 15891	-0.74024±0.14606
3785.7	1732.7	$17/2^+$-$13/2^+$	0.39(14) ……..	-1.03292±0.37079	
4938.0	1710.4	$21/2^+$-$17/2^+$	0.34(11) -0.07(12)	-0.92843±0.30037	-0.92843±0.30037

The $\rho_2(J_i)$ values thus obtained were then used to calculate the δ-values γ-transitions whose angular distributions have been measured. The results are presented in table[2]. As it can be seen the δ-values of γ-transitions from level with J_i=15/2 and J_i=19/2 could not be calculated by this method. Since on pure transitions from such levels were reported in ref[5] the results of γ-transitions from other levels are discussed as follows:

1) The levels with J_i=9/2: the δ-values calculated for (9/2-7/2) transitions are in rather good agreement with those of ref[5].
2) The levels with Ji=13/2:no pure transition, namely, the 987.9 KeV from 2053.5 KeV, was reported in ref.[5] only. The a_2-coefficficent reported for this transition was used to calculate $\rho_2(13/2^+)$ which was then used to calculate the δ-values of other γ-transitions from levels with J_i=13/2, these values are in good agreement with that of ref.[5].

Table 2. Multiple mixing ratios of γ-transitions from levels of ^{65}Zn calculated by CST and LSF methods

δ			$\frac{a_2}{a_4}$[5]		Eγ(KeV)	Ei (KeV)
LSF(P.W)	**CST(P.W)**	$t_{1/2(p.s)}$		J_i^π -J_f^π		
1.6(3) -($0.37^{+0.12}_{-0.09}$)	…………	3^{+5}_{-2}	-0.53(6) 0.22(7)	7/2$^-$-5/2$^-$	864.2 88.8(51)	864.2
0.00(2)	0.00(2)	575(26)	-0.21(2) 0.02(4)	9/2-7/2	201.4 69(64)	1065.6
0.00(14)	0.00(22)	1.4 >	0.29(12) -0.22(13)	13/2$^+$ - 9/2$^+$	987.9	2053.5
-0.03(7)	-0.02(9)	$0.44^{+0.18}_{-0.14}$	0.26(6) -0.14(8)	17/2$^+$ -13/2$^+$	1174.1	3227.6
0.38(6) $4.0^{+1.2}_{-0.8}$	…………	…………	0.26(6) -0.14(8)	15/2$^+$-13/2$^+$		
0.81(22) -($0.16^{+0.12}_{-0.14}$)	$0.82^{+0.48}_{-?}$ $-0.16^{+0.25}_{-?}$	……….	0.26(6) -0.14(8)	13/2$^+$ -13/2$^+$		
$0.13^{+0.20}_{-0.17}$	$0.31^{+0.24}_{-0.27}$	$\geq$0.4	0.39(14) …………	17/2$^+$-13/2$^+$	1732.7 74.6(99)	3785.7
$0.53^{+0.35}_{-0.16}$ $2.5^{+1.7}_{-1.1}$	…………	………	0.39(14) …………	15/2$^+$ -13/2$^+$		
Imaginary roots	Imaginary roots	……….	0.39(14) …………	13/2$^+$ -13/2$^+$		
-($0.61^{+0.06}_{-0.38}$) $1.8^{+4.2}_{-0.9}$	$0.61^{+0.59}_{-0.38}$- $1.8^{+4.1}_{-0.9}$	……….	0.04(19) -0.11(21)	13/2$^+$ -13/2$^+$	1155.944	4078.8
-($0.18^{+0.17}_{-0.15}$)	…………	………	0.04(19) -0.11(21)	15/2$^+$-13/2$^+$		2922.9
-($0.29^{+0.34}_{-0.23}$)	- $0.29^{+0.35}_{-0.23}$	……….	0.04(19) -0.11(21)	17/2$^+$-13/2$^+$		
-0.01(10)	0.00(15)	$0.18 \leq \tau \leq 0.30$	0.34(11) -0.07(12)	21/2$^+$-17/2$^+$	1710.4	4938
$0.40^{+0.13}_{-0.10}$ $3.3^{+1.4}_{-1.0}$	…………	……….	0.34(11) -0.07(12	19/2$^+$-7/2$^+$		
$0.02^{+?}_{-0.30}$ $0.42^{+0.40}_{-?}$	$0.04^{+?}_{-0.35}$ $0.39^{+0.49}_{-?}$	……….	0.34(11) -0.07(12	17/2$^+$-17/2$^+$		

3) The levels with J_i=17/2. No pure transition, namely, the 1174 KeV, was reported in ref[5] the a_2-coefficient reported for this transition was used to calculate $\rho_2(17/2)$ which was then used to calculate the δ-values of other γ-transition from levels with J_i=17/2, these δ-values are compared with other methods and other references.

4) The levels with J_i=21/2. The δ-values calculated for the 1710.4 KeV (21/2-17/2) transition from 4938.0 KeV levels in fair agreement with those calculated by LSF and σ/J methods and ref.[5]. This indicates that the a_2-coefficinet reported in ref. [5] is under estimated.

2) Results calculated by the LSF-method

The weighted averages of $\rho_2(J_i)$ presented in table (1) were computer fitted as mentioned in section B. in this fitting, $\rho_2(15/2)$ and $\rho_2(19/2)$ were excluded since a_2-coefficints were not reported in ref. [5].

The fitting equation was follows:

$$\rho_2(J_i) = 0.52991 - 0.56855\, J_i + 0.085\, J_i^2 - 0.0043\, J_i^3 \quad (5)$$

$R^2=0.9881$ and $\chi^2 = 0.1$

the$\rho_2(J_i)$ values calculated for each J_i were then as follows:

$\rho_2(7/2) = -\ 0.59443$
$\rho_2(9/2) = -\ 0.68478$
$\rho_2(13/2) = -\ 0.72531$
$\rho_2(15/2) = -0.72709$
$\rho_2(17/2) = -0.75096$
$\rho_2(19/2) =-\ 0.82270$
$\rho_2(21/2) =-\ 0.96813$

The δ-values calculated using these $\rho_2(J_i)$ values are also presented in table (2). The comparison of δ-values calculated by CST-method shows the agreement is excellent for all γ-transition.

The imaginary roots obtained in the calculation of δ-values of 1732.7 KeV, ($13/2^+$-$13/2^+$) transition from the 3785.7 KeV level confirm the inaccuracy of the a_2-coefficent reported in ref. [5] for this transition.

3) Results calculated by σ/J method

The statistical tensors $\rho_K(J)$ obtained by LSF-method have been used to calculate the attenuation coefficients, $\alpha_2(J)$ from the following relationship [12,14]:

$$\alpha_K(J) = \frac{\rho_k(J)}{B_k(J)} \quad (6)$$

Where $B_k(J)$ is the statistical for complete alignments and is given by[16].The $\rho_K(J)$ values are considered to be constant for all levels with the same J_i value. The $\alpha_k(J)$ are used together with σ/J values from ref. [5] for J=7/2 to 21/2. Were fitted to a polynomial series of the from

$$\sigma/J = B_0 + B_1\alpha_2 + B_2\alpha_2^2 \quad (7)$$

To obtain the B_0, B_1, B_2 parameters the equation obtained were as follows:

J_i
$\frac{7}{2}\ \sigma/J=0.801184+0.097702\alpha_2-0.631504\alpha_2^2$
$\frac{9}{2}\ \sigma/J=0.733245-0.430658\alpha_2-0.134594\alpha_2^2$
$\frac{13}{2}\ \sigma/J=0.878417-0.91194\alpha_2+0.203641\alpha_2^2$
$\frac{15}{2}\ \sigma/J=0.879439-0.923872\alpha_2-0.224456\alpha_2^2$
$\frac{17}{2}\ \sigma/J=0.879978-0.940630\alpha_2+0.240313\alpha_2^2$
$\frac{19}{2}\ \sigma/J=1.159938-1.457220\alpha_2+0.432500\alpha_2^2$
$\frac{21}{2}\ \sigma/J=3.147636-5.212504\alpha_2+2.142935\alpha_2^2$

The σ/J values thus obtained are presented in table (3).

Table 3. *σ/J values*

J_i	$\rho_2(J_i)$ (LSF)	$B_2(J_i)$	$\alpha_2(J_i)$	σ/J_iref[. 5]	σ/J_i (p.w)
$\frac{7}{2}$	**-0.59443**	**-1.09107**	**0.544814**	**0.37**	**0.66697**
$\frac{9}{2}$	**-0.68478**	**-1.10095**	**0.621990**	**0.38**	**0.41331**
$\frac{13}{2}$	**-0.72531**	**-1.10939**	**0.653792**	**0.3025**	**0.37627**
$\frac{15}{2}$	**-0.72709**	**-1.11144**	**0.654187**	**0.2867**	**0.37111**
$\frac{17}{2}$	**-0.75096**	**-1.11283**	**0.674820**	**0.255**	**0.35466**
$\frac{19}{2}$	**-0.82270**	**-1.11382**	**0.738629**	**0.23**	**0.31956**
$\frac{21}{2}$	**-0.96813**	**-1.11453**	**0.868644**	**0.23**	**0.23676**

These σ/J values where then used in polynomial series of the form

$$\alpha_2 = A_0 + A_1\,(\sigma/J) + A_2\,(\sigma/J)^2 \quad (8)$$

To obtain the A_0, A_1, A_2 parameters the equations obtain were as follow :

$J_i\alpha_2=A_0+A_1\,(\sigma/J)+A_2\,(\sigma/J)^2$
$7/2\ \alpha_2=1.336975-1.77109\ \sigma/J+0.2684(\sigma/J)^2$
$9/2\ \alpha_2=1.34375-1.948095\ \sigma/J+0.49935(\sigma/J)^2$
$13/2\ \alpha_2=1.079039-0.534925\ \sigma/J-1.55135(\sigma/J)^2$
$15/2\ \alpha_2=1.080039-0.575355\ \sigma/J-1.50515(\sigma/J)^2$

$17/2\ \alpha_2=0.949128-0.60774\ \sigma/J-1.4684(\sigma/J)^2$
$19/2\ \alpha_2=1.008968-0.02089\ \sigma/J-2.6652(\sigma/J)^2$
$21/2\ \alpha_2=0.998776-0.02243\ \sigma/J-2.6815(\sigma/J)^2$

The $\alpha_2(J)$ values thus obtained were used to calculate $\rho_2(J)$ for each (J_i)-values.

Table (4) shows $\rho_2(J_i)$ values were then used to calculate the δ-values as mentioned in LSF-method.

Table 4. *ρ_2 (Ji) values calculated in σ/J method*

J_i	σ/J_i	a_2	$\alpha_2(J_i)$	$B_2(J_i)$	$\rho_2(J_i)$
$\frac{7}{2}$	0.37	-0.53(6)	0.71842	-1.09107	-0.78385
$\frac{9}{2}$	0.38	-0.21(2)	0.67558	-1.10095	-0.74378
$\frac{13}{2}$	0.26	0.29(12)	0.83509	-1.10939	-0.92644
$\frac{13}{2}$	0.35	0.26(6)	0.70177	-1.10939	-0.77854
$\frac{13}{2}$	0.31	0.39(14)	0.76413	-1.10939	-0.84772
$\frac{13}{2}$	0.29	0.04(19)	0.78274	-1.10939	-0.86836
$\frac{15}{2}$	0.31	0.26(6)	0.75703	-1.11144	-0.84139
$\frac{15}{2}$	0.28	0.93(14)	0.80094	-1.11144	-0.74139
$\frac{15}{2}$	0.27	0.04(19)	0.81497	-1.11144	-0.90579
$\frac{17}{2}$	0.28	0.26(6)	0.66384	-1.11283	-0.73874
$\frac{17}{2}$	0.25	0.39(4)	0.70542	-1.11283	-0.78501
$\frac{17}{2}$	0.24	0.04(19)	0.71869	-1.11283	-0.79978
$\frac{17}{2}$	0.25	0.34(11)	0.70542	-1.11283	0.78501
$\frac{19}{2}$	0.23	0.34(11)	0.86317	-1.11382	-0.96142
$\frac{21}{2}$	0.23	0.34(11)	0.85177	-1.11453	-0.94932

It is clear that these $\rho_2(J_i)$ values are rather different than those obtained by the CST- and LSF-methods. Never the less. These values were also used to calculate the δ-values of the γ-transition from the levels of ^{65}Zn. The results are presented in table (5) for the purpose of comparison.

4) *Adopted δ-values for mixed transitions*

The weighted average of δ-values calculated for mixed transitions from levels of ^{65}Zn are presented in table (5) as adopted δ-values. The large errors associated with δ-values are taken into consideration.

Table 5. Adopted δ- values for mixed transition from level of ^{65}Zn

δ				Ref[5]	Ref[2]	Ref[1]	*J_i^π -J_f^π*	*E_γ (KeV)*	*E_i (KeV)*
Adopted	**σ/J(P.W)**	**LSF(P.W)**	**CST(P.W)**						
-2.2(1) -0.23(5)	-2.3(3)	-1.6(3) $-(0.37^{+0.12}_{-0.09})$	………..	1.77(3) -0.28(2)	-0.27	-2.33(20)	$7/2^- - 5/2^-$	864.2 88.8(51)	864.2
0.01(1)	0.01(2)	0.00(2)	0.00(2)	……..	0.00(1)	0.02(1)	9/2-7/2	201.4 96.6(64)	1065.6
-0.02(6)	-1.05(12)	0.00(14)	0.00(22)	…….	0.01(2)	-0.02(10)	$13/2^+ - 9/2^+$	987.9	2053.5
-0.04(4)	-0.04(7)	-0.03(7)	-0.02(9)	……..	……..	-0.07(8)	$17/2^+ -13/2^+$	1174.1	3227.6
0.35(4) 4.4(8)	0.33(5) $4.9^{+1.2}_{-0.9}$	0.38(6) $4.0^{+1.2}_{-0.8}$	…………	………	………	≈0.4	$15/2^+ -13/2^+$		
0.88(13) -0.20(8)	0.96(19) -0.24(11)	0.81(22) $-(0.16^{+0.12}_{-0.14})$	$0.82^{+0.48}_{-?}$ $-0.16^{+0.25}_{-?}$	……..	……..	0.81(31)	$13/2^+ -13/2^+$		
0.12(11)	$-(0.11^{+0.19}_{-0.16})$	$0.13^{+0.20}_{-0.17}$	$0.31^{+0.24}_{-0.27}$	………	0.00(6)	-0.23(25)	$17/2^+ -13/2^+$	1732.7 74.6(199)	3785.7
0.44(11) 2.8(12)	$0.44^{+0.17}_{-0.12}$ $3.2^{+1.8}_{-1.0}$	$0.53^{+0.35}_{-0.16}$ $2.5^{+1.7}_{-1.1}$	………..	……..	……..	0.42(17)	$15/2^+ -13/2^+$		
0.74(25) …………..	$0.73^{+0.26}_{-?}$ $0.02^{+?}_{-0.28}$	Imaginary roots	Imaginary roots	……..	……..	0.91(100)	$13/2^+ -13/2^+$		
-0.61(27) $1.9^{+2.0}_{-0.6}$	$-(0.26^{+0.48}_{-0.33})$ $1.9^{+2.7}_{-0.8}$	$-(0.61^{+0.06}_{-0.38})$ $1.8^{+4.2}_{-0.9}$	$-(0.61^{+0.59}_{-0.38})$ $1.8^{+4.1}_{-0.9}$	……..	……..	-0.6(50)	$13/2^+ -13/2^+$	1155.9	4078.8
0.19(9)	$0.17^{+0.14}_{-0.12}$	$-(0.18^{+0.17}_{-0.15})$	…………	……..	……..	0.22(17)	$15/2^+ -13/2^+$		2922.9
-0.30(14)	$-(0.29^{+0.33}_{-0.22})$	$-(0.29^{+0.34}_{-0.23})$	$-(0.29^{+0.35}_{-0.23})$	………	……..	-0.31(20)	$17/2^+ -13/2^+$		
-0.01(6)	-0.01(10)	-0.01(10)	0.00(15)	………..	……..	-0.03(15)	$21/2^+ -17/2^+$	1710.4	
0.40(7) 3.5(10)	$0.37^{+0.10}_{-0.08}$ $3.8^{+1.6}_{-1.0}$	$0.40^{+0.13}_{-0.10}$ $3.3^{+1.4}_{-1.0}$	………..	………	………	0.42(12)	$19/2^+ -7/2^+$		4938
$0.01^{+?}_{-0.17}$ $0.41^{+0.25}_{-?}$	$-(0.02^{+0.27}_{-?})$ $0.42^{+0.43}_{-?}$	$0.02^{+?}_{-0.30}$ $0.42^{+0.40}_{-?}$	$0.04^{+?}_{-0.35}$ $0.39^{+0.49}_{-?}$	………	………	≈ -0.3	$17/2^+ -17/2^+$		

Conclusion

The δ-values of γ-transitions from high spin states populated in the ^{63}Cu (α,pn)^{65}Zn reaction have been calculated in the present work using CST, LSF and σ/J methods and the experimented a_2-coefficients reported in ref[5]. The good agreement between δ-values calculated by the three methods for most of the γ-transitions confirm the validity of these methods for calculating the δ-values of γ-transitions of high spin states. The weighted averages of δ-values calculated for mixed γ-transition, May, there for, considered as adopted δ-values for such transitions.

Furthermore, all the three methods depend upon the experimental data only and rather simple. An ordinary modern calculator is quite enough to perform all the necessary calculations by CST method and a personal computer for the LSF and σ/J methods.

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