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Multipole Mixing Ratios of γ-Transitions from Excited Levels of the ^{73}As Nucleus Populated in the ^{73}G(p, n γ) Nuclear Reactions

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Abstract

The multipole mixing ratios, δ, for gamma transitions from excited levels in the^{73}As nucleus populated in the ^{73}Ge(p,n γ) reaction have been calculated by using the theoreticalinternal conversion coefficients and compared whenever possible with δ-values of other authors obtained from γ-angular distribution measurements. Initial levels with undefined parities are taken in consideration , and accepted reasons for the difference between δ-values deduced from internal conversion coefficients and experimental δ-values of others are given in the this paper.

Keywords: multiople mixing ratio, δ, internal conversion coefficients, α_{tot}, α_{tot}(Eor M, L), α_{tot}(Eor M, L +1)

1. Introduction

Recently, the study of multipole mixing ratio, δ, for γ-transitions connecting nuclear levels has been widely used as a source of information about nuclear level structure and transition properties. The multipole mixing ratios is defined by (Yasar, 2010).

$$\delta = \pm\sqrt{\frac{\Gamma(Eor\ M,L+1)}{\Gamma(EorM,L)}} \tag{1}$$

where Γ(E or M, L) and Γ(E or M, L+1) are transition partial widths whose sum yields (Brussard, 1977) the total γ- transition-width Γ_γ, i.e.

$$\Gamma(E\ or\ M,L) + \Gamma\ (E\ or\ M,\ L+1) = \Gamma_\gamma \tag{2}$$

With L= 1, 2, 3 denoting the transition multipole order. Note that δ depends on L and is positive or negative depending on the adopted definition (Yasar, 2010). Experimentally, δ-values can be derived mainly from angular distribution measurements (Yamazaki, 1967).

Singh et al. (2004) are used the angular distributions to assign the spins and the multipole mixing ratios using ^{73}Ge(p, n γ)^{73}As reaction with proton beam energies from 2.5-4.3 Mev. The experimental analysis of ^{73}As by (Van der Merwe et al., 1975) from (p, n γ) and (p, n) reactions have provided information about a few low–lying levels .The high spin states are populated by heavy–ion reaction studies (Heits et al., 1977).

In addition to angular distribution measurements, the multipole mixing ratio, δ, can be extracted from internal conversion coefficients data. On the theoretical side, it can be calculated using the following expression (Giannatiempo, 2005; Raman, 2006) of the total conversion coefficient, α_{tot}, for a mixed transition

$$\alpha_{tot} = \frac{\alpha_{tot}(EorM,L)+\delta^2\alpha_{tot}(EorM,L+1)}{1+\delta^2} \tag{3}$$

where δ^2 takes on any non-negative value (Raman, 2006). Besides, following (Andrejtscheff, 1975) one has

$$\alpha_{tot}(E\ or\ M,\ L) = \alpha_K\ (E\ or\ M,\ L) + \alpha_L(E\ or\ M,\ L) + \alpha_M(E\ or\ M,\ L) + \ ... \tag{4}$$

In these expression α_{tot}(E or M, L) and α_{tot}(E or M, L +1) are the total conversion coefficients of the unmixed transitions.

Giannatiempo et al. (2005) calculated the theoretical values for internal conversion coefficients with the aid of relation (3) and then compared with the experimental values when δ^2 has been evaluated.

The main aim of the present work is to confirm the validity of the internal conversion coefficient relation for calculating the δ-values of 15 γ-rays de-exciting 14 energy levels in ^{73}As nucleus and its capability of predicting the undefined levels parities.

2. Results and Calculations

The internal conversion coefficients for mixed γ-transitions have been used to calculate the multipole mixing ratios, δ, for excited levels of the^{73}As nucleus produced in the ^{73}G(p, n γ) nuclear reaction .For this purpose, Equation (3) was used with the values of α_{tot}(E or M, L) and α_{tot}(E or M, L +1) taken from (Hager & Seltzer, 2001), An adequate treatment has been made for γ– transitions from ^{73}As initial levels of undefined parities. The current absolute δ-values for the γ-transitions in ^{73}As are compared in Table 1, whenever possible, to experimental data extracted from angular distribution measurements (Singh et al., 2004).

Table 1. Transition energies, gamma energies E_{γ}, (in keV.), initial and final spin of states with parities reported by (Singh et al., 2004). are tabulated, with our possible suggestion formultipolarity, Equation (3) is listed in the ninth column and a comparison of the present absolute multipole mixing ratios Lδ l for gamma transitions from excited levels in ^{73}As with the experimental results are presented in last two columns

Transitions	Eγ.	$J_i^{\pi} \rightarrow J_f^{\pi}$	Multipolarity	α_{tot}	α_K	α_{tot} (EL)	α_{tot} (ML)	δ^2	Lδ l values Present work	δ-values Exper.
674.0 → 509.8	164.2	$\frac{5^-}{2} \rightarrow \frac{5^+}{2}$	E1+M2	0.133(3)	0.101(3)	0.0166(3)	0.0120(3)	$\frac{0.1164 \mp 0.0058}{0.032 \mp 0.0058}$	1.91±0.17	$1.39^{-0.8}_{-0.6}$
769.6 → 0	769.6	$\frac{5^-}{2} \rightarrow \frac{3^-}{2}$	M1+E2	5.6 E-4(3)	0.00058(3)	6.6 E-4(3)	5.3 E-4(3)	$\frac{0.3 \mp 0.42}{1.0 \mp 0.42}$	(0.56±0.24)	-0.74±1.6
850.4 → 0	850.4	$\frac{5^-}{2} \rightarrow \frac{3^-}{2}$	M1+E2	4.3 E-4(3)	0.000439(3)	5.1 E-4 (3)	4.3E-4(3)	$\frac{0}{0.8 \mp 0.42}$	0	$0.2^{-0.1}_{-0.02}$
860.5 → 0	860.5	$\frac{7^-}{2} \rightarrow \frac{3^-}{2}$	E2	---					0	
993.7 → 0	993.7	$\frac{7^-}{2} \rightarrow \frac{3^-}{2}$	E2	E-4(3)3.5	0.00035(3)	E-4(3)3.5	-	0	0	0.5 or $3.0^{+0.6}_{-0.7}$
1037.0 → 427.8	609.1	$\frac{13^+}{2} \rightarrow \frac{9^+}{2}$	E2	0.00139(5)	0.001269(4)	0.00139(5)	-	0	0	$10.6^{-0.02}_{-0.05}$
1086.7 → 84.2	1002.4	$\frac{5^-}{2} \rightarrow \frac{1^-}{2}$	E2	3.4E-4(3)	-	3.4E-4(3)	-	0	0	1.5±0.01
1177.8 → 67.0	1110.9	$\frac{7^-}{2} \rightarrow \frac{5^-}{2}$	M1	2.5 E-4 (3)	0.00025(3)	2.7E-4(3)	2.5E-4(3)	$\frac{0}{0.2 \mp 0.42}$	0	$0.5^{-0.2}_{-0.2}$
1221.3 → 67.0	1154.1	$\frac{7^-}{2} \rightarrow \frac{5^-}{2}$	M1	2.3E-4(3)	0.00023(3)	2.5E-4(3)	2.3E-4(3)	$\frac{0}{0.1 \mp 0.42}$	0	-0.3±0.1
1274.9 → 509.8	765.1	$\frac{7^+}{2} \rightarrow \frac{5^+}{2}$	M1+E2	6.4E-4(3)	0.00064(3)	6.7E-4(3)	5.4E-4(3)	$\frac{1 \mp 0.42}{0.2 \mp 0.42}$	1.82±0.89	$-1.8^{-0.12}_{-0.06}$
1344.1 → 67.0	1277.2	$\frac{7^-}{2} \rightarrow \frac{5^-}{2}$	M1	1.9E-4(3)	0.00019(3)	-	1.9E-4(3)	0	0	$-1.3^{+0.5}_{-0.4}$

1489.3→509.8	979.6	$\frac{5}{2}\rightarrow\frac{5^{+}}{2}$	E1+M2	6.1E-4(3)	0.00061(3)	1.5E-4(3)	7.4E-4(3)	$\frac{4.6\mp 0.42}{1.3\mp 0.42}$	1.88± 0.27 or	-1.8 ± 0.1 or
										-0.2 ± 0.1
		For		1.8E-(3)	0.00018(3)	1.5E-4(3)	7.4E-4(3)	$\frac{0.3\mp 0.42}{5.6\mp 0.42}$	0.23 ± 0.11	
		$\frac{5^{-}}{2}\rightarrow\frac{5^{+}}{2}$	M1+ E2							
				3.5E-4(3)	0.00035(3)	3.6E-4(3)	3.2E-4(3)	$\frac{0.3\mp 0.42}{0.1\mp 0.42}$	1.73 ±5.4 or	
		or								
		$\frac{5^{+}}{2}\rightarrow\frac{5^{+}}{2}$		3.2E-4(3)	0.00032(3)	3.6E-4(3)	3.2E-4(3)	$\frac{0.0}{0.4\mp 0.42}$	0	
1557.1→860.5	696.5	$\frac{7}{2}\rightarrow\frac{7^{-}}{2}$	M1+E2	7.0E-4(3)	0.00070(3)	8.6E-4(3)	6.6E-4(3)	$\frac{0.4\mp 0.42}{1.6\mp 0.42}$	0.50 ± 0.38	0.50 ± 0.10
		For						$\frac{3.0\mp 0.42}{13.8\mp 0.42}$		
		$\frac{7^{-}}{2}\rightarrow\frac{7^{-}}{2}$	E1+M2	6.1E-4(3)	0.00061(3)	3.1E-4(3)	0.00199(3)		0.47 ± 0.05	
		or								
		$\frac{7^{+}}{2}\rightarrow\frac{7^{-}}{2}$								
1612.2→67.0	1545.3	$\frac{7}{2}\rightarrow\frac{5^{-}}{2}$	M1+E2	Calculation failed ,no data for this transition (Hager & Seltzer, 2001).						$-1.3^{+1.0}_{-0.8}$
		For								
		$\frac{7^{-}}{2}\rightarrow\frac{5^{-}}{2}$	E1+M2							
		or								
		$\frac{7^{+}}{2}\rightarrow\frac{5^{-}}{2}$								

1975.2→1274.9	*700.5*		*M1+E2*	*6.5E-4(3)*	*0.00075(3)*	8.5E-4(3)	*6.5E-4(3)*	$\frac{0}{1\pm 0.42}$	*0*	
			E1+M2	*3.1E-4(3)*	*0.00031(3)*	*3.1E-4(3)*	*0.00196(3)*	$\frac{0}{16.5\pm 0.42}$	*0*	
1975.2 → 1274.9	*700.5*		*M1+E2*	7.5E-4(3)	*0.00075(3)*	*8.5E-4(3)*	*6.5E-4(3)*	$\frac{1.0\pm 0.42}{1.0\pm 0.42}$	*1.0*	*0.97±0.05*
			E1+M2	*0.00113(4*	*0.00102(3)*	*3.1E-4(3)*	*0.00196(7)*	$\frac{8.2\pm 0.5}{8.3\pm 0.8}$	*0.99*±0.08	

3. Discussion

The multipole mixing ratios for the transitions energy; 164.2, 769.6 and 765.1 keV deduced from internal conversion coefficients are in a good agreement with the experimental results in Table 1. The mixing ratios for the 860.5, 993.7, 609.1 and 1002.4 keV transitions are not in agreement with the experimental results of (Singh et al., 2004) since the measured conversion coefficients α_{tot} are consistent with $\alpha_{\text{tot}}(\text{E2})$. For this reason, the transitions are expected to be pure E2.

Table 1 shows the measured conversion coefficients α_{tot} are consistent with $\alpha_{\text{tot}}(\text{M1})$ for the 850.5, 1110.9, 1154.1 and 1277.2 keV transitions. Thus, the transitions are considered pure M1.

Inaddition coefficients of mixed transition relation would help to define the parities for levels as follows:

Table 1 indicates that the 979.6 keV ($5/2\rightarrow5^{+}/2$) transition from the 1489.3 keV level with two experimental δ-

values; (–1.80±0.10 and –0.20±0.10). (Singh et al., 2004) suggested 5/2 as the possible assignments of the initial level with undefined parity.For this purpose two probability for mixing transitions are taken ,If the initial level is assigned by $5^-/2$ with negative parity, E1 + M2 transition is obtained, with the two absolute δ- values deduced from Eq.(3) were in a good agreement with the experiment results. If the initial level was assigned by $5^+/2$, the second probability for mixing transition is M1 + E2, with two deduced $|\delta|$ from Equation (3) the first one is ((1.73 ± 5.40)) (1.73 ± 5.40) and the second is zero. In the first one, the error in the value is greater than the value itself, the value is uncertain and it may be ruled out, and the second one is zero, where the experiment δ is (0.20±0.10). Our suggestion is that the 979.6 keV level may be assigned as $5^-/2$.

Our calculation failed to define the parity of the 1557.1 keV level ,due to the deduced $|\delta|$ two values for the 696.5 keV transition from internal conversion coefficients which are in a good agreement with (Singh et al., 2004) value in each case of mixing multipolarity as shown in Table 1.

Finally, we found that the 700.5 keV (5/2 or 7/2→$7^+/2$) transition from 1975.2 keV level may be uncertain. If the initial level 5/2 is assumed to be ($5^+/2$ or $5^-/2$). The deduced $|\delta|$ values from Equation (3) in each case of mixing multipolarity, are far from agreement with (Singh et al., 2004) experimental value shown in Table 1. But, when the initial level is assigned by 7/2 with experiment (δ = -0.97±0.05) for the700.5 keV transition and the assumption of the initial level would be (7+/2 or $7^+/2$). The deduced $|\delta|$ values for the 700.5 keV ($7^+/2$→$7^+/2$) transition would be (1.0±0.25) and for 700.5 keV ($7^+/2$→$7^+/2$) transition is (0.99±0.88). The values for each case of mixing transition are in a good agreement with the experimental δ- value .The calculation failed to define the parity of initial level, and the results indicated the possible 1975.2 keV Level spin may be assigned as (7/2.

4. Conclusion

In the present work, the internal conversions have been applied to calculate the multipole mixing ratios of γ-transitions from excited levels of ^{73}As. The good agreement of the present δ-values with those of (Singh et al., 2004) has confirmed the validity of the internal conversion coefficients mixing relation, also the internal conversion measurements were used for first time for predicting the excited levels parities in ^{73}As nucleus.

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