Iraqi Journal of Science

TRANSITION STRENGTHS OF GAMMA RAYS FROM EXCITED LEVELS OF ^{90} Tc NUCLEUS

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Abstract

Transition strengths for γ- transitions from the excited levels in ^{90}Tc nucleus have been calculated; γ-ray branchings and multipole mixing ratios values for gamma transitions are used together with mean life times for these levels to calculate the transitions strengths of γ- transitions

In general , the present results are compared with other theoretical results based on different nuclear models and given a reasonable agreement.

الخلاصة

تم في هذا البحث حساب قوى الانتقال لانتقالات أشعة كاما لبعض المستويات المتهيجة في نواة ^{90}Tc حيث حسبت قوى الانتقال بالاعتماد على حساب نسبة الخلط (δ) وكذلك على حساب كل من نسب التفرع لانتقالات كاما بين المستويات المتهيجة ومعدل أعمار تلك المستويات ولو حظت صحة النتائج التي تم الحصول عليها من خلال مقارنتها مع النتائج العملية تتضمن أعلى حدود القيم المسموح لها لقوى الانتقال.

Introduction

The γ-ray transition strength is difined as [1] the ratio of γ-width to γ- width in Weisskoph unit , measurements of γ- transition strength provide important tests to nuclear – models .

It have been calculated in present work by using;

1- Gamma width (Γγ) for each energy level whose mean life times (τ_m) reported in Ref . [2] .

2- The branching ratios (BR) of γ-transitions calculated using the relative intensities (I_γ) reported in Ref . [2] .

3- The weighted average values of multipole mixing ratios (δ) calculated by Ref . [2] and Ref. [3] were used as adopted δ- values .

4- Gamma widths in Weisskoph units($\Gamma_{\gamma w}$) derived by Weisskoph from single – particle model .

It is clear from the present result that the most of transition strengths values gamma transitions are consistent with the recommended upper limits of table (1) [2]. These values can be used to help discern nuclear structure and transition properties.

Theory

The partial width of a γ- ray transition from an initial state with spin J_i to final state with spin J_f is given by [1] :

$$\Gamma_{\gamma L}=\frac{8\pi(L+1)}{L[(2L+1)!!]^2}\left[\frac{E_\gamma}{c\hbar}\right]^{2L+1} B(L) \qquad (1)$$

Where:

$\hbar$ = Dirac constant = $\frac{h}{2\pi}$, h = Plank's constant.

c = Speed of light

E_γ = Gamma energy

B (L)= Reduced transition probability

If the total width is

$$\Gamma_\gamma = \sum\Gamma_{\gamma L} \qquad (2)$$

Then

$$\Gamma_\gamma\tau_m = \hbar = 0.65822 \times 10^{-15}\ \text{eV.s} \qquad (3)$$

Where τ_m is the mean life time of the initial

$$\text{state} = \frac{t_{1/2}}{\ln 2} \qquad (4)$$

The γ-ray transition strength $[M]^2$ is defined as [1] ;

$$[M]^2 = \frac{\Gamma_\gamma}{\Gamma_{\gamma w}} \quad \text{Weisskoph (W. u .)} \qquad (5)$$

$\Gamma_{\gamma w}$ = width in Weisskoph unit .

By using single particle shell model , the following values for the widths in W. u . for nuclear of mass No . **A** may be obtained . (E_γ in keV , $\Gamma_{\gamma w}$ in eV)

$$\Gamma_{\gamma w}(E1) = 6.7469 \times 10^{-11}\ A^{2/3}\ E_\gamma^3 \qquad (6)$$

$$\Gamma_{\gamma w}(E2) = 4.7907 \times 10^{-23}\ A^{4/3}\ E_\gamma^5 \qquad (7)$$

$$\Gamma_{\gamma w}(E3) = 2.2319 \times 10^{-35}\ A^2\ E_\gamma^7 \qquad (8)$$

$$\Gamma_{\gamma w}(M1) = 2.0722 \times 10^{-11}\ {}_\gamma^3 \qquad (9)$$

$$\Gamma_{\gamma w}(M2) = 1.4714 \times 10^{-23}\ A^{4/3}\ E_\gamma^5 \qquad (10)$$

$$\Gamma_{\gamma w}(M3) = 6.8550 \times 10^{-30}\ A^{4/3}\ E_\gamma^7 \qquad (11)$$

For γ- transitions with mixed multipolarities L and L+1 and by theoretical calculation from Ref . [4] using eqs . (3) and (4) the mixing ratio δ can be written as

$$\delta^2 = \frac{t_{1/2}(\gamma)^L}{t_{1/2}(\gamma)^{L+1}} \qquad (12)$$

Also δ^2 may be written as follows ;

$$\delta^2 = \frac{\Gamma(L+1)}{\Gamma(L)} \qquad (13)$$

$$\text{Where } \Gamma(L)+\Gamma(L+1)=\Gamma_\gamma \qquad (14)$$

Recommended upper limits for Γ_γ / $\Gamma_{\gamma w}$ are exactly as those presented in table (1) [1] for $t_{1/2}$ (W . u.) / $t_{1/2}$ (exp)

Partial width of each γ-ray can be calculated as follows:

$$\Gamma_{\gamma L} = BR_i \times \Gamma_\gamma \qquad (15)$$

BR_i is the branching ratio of (γ_i) and can be calculated from :

$$BR_i(\gamma_i) = \frac{I_{\gamma i}}{I_{tot}} \times 100\ \% \qquad (16)$$

$I_{\gamma i}$ =is the relative intensity of γ_i

$I_{tot} = \sum I_i$ (Summation for all γ's de excite from certain level)

For a pure E1 or E2 transition, δ = 0 and hence

$$\Gamma(E1) \text{ or } \Gamma(E2)=\Gamma_\gamma \qquad (17)$$

And the transition strength of this transition can then be calculated by using eq. (5), the corresponding $\Gamma_{\gamma w}$ (E1) or $\Gamma_{\gamma w}$ (E2) values are calculated for the transition.

For mixed transition such as M1 + E2 with mixing ratio δ , the partial widths Γ (M1) and Γ (E2) can be calculated by using eqs (13) , (14) . The transition strengths can then be calculated as follows:

$$[M(M1)]^2 = \frac{\Gamma(M1)}{\Gamma_{\gamma w}(M1)} \qquad (18)$$

$$[M(E2)]^2 = \frac{\Gamma(E2)}{\Gamma_{\gamma w}(E2)} \qquad (19)$$

Calculations and Results

Gamma transition strengths from excited levels in ^{90}Tc nucleus. [1],

Fig. (1) have been calculated as follows :

1-The levels whose mean life times (τ_m) have been measured are presented in table (2) together with gamma width (Γ_γ) calculated for each level using eq . (3) .

2- The branching ratio of γ- transition calculated by eq . (16) using the relative intensities (Iγ) reported in Ref . [2] the results also presented in table [2] .

3- The weighted averages of δ- values reported in Ref. [3] from the experimental results of the gamma angular distribution (SAD) and gamma-gamma correlation (DCO) with those of Ref . [2] are presented in table (3) as adopted δ-values .

4- The adopted δ- values for each transition was then used to calculate the partial gamma width Γ(L) and Γ(L +1) by eqs . (13) and (14) .

5- The partial gamma width in W. u. are calculated for each γ-transition using eq. (6) to eq. (11).

6- The transition strength of γ-ray was then calculated by dividing the partial width by corresponding partial gamma width in W.u. eqs. (18), (19). For a pure E1 or E2 transition eq. (5) was used .

7- The obtained results are presented in table (4). For convenience, the adopted δ- values and branching ratios are also presented in table (4).

Discussion and Conclusion

It is clear from table (4) that; For 509 KeV (11^- - 11^+) transition from the (1995.1) KeV level , 1001 KeV (11^- - 10^+) transition from the (1995.1) KeV level .

The transition strengths $[M(E1)]^2$ are consistent within associated errors with the recommended upper limits values presented in table (1) , while the associated errors with transition strengths $[M(M2)]^2$ are higher than the values themselves , $[M(M2)]^2$ values may be considered to be zero and (509 , 1001) KeV γ- transition can be considered pure E1 transitions .

For 599 KeV (13^+ - 12^+) transition from the 2537.4 KeV level , the transition strength $[M(M1)]^2$ with associated error is consistent with the recommended upper limit presented in table (1), while $[M(E2)]^2$ value; the associated error is higher than the value itself, so $[M(E2)]^2$ can be neglected and (599) KeV transition is considered pure $[M(M1)]^2$ transition .

The 713 KeV (14^- - 13^-) transition from the 3488.7 KeV level, each value of $[M(M1)]^2$ and $[M(E2)]^2$ are consistent with recommended upper limits of table (1) with associated errors , so this transition is considered mixing from M1 and E2, (M1 + E2) transition.For The 964 KeV (17^- - 15^-) transition is from the 4637 KeV level.

The 1229 KeV (14^+ -12^+) transition is from the 3167.8 KeV level.

The transition strengths $[M(E2)]^2$ are consistent within associated errors within the recommended upper limits present in table (1), while the transition strengths $[M(M3)]^2$ are higher than the recommended upper limits values although the associated errors are higher than the values themselves , $[M(M3)]^2$ can be ruled out ; and the transitions are considered pure E2 transitions .

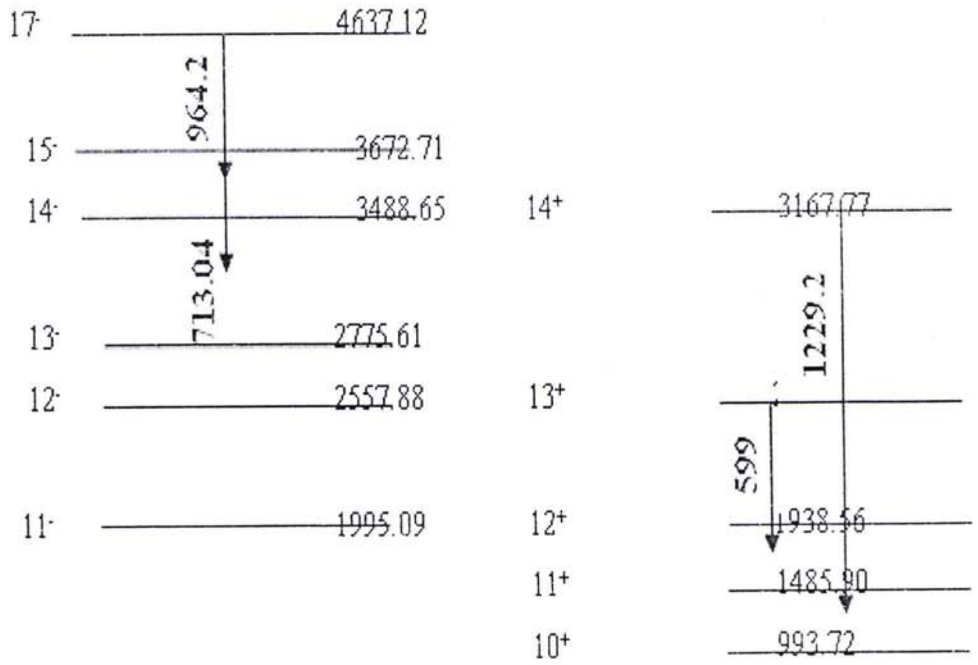

Figure (1): Decay Scheme for some excited levels in ^{90}Tc [1]

Table (1): $t_{1/2}$ (W.u.) / $t_{1/2}$ (exp) (Recommended upper limits) [1]

Multipolarity	**$45 \leq A \leq 90$**
E1	0.01
E2	300
E3	100
M1	3
M2	1
M3	10

Table (2): Mean life times (τ_m) total gamma widths (Γ_γ) for levels and relative intensities ($I\gamma$) with branching ratios γ- transitions from levels of ^{90} Tc

E_i KeV)	**(τ_m) (ps)**	**Γ_γ 10^{-6} (eV)**	**E_γ (KeV)**	**J_i^π _J_i^π**	**Iγ (%)**	**BR (%)**
1995.1	47.6(58)	13.83 ± 1.68	509	$11^- - 11^+$	22.9(21)	16.9 ± 1.6
			1001	$11^- - 10^+$	100 (3)	73.7 ± 3.1
2537.4	< 1.01	> 651.68	599	$13^+ - 12^+$	100 (3)	86.3 ± 3.5
3167.8	1.44(58)	457.08 ± 184.1	1229	$14^+ - 12^+$	100 (4)	84.4 ± 4.5
4388.7	< 2.02	> 325.84	713	$14^- - 13^-$	100 (3)	49.2 ± 2.33
4637.0	2.31(29)	284.9 ± 35.8	964	$17^- - 15^-$	100	100

Table (3): Multipole Mixing ratios (δ) of γ-transitions from ^{90}Tc levels

E_i (KeV)	**E_γ (KeV)**	**J_i^π - J_i^π**	**δ - Values**			
			Ref .[1]			
			SAD	**DCO**	**Ref. [1]**	**Adopted**
1995.1	509	$11^- - 11^-$	$(0.02)^{+36}_{-69}$	$(0.05)^{+53}_{-80}$	E1	0.03 (42)
	1001	$11^- - 10^+$	0.04 (7)	$-(0.04)^{+14}_{-4}$	E1	0.04 (5)
2537.4	599	$13^+ - 12^+$	0.03 (6)	$(0.03)^{+28}_{-8}$	$(0.07)^{+10}_{-8}$	0.04 (5)
3167.8	1229	$14^+ - 12^+$	0.02 (6)	0.00 (7)	E2	0.01 (4)
3488.7	713	$14^- - 13^-$	0.14 (7)	$(0.15)^{+22}_{-11}$	$(0.14)^{+9}_{-6}$	0.14 (5)
4637.1	964	$17^- - 15^-$	0.02 (4)	- 0.02 (6)	E2	0.02 (3)

Table (4): Transition strengths of γ-transitions from ^{90}Tc levels

E_i (KeV)	**E_γ (KeV)**	**$J_i^\pi - J_f^\pi$**	**BR (%)**	**δ**	**$[M(E1)]^2$ (W . u.)**	**$[M(M2)]^2$ (W . u.)**
1995.1	509	$11^- - 11^+$	16.9 (16)	0.03(4)	$(1.30 \pm 0.2)\times10^{-5}$	0.231 ± 4.140
	1001	$11^- - 10^+$	73.7 (31)	0.04(5)	$(0.74 \pm 0.09)\times10^{-5}$	0.06 ± 0.09
E_i (KeV)	E_i(KeV)	J_i^π _ J_f^π	BR (%)	δ	$[M(M1)]^2$ (W .u.)	$[M(E2)]^2$ (W .u.)
2537.4	599	$13^+ - 12^+$	86.3 (35)	0.04(5)	$> 0.12 \pm 0.01$	$> 0.61 \pm 1.07$
3488.7	713	$14^- - 13^-$	49.2 (233)	0.14(5)	$> 0.021 \pm 0.01$	$> 0.87 \pm 0.42$
E_i (KeV)	E_γ (KeV)	$J_i^\pi - J_f^\pi$	BR (%)	δ	$[M(E2)]^2$ (W . u.)	$[M(M3)]^2$ (w . u.)
3167.8	1229	$14^+ - 12^+$	84.46 (450)	0.01(4)	7.12 ± 2.87	3331 ± 19814
4637.1	964	$17^- - 15^-$	100	0.02(3)	17.70 ± 2.23	51428 ± 107531

Hints:

1- It should be mentioned that for the same class of transition the sign of δ obtained from the single angular distribution (SAD) is opposite to the sign obtained from gamma gamma correlation (DCO) of the I_i –I_f– I cascade [5] as it clear in table (3) in present calculation for Weighted average values of δ, the signs of δ values for the same class of transition were considered same.

2- In this table average values of + and – errors are taken into consideration.

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