



Electromagnetic Transition Strengths in ^{110}Cd Nucleus

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Abstract

Pure transition strengths $[M(E1)]^2_{w.u.}$, $[M(E2)]^2_{w.u.}$ and $[M(M1)]^2_{w.u.}$ for γ -transitions from four excited states in ^{110}Cd populated in the $^{108}\text{Pd}(\alpha, 2n)$ reaction have been studied through the mean life times with relative intensities of γ -transitions measurements. Good information describes the main features of the transition modes for electric quadrupole $[M(E2)]^2_{w.u.}$ and electric dipole $[M(E1)]^2_{w.u.}$ in addition to magnetic dipole $[M(M1)]^2_{w.u.}$ are concluded.

PACS:- 27.60-j, 23.20-g, 23.20.Ck, 23.20.Gq.

Keywords: Pure transition strengths $[M(E1)]^2_{w.u.}$, $[M(E2)]^2_{w.u.}$ and $[M(M1)]^2_{w.u.}$

قوى الانتقال الكهرومغناطيسي في نواة الكاديوم ^{110}Cd

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الخلاصة

تم حساب قوى الانتقال لانتقالات رباعي القطب الكهربائي وثنائي القطب الكهربائي والمغناطيسي النقية من بعض المستويات المثيجة لنواة ^{110}Cd المتولدة من التفاعل $^{108}\text{Pd}(\alpha, 2n)$ وذلك بالاستعانة بمعدل أعمار المستويات المثيجة والشدة النسبية لأشعة كما المنقلة. أن القيم المحسوبة لكل من $[M(E1)]^2_{w.u.}$, $[M(E2)]^2_{w.u.}$ و $[M(M1)]^2_{w.u.}$ قد ساهمت في التحليل الدقيق لطبيعة تلك الانتقالات.

Introduction

The transition strengths for gamma transitions are important parameters which use to determine the relative importance of the collective and single-particle effect to describe the level structure of the nucleus and transitions modes .

The study for electromagnetic transitions in ¹¹⁰Cd nucleus by Kostov et.al.[1]is provided additional experimental information about the existing levels structure , where the present calculations for the absolute Electromagnetic transitions $[M(EL,ML)]^2_{W.u}$ in ¹¹⁰Cd nucleus are giving an accurate results for transition modes structure to theoretical physicists for their transition modes predictions

Theory

The WeissKoph single-particle transition probability B(EL,ML) is defined [2] as the ratio of the single-particle half-life time to the experimental half-life time for gamma transition

$$B(EL,ML)_{W.u} = \frac{t_{1/2}^\gamma(EL,ML)_{SP}}{t_{1/2}^\gamma(EL,ML)_{exp}} \dots\dots\dots(1)$$

Where L is the multi polarities L=1,2,3, L≠ 0
The half –life $t_{1/2}$ and mean life T are related by the following relation

$$T = \frac{\tau_{1/2}}{\ln 2} \dots\dots\dots(2)$$

For the K_{th} γ -ray of n γ -rays de exciting a level ,the partial half –life for γ -ray emission $t_{1/2}(\gamma)$ is related to the level half –life $t_{1/2}$ by [2]

$$t_{1/2}(\gamma) = t_{1/2} \sum_{i=1}^n (I_i)^\gamma \left(\frac{1 + \alpha_i}{I_k} \right) \dots\dots\dots(3)$$

Where the summation is over the intensity of all γ -ray de exciting the level, correcting for the internal conversion coefficient α_i .

I_k is the intensity of K_{th} γ -ray. For γ -transition with mixed multi polarities L and L+1 the γ -ray half-life time become

$$\tau_{1/2}(\gamma)^L = \tau_{1/2}(\gamma) (1 + \delta^2) \dots\dots\dots(4)$$

$$\tau_{1/2}(\gamma)^{L+1} = \tau_{1/2}(\gamma) \frac{(1 + \delta^2)}{\delta^2} \dots\dots\dots(5)$$

Where δ is mixing ratio

Then $\delta^2 = \frac{\tau_{1/2}^\gamma(\gamma)^L}{\tau_{1/2}^\gamma(\gamma)^{L+1}} \dots\dots\dots(6)$

Since $\Gamma_\gamma T \approx \hbar$ (7)
 Γ_γ is the total width

$$\hbar = \frac{h}{2\pi} = 0.65822 \times 10^{-15} \text{ eV.s} \quad \text{h is Plank constant.}$$

According to eq.(2) and eq.(7) equation (6) may be written as:

$$\delta^2 = \frac{\Gamma(L+1)}{\Gamma(L)} \dots\dots\dots(8)$$

Where

$$\Gamma_{\gamma L} = \Gamma(L) + \Gamma(L+1) \dots\dots\dots(9)$$

Partial width ($\Gamma_{\gamma L}$) of each γ -ray can be calculated as .[3] suggested

$$\Gamma_{\gamma L} = BR_i \times \Gamma_\gamma \dots\dots\dots(10)$$

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

$$BR(\gamma_i) = \frac{I_{\gamma_i}}{I_{tot}} \times 100 \% \dots\dots\dots(11)$$

Where

I_{γ_i} is the relative intensity of γ_i

$$I_{tot} = \sum I_{\gamma_i} \dots\dots\dots(12)$$

(Summation for all γ de excited from certain level)

While the γ -ray transition strength $[M(EL,ML)]^2$ is defined in [4] as the ratio of gamma width to gamma width in Weiss Kopf unit (W.u)

$$[M(EL,ML)]^2_{W.u} = \frac{\Gamma(EL,ML)_{exp}}{\Gamma(EL,ML)_{W.u}} \dots\dots\dots(13)$$

From eqs. (1,2, 7 and 13) , can be concluded

$$B(EL,ML)_{W.u} = [M(EL,ML)]^2_{W.u} \dots\dots\dots(14)$$

Hence recommended upper limits for $\frac{\Gamma(EL,ML)_{exp}}{\Gamma(EL,ML)_{W.u}}$ are exactly is those presented in

table-1 [2] for $\frac{t_{1/2}^\gamma(EL,ML)_{SP}}{t_{1/2}^\gamma(EL,ML)_{exp}}$ For a pure M1 or

$$E2, \delta=0 \text{ and hence } \Gamma(M1) \text{ or } \Gamma(E2) = \Gamma_\gamma \dots\dots\dots(15)$$

The transition strength of this transition can then calculated using eq .(13)

On the basis of an extreme single particle model

the following values for the γ - widths in W.u. for

nuclear of mass number. A may be obtained(E_γ in KeV. Γ_γ in eV).[2]

$$\Gamma(M1)_{W.u.} = 2.0722 \times 10^{-11} E_\gamma^3 \dots \dots (16)$$

$$\Gamma(E1)_{W.u.} = 6.7469 \times A^{\frac{2}{3}} E_\gamma^3 \dots \dots (17)$$

$$\Gamma(E2)_{W.u.} = 4.7907 \times 10^{-23} A^{\frac{4}{3}} E_\gamma^5 \dots \dots (18)$$

Results and Calculations

1-Mean life times (τ_m) for the excited states calculated by using eq. (2) from half life times ($\tau_{1/2}$) related to these states measuring in [1] are present in table-2 with the total gamma widths (Γ_γ) calculated by eq.(7)

2-The partial gamma width ($\Gamma_{\gamma l}$) was calculated for each γ -transition by eq.(10) Where branching ratio can be calculated from eq. (11) .The transition strengths $[M(ML)]^2$, $[M(EL)]^2$ then calculated by dividing partial gamma width $\Gamma(ML)$ and $\Gamma(EL)$ by corresponding partial gamma width in W.u.

3- the final results thus obtained by step2 are presented and compared where possible with reduced transitions probabilities $B(EL,ML)_{W.u}$ values extracted from half -lives corrected for

internal conversion coefficient α_{tot} . [1] as showing in two last columns of table-3.

$$\text{Eqs. } |M(ML)|_{W.u.}^2 = \frac{\Gamma(ML)_{exp}}{\Gamma(ML)_{W.u.}} \text{ and ,}$$

$$|M(EL)|_{W.u.}^2 = \frac{\Gamma(EL)_{exp}}{\Gamma(EL)_{W.u.}} \text{ were used .}\Gamma(ML) \text{ and}$$

$\Gamma(EL)$ are presented in table-2.

Possible with reduced transitions probabilities $B(EL,ML)_{W.u}$

Table-1: $\tau_{1/2}^{(W.u.)} / \tau_{1/2}^{(exp)}$ (Recommended upper limits) [2]

Multipolarity	$91 \leq A \leq 150$
E1	0.01
E2	300
M1	3

Table-2: Experimental values (Initial energies, half lives, initial and final spin for excited levels ,relative intensities for gamma transitions) in ^{110}Cd nucleus are reported in [1] and used in present work

Ref.[1]	E_i Ke v.	$\tau_{1/2}$ ns	$J_i^\pi \rightarrow J_f^\pi$	E_γ	I_γ	EL,ML	T ns	$\Gamma_\gamma \times 10^{-6}$ eV	B.R.%	$\Gamma(EL,ML) \times 10^{-11}$ eV
361 1	0.45(10)	$10^+ \rightarrow$ 8_3^+ 9_1^- 8_2^+ 8_1^+	171.3 265.2 335.6 423.5	14.2 4.3 93.9 2.1	E2 E1 E2 E2	0.6494 ± 0.1443	1.0136 ± 0.2253	12.40 3.76 82.01 1.83	12571 ± 2790 3806 ± 846 83128 ± 18473 1859 ± 413	
305 6	2.25(10)	$8_1^- \rightarrow$ 6_1^- 7_1^-	159.7 176.5	23.9 56.6	E2 M1	3.2467 ± 0.14430	0.20273 \pm 0.00901	29.69 70.31	6019 ± 268 14254 ± 268	
302 9	0.30(10)	$7_2^- \rightarrow$ 7_1^- 5_2^- 5_1^- 6_1^+	149.9 369.2 489.4 549.1	4.8 4.4 22.9 30.5	M1 E2 E2 E1	0.4329 $\pm 0.$ 14430	1.52047 ± 0.506 82	7.67 7.03 36.58 48.72	11659 ± 3886 10687 ± 3562 55621 ± 18540 74080 ± 24694	
287 9	0.60(10)	$7_1^- \rightarrow$ 5_2^- 5_1^- 6_1^+	219.3 339.5 399.2	3.5 57.9 180	E2 E2 E1	0.8658 $\pm 0.$ 1443	0.76024 ± 0.126 71	1.45 23.99 74.57	1102 ± 184 18234 ± 3039 56687 ± 9448	

Table-3:Transition strengths $[M(EL,ML)]^2_{w.u}$ values from some excited levels in ^{110}Cd nucleus are compared with reduced transition probabilities $B(EL,ML)_{w.u}$ reported in [1]

E_i Kev.	$J_i^\pi \rightarrow J_f^\pi$	E_γ Kev.	EL ,ML	$[M(EL,ML)]^2_{w.u}$ Present Work	$B(EL,ML)_{w.u}$ Ref.[1]
3611	$10^+ \rightarrow$				
	$8^+_{\frac{3}{2}}$	171.3	E2	33.8(7.5)	33.5(8.5)
	9^-_1	265.2	E1	$1.3(3) \times 10^{-6}$	$1.3(3) \times 10^{-6}$
	$8^+_{\frac{3}{2}}$	335.6	E2	7.7(1.7)	7.7(1.8)
	$8^+_{\frac{1}{2}}$	423.5	E2	$5.4(1.2) \times 10^{-2}$	$5.4(1.8) \times 10^{-2}$
3056	$8^-_1 \rightarrow$				
	6^-_1	159.7	E2	22.9(1.0)	20(1)
	7^-_1	176.5	M1	$1.3(1) \times 10^{-3}$	$5.1(2.6) \times 10^{-4}$
3029	$7^-_2 \rightarrow$				
	7^-_1	149.9	M1	$1.7(6) \times 10^{-3}$	$1.6(7) \times 10^{-3}$
	5^-_2	369.2	E2	0.6(2)	0.6(3)
	5^-_1	489.4	E2	0.78(0.26)	0.8(3)
	$6^+_{\frac{1}{2}}$	549.1	E1	$2.9(1.0) \times 10^{-6}$	$2.9(1.0) \times 10^{-6}$
2879	$7^-_1 \rightarrow$				
	5^-_2	219.3	E2	0.9(1)	0.9(2)
	5^-_1	339.5	E2	1.6(3)	1.6(3)
	$6^+_{\frac{1}{2}}$	399.2	E1	$5.8(1.0) \times 10^{-6}$	$5.8(1.0) \times 10^{-6}$

Discussion

The results of our analysis to table -3 is that;

1- Transitions strengths for all γ - transitions in the present work are in excellent agreement with that of experimental of .[1] excepted $B(M1)_{w.u}$ value reported in .[1] for 176.5 KeV. $8^-_1 \rightarrow 7^-_1$ transition from 3056 KeV level is unaccurate it may be equal to $1.14(5) \times 10^{-3}$ by using eqs(3 and 1) with the experimental data of table-1 in [1] since α_{tot} is equal to 0.098.

2-All the $[M(EL,ML)]^2_{w.u}$ values within the associated errors are consistent with upper limit presented in table-1.

3- A recent study of the mixing transitions for $\Delta I=0,1$ in neutron rich isotopes indicated that nearly pure M1 radiation was observed [5].For the following transitions; the 176.5 KeV. $8^-_1 \rightarrow 7^-_1$ transition from 3056 KeV. level and the 149.9Kev. $7^-_2 \rightarrow 7^-_1$ transition from 3029 KeV. level in ^{110}Cd isotope are observed to be almost M1 radiation

4-The largest values of $[M(E2)]^2_{w.u}$ to electric quadrupole transitions for;171.3 KeV. $10^+ \rightarrow 8^+_{\frac{3}{2}}$ transition from 3611 KeV level, and 159.7 KeV. $8^-_1 \rightarrow 6^-_1$ transition from 3056 KeV, level are indicated ; a high collectivity of excited states and the cooperative effects between nucleons governs the behavior of the transitions.

Where the $[M(E2)]^2_{w.u}$ value for 335.6 KeV. $10^+ \rightarrow 8^+_{\frac{3}{2}}$ transition from 3611 KeV.,level reveals the inter play of collective and single-particle excitation in nucleus .While all very low transition strengths values of E1 and E2 transitions in table-3 are indicating allow collectivity of the excited states and the dominance of single particle degrees of freedom [6] .

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