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}Pd (α,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 .
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قوى الانتقال الكهرومغناطيسي في نواة الكادميوم ^{110}Cd

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الخلاصة

تم حساب قوى الانتقال لانتقالات رباعي القطب الكهربائي وثنائي القطب الكهربائي والمغناطيسي النقية من بعض المستويات المتهيجة لنواة ^{110}Cd المتولدة من التفاعل ^{108}Pd (α,2n) وذلك بالاستعانة بمعدل أعمار المستويات المتهيجة والشدة النسبية لأشعة كاما المنتقلة. أ ن القيم المحسوبة لكل من $[M(E1)]^2_{W.u}$, $[M(E2)]^2$ W.u ,$[M(M1)]^2_{W.u}$ قد ساهمت قي 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 ^{110}Cd 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^{110}Cd 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

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

Where L is the multi polarities L=1,2,3, L$\neq$ 0

The half –life $t_{1/2}$ and mean life T are related by the following relation

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

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]

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

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

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

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

Where δ is mixing ratio

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

Since $\Gamma_\gamma T\approx\hbar$ ....(7)

Γ_γ is the total width

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

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

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

Where

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

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

$\Gamma_{\gamma L}=BR_i \text{ x } \Gamma_\gamma$ …………………….(10)

BR$_i$ is the branching ratio of (γ_i) can be calculated from

$$BR(\gamma_i)=\frac{I_{\gamma_i}}{I_{tot}}x100\%\text{ ....(11)}$$

Where

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

$I_{tot}=\sum I_{\gamma i}$ ……………………….(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)

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

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

$B(EL,ML)_{W.u}=[M(EL,ML)]^2{}_{W.u}$ ..(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 $\frac{t^{\gamma}_{1/2}(EL,ML)_{SP}}{t^{\gamma}_{1/2}(EL,ML)_{\exp}}$ For a pure M1 or E2 , δ=0 and hence

$\Gamma(M1)$ or $\Gamma(E2)=\Gamma_\gamma$ ……… .(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 nomber. A may be obtained(Eγ in KeV. Γγw in eV) .[2]

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

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

$\Gamma(E2)_{W.u} = 4.7907\text{X}\ 10^{-23}\ A^{4/3} E_\gamma^5$ ……(18)

Results and Calculations

1-Mean life times (τ_m) for the excited states calculated by using eq. (2) from half life times ($\tau_{½}$) 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 Γ(ML) and Γ(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.

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

$|M(El)|^2_{W.u.} = \dfrac{\Gamma(El)_{\exp}}{\Gamma(El)_{W.u}}$ were used .Γ(ML) and Γ(EL) are presented in table-2.

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

Table-1: $\tau_{½}(\text{W.u}) / \tau_{½}(\text{exp.})$ (Recommended upper limits) [2]

Multipolarity	91≤A≤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]						T ns	Γ_γ x10^{-6} eV	B.R.%	Γ(EL,ML)X10^{-11} eV
E_i KeV.	$\tau_{½}$ ns	$J_I^\pi \rightarrow J_f^\pi$	E_γ	I_γ	EL,ML				
3611	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
3056	2.25(10)	$0_1^- \rightarrow$ 6_1^- 7_1^-	159.7 176.5	23.9 56.6	E2 M1	3.2467 ±0.14430	0.20273 ± 0.00901	29.69 70.31	6019±268 14254±268
3029	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±0.14430	1.52047±0.50682	7.67 7.03 36.58 48.72	11659±3886 10687±3562 55621±18540 74080±24694
2879	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±0.1443	0.76024±0.12671	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.	$I_i^\pi \to J_f^\pi$	E_γ Kev.	EL ,ML	$[M(EL,ML)]^2_{W.u}$ Present Work	$B(EL,ML)_{W.u}$ Ref.[1]
3611	$10^+ \longrightarrow$				
	8_3^+	171.3	E2	33.8(7.5)	33.5(8.5)
	9_1^-	265.2	E1	$1.3(3)\text{x}10^{-6}$	$1.3(3)\ \text{x}10^{-6}$
	8_2^+	335.6	E2	7.7(1.7)	7.7(1.8)
	8_1^+	423.5	E2	$5.4(1.2)\ \text{x}10^{-2}$	$5.4(1.8)\ \text{x}10^{-2}$
3056	$8_1^- \to$				
	6_1^-	159.7	E2	22.9(1.0)	20(1)
	7_1^-	176.5	M1	$1.3(1)\ \text{x}10^{-3}$	$5.1(2.6)\text{x}10^{-4}$
3029	$7_2^- \to$				
	7_1^-	149.9	M1	$1.7(6)\ \text{x}10^{-3}$	$1.6(7)\ \text{x}10^{-3}$
	5_2^-	369.2	E2	0.6(2)	0.6(3)
	5_1	489.4	E2	0.78(0.26)	0.8(3)
	6_1^+	549.1	E1	$2.9(1.0)\ \text{x}10^{-6}$	$2.9(1.0)\ \text{x}10^{-6}$
2879	$7_1^- \to$				
	5_2^-	219.3	E2	0.9(1)	0.9(2)
	5_1^-	339.5	E2	1.6(3)	1.6(3)
	6_1^+	399.2	E1	$5.8(1.0)\ \text{x}10^{-6}$	$5.8(1.0)\ \text{x}10^{-6}$

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. $8_1^- \to 7_1^-$ transition from 3056 KeV level is unaccurate it may be equal to$1.14(5)\ \text{x}10^{-3}$ 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 ΔI= 0,1 in neutron rich isotopes indicated that nearly pure M1 radiation was observed [5].For the following transitions; the 176.5 KeV. $8_1^- \to 7_1^-$ transition from 3056 KeV. level and the 149.9Kev. $7_2^- \to 7_1^-$ 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. $10^+ \to 8_3^+$ transition from 3611 KeV level, and 159.7 KeV. $8_1^- \to 6_1^-$ 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. $10^+ \to 8_2^+$ 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] .

References

[1] Kostov L.K. , Andrejtscheff W., Kostova L.G., Kaubler L. , Prade H.,and Schwenngner R **1998**, Absolute E1and E2 transition rates in ^{110}Cd, Eur.Phys.J. A2, p.263-273.

[2] Fore stone R.B., and Shirley V.S., **1999**, Appendix 1 . Reduced transition Probabilities, Table of Isotopes , 8th edition, John Wiley and Sons ,p.1.1-1.8.

[3] Martin B.R., **2008**, Nuclear and particle physics ,3rd Edition ,John Wiely and sons P.27

[4]Skerka S.J., Hertal J.and Retzschaidt, **1966**, Nucl.Data A2, p.341

[5] Fenker B.B., **2010**,Multipole mixing ratios of transitions out high spin gamma vibrational states in neutron rich Mo ,Ru isotopes ,Vanderbilt University ,Nashville TN 37235 undergraduate Departmental Honors Thesis ,P.6.

[6] Lucas R., **1998**, Nuclear shapes , Euro physics News ,Vol.31 No.7 p.1-8