# Determination of $\delta$ – Mixing Ratios of $\gamma$ – Transitions From Levels of $^{110, 112, 114}$ Cd populated in The $^{110, 112, 114}$ Cd (n,ń $\gamma$) Reactions

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## Abstract

The $\delta$ – mixing ratios of $\gamma$– transitions from levels of $^{110, 112, 114}$ Cd populated in the $^{110, 112, 114}$ Cd (n,ń $\gamma$) reactions have been calculated in the present work using the $a_2$ – ratio method. The results obtained confirm the validity of this method and its capability in predicting any inaccuracy in the experimental data.

## Introduction

The $^{110}$ Cd, $^{112}$ Cd and $^{114}$ Cd isotopes have been subject of several investigations. The information obtained on $^{110}$Cd up to 1983 and$^{112}$Cd up to 1980 have been compiled by DeGlder et. al. (1) and peker (2) respectively . The data published on $^{114}$Cd up to 1982 have been reported by Blacot and Marguier (3).

Levels in $^{110, 112, 114}$ Cd isotopes have been studied by youhana et. al. (4) using (n,ńγ)reactions with reactor fast neutrons. Angular distributions of several γ - rays in each isotope have been measured. The mixing ratios of several γ - transitions in each isotope have deduced and compared where possible with those previously reported by other authors.

E2 /M1 mixing ratios of $(2^- - 2^+)$ γ - transitions in $^{110,112,114}$ Cd isotopes have been determined by youhana and Al- Amili (5) by measuring the angular distributions of γ - rays depopulating $^{2+}$ levels excited in the $^{110,112,114}$ Cd (n,ń γ) reactions. Spin – parity of $J^{\pi} = 2^+$ have been assigned to the 250 6.6 Ke V level of $^{112}$ Cd

Levels in $^{112}$Cd have been studied through the (n,ń γ) reaction with monoenergetic neutrons by Garrett et. al. (6). An extended set of experiments including γ - ray angular distributions and γ - γ

coincidence measurement, was performed. A total of 375 γ - rays were placed in a level scheme comprising 200 levels up to 4 Mev in excitation. Mixing ratios of 68 γ- transitions have been determined but, unfortunatdy the corresponding $a_2$ – coefficients have not been reported.

The structure of $^{112}$Cd was investigated by Drissi et.al (7) using the $^{48}$ Cd (n,ń γ) $^{112}$Cd and $^{46}$ Pd ($\alpha$, 2n γ ) $^{48}$ Cd reactions . The results were combined with published data resulting in a complete level scheme over large range of spins and excitation energies . Mixing rations of several -γ- transitions have also been determined.

The energies and intensities of γ - rays form levels of $^{110,112,114}$ Cd have also been published in the Table of Isotopes 8$^{th}$ edition (8).

The main aim of the present work is to confirm the validity of $a_2$ – ratio method to calculate the multi pole mixing ratios, $\delta$ of γ- transition Form level excited in the $^{110,112,114}$ Cd (n,ń γ ) reactions.

## Data Reduction Analysis

In this method the levels of the product nuclei that have at least two – γ – transitions whose angular distributions have been measured and one of which is pure transition or can be considered as a pure γ transitions are taken into consideration.

The $\delta$ - mixing ratios of the other transition can then be calculated using eq [1]

$$\frac{a_2(Ji - J_{f2})}{a_2(Ji - Jf_1)} = \frac{F_2(Ji - Jf_1) + 2_\delta F_2(JF_2L_1Ji) + \delta_2 F_2(Jf_2L_2L_2Ji)}{(1+\delta 2)F2(f1L1L1Ji)} \text{-----[1]}$$

the values of $F_2$ – coefficients are presented in ref (9).

In this equation, $a_2$ ($J_i$ – $J_f$) represents the experimental $a_2$ – coefficient reported for the γ transitions whose $\delta$ - values are to be calculated and $a_2$ ($J_i$ – $J_{f2}$) represents the experimental $a_2$- coefficient reportal For the pure transition angular momentum $L_1$ , taken to be

$L_1 = |Ji - Jf|$ and $L_2 = L_1 \neq 0$

for such - transition , the equation become :

$$a_2(J_i - J_f) = f_2(Ji)\frac{F_2(J_f L_1 L_1 Ji + 2\delta f_2(J_f L_1 L_2 Ji) + \delta^2 F_2(J_2 L_2 L_2 Ji))}{1+\delta 2}$$

------[2]

Which are in the case of $^{110,12,114}$Cd isotopes are :

$$\frac{a_2(2-2)}{a_2(2-0)} = \frac{-0.41833 - 1.22476\delta + 0.128\delta}{-0.59761(1+\delta^2)} \text{ ---------[3]}$$

$$\frac{a_2(4-2)}{a_2(4-2)} = \frac{0.4477 - 1.0594\delta + 0.4700\delta^2}{-0.4477(1+\delta^2)} \text{ ----------[4]}$$

## Result Discussion

The energy levels of $^{110,12,114}$Cd and the related $\gamma$ - transitions whose $a_2$- coefficients have been used to calculate the corresponding $\delta$ - values by this method are presented in table (1). The - values of $2^+$ - $2^+$ transitions are calculated using eq [3] and those of $4^+$ - $2^+$ transitions are calculated using eq [4].

It is clear form table (1) that the $\delta$ – values calculated in present work are in general, in good agreement or consistent within the associated errors with those of ref (4,5) . Since this method depends upon the experimental $a_2$- coefficients of such $\gamma$ - transitions only, it may also be used to determine any inaccuracy existing in the experimental data.

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**Table (1):Multipole mixing ratio of $\delta$ – Transitions form energy levels of $^{110,12,114}$Cd calculated by the $a_2$- ratio method.**

| Isotope | $E_{level}$ (KeV) | $E\gamma$ (KeV) | $J_I^{\pi} J_F^{\pi}$ | $a_2$* $a_4$ | $\delta$-Values → | | |
|---|---|---|---|---|---|---|---|
| | | | | | Ref. [4] | Ref. [5] | P.W. |
| $^{110}$Cd | 1475.8 | 1475.8 | $2^+$-$0^+$ | 0.291 (51) 0.070(58) | E2 | E2 | E2 |
| | | 818.0 | $2^+$-$2^+$ | -0.250(19) -0.032(26) | - $(1.1^{+?}_{-0.3})$ - $(2.4^{+1.6}_{-?})$ | - $(1.0^{+0.6}_{-0.2})$ -2.5(9) | $-(1.3^{+?}_{-0.5})$ $-(1.9^{1.5}_{-?})$ |
| | 1783.5 | 1783.5 | $2^+$-$0^+$ | 0.291 (50) 0.070(58) | E2 | E2 | E2 |
| | | 1125.7 | $2^+$-$2^+$ | 0.274(33) -0.017(32) | 0.13 $^{+0.17}_{-0.12}$ | 0.08 (5) – | $0.13^{+0.13}_{-0.11}$ 1 .6 (4) |

| Isotope | $E_{level}$ (KeV) | $E\gamma$ (KeV) | $J_I^{\pi} J_F^{\pi}$ | $a_2$* $a_4$ | $\delta$-values | | |
|---|---|---|---|---|---|---|---|
| | | | | | Ref. {4} | Ref. {5} | P.W. |
| $^{112}$Cd | 1312.3 | 1312.3 | $2^+$-$0^+$ | 0.308(31) - 0.063(32) | E2 | E2 | E2 |
| | | 694.7 | $2^+$-$2^+$ | - 0.134(19) - 0.028(23) | - $(0.57^{-0.11}_{-0.07})$ $-(94^{+3.0}_{-0.4})$ | (- $0.54^{0.32}_{-0.21}$) - | -0.59 (6) - $(8.7^{4.9}_{-2.4})$ |
| | 1468.7 | 1468.7 | $2^+$-$0^-$ | 0.322(19) 0.060(22) | E2 | E2 | E2 |
| | | 851.1 | $2^+$-$2^-$ | 0.363 (40) -0.016 (45) | $0.27^{-0.23}_{-0.14}$ 1.2 (4) | $0.21^{+0.10}_{-0.08}$ 1.4 (3) | $0.25^{+0.13}_{-0.10}$ 1.3 (3) |
| | 2156.2 | 1538.5 | $2^+$-$2^-$ | .199 (28) - 0.037(32) | -0.04 (11) $2.5^{-1.0}_{-0.7}$ E2 | - - - | -0.03 (2) 2.0 (4) |
| | | 932.0 | $2^+$-$0^-$ | 0.259(43) -0.039 (46) | | | E2 |
| | 2506.6 | 2506.6 | $2^+$-$2^-$ | 0.314(82) - 0.119(86) | E2 -0.01 (13) $2.4^{+1.1}_{-0.8}$ | E2 -0.05 (16) $1.9^{+0.9}_{-0.6}$ | E2 0.08 |
| | | 1888.8 | $2^+$-$0^-$ | 0.269(72) - 0.080(82) | | | $1.8^{+1.0}_{-0.6}$ |

| Isotope | $E_{level}$ (KeV) | $E\gamma$ (KeV) | $J^{\pi}{}_{i} J^{\pi}{}_{f}$ | $a_2$* $a_4$ | $\delta$-values | | |
|---|---|---|---|---|---|---|---|
| | | | | | Ref. [4] | Ref. [5] | P.W. |
| $^{114}$Cd | 1209.7 | 1312.3 | $2^+$-$0^+$ | 0.305(26) -0.066(30) | E2 | E2 | E2 |
| | | 694.7 | $2^+$-$2^+$ | -0.259(17) | $-(1.3^{+?}_{-0.4})$ | $(-1.2^{+0.5}_{-0.2})$ | $-(1.2^{+?}_{-0.3})$ |
| | | | | -0.011(23) | $-(94^{+11}_{?})$ | -2.2 (6) | $-(8.7^{-0.8}_{-?})$ |
| | 1364.3 | 1468.7 | $2^+$-$0^+$ | 0.287(37) 0. 60(42) | E2 | E2 | E2 |
| | | 851.1 | $2^+$-$2^-$ | 0.256 (41) -0.042 (46) | 0.07(8) 1.9 (4) | 0.09 (6) 1.8 (3) | 0.07(6) 1.8 (4) |
| | 1732.2 | 1538.5 | $4^+$-$2^+$ | 0.291 (50) -0.070(58) | -0.09(7) | - - | E2 -0.02 (14) |
| | | 932.0 | $4^+$-$0^+$ | 0.305(88) -0.066 (95) | -0.06(12) | - | 0.02 (15) E2 |
| | 1841.9 | 2506.6 | $2^+$-$0^+$ | 0.329(79) -0.101(84) | E2 -0.04 (8) | E2 $-0.05^{+0.10}_{-0.08}$ | E2 0.02 (7) |
| | | 1888.8 | $2^+$-$2^-$ | 0.246(29) -0.0.49(34) | $2.5^{+0.7}_{-0.5}$ | 2.0 (5) | 2.1 (3) |

| Isotope | $E_{level}$ (KeV) | $E\gamma$ (KeV) | $J_I^{\pi} J_F^{\pi}$ | $a_2$* $a_4$ | $\delta$ -values | | |
|---|---|---|---|---|---|---|---|
| | | | | | Ref. {4} | Ref. {5} | P.W. |
| $^{114}$Cd | 2316.8 | 1182.4 | $2^+$-$0^+$ | 0.286 (71) - | E2 | E2 | E2 |
| | | 1107.2 | $2^+$-$2^+$ | 0.081(81) | $0.77^{+0.36}_{-0.20}$ | $0.79^{+0.18}_{-0.11}$ | $0.86^{+?}_{-0.22}$ |
| | | | | - 0.200(32) | - $(4.1^{+3.2}_{-1.9})$ | - $(3.9^{+2.0}_{-1.2})$ | - $(3.4^{+3.3}_{-?})$ |
| | | | | - 0.012(35) | | | |

*The a2 and a4 coefficients are those calculated in the present work.

# حساب نسب الخلط لاشعة كاما المنبعثة من مستويات في $^{110,112,114}Cd$ $^{110,112,114}Cd\ (n,\acute{n}\ \gamma)$

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## الخلاصة

حسبت نسب الخلط ( $\delta$ ) للانتقالات الكامية من مستويات الطاقة في $^{110,112,114}Cd$ المتولدة من التفاعلات النووية $^{110,112,114}Cd\ (n,\acute{n}\ \gamma)$ بطريقة نسبة $a_2$ . والنتائج التي تم لحصول عليها تثبت صحة هذه الطريقة في حساب نسب الخلط وقابليتها في التنبوء بأي خطأ موجود في المعطيات التجريبية .