Delta J. Sci. 16 (1) 1992, 31-42

ON THE LEVEL STRUCTURE OF ^{154}Gd

BY

S.U. El-Kameesy, H.M. Hanafi*, M.A. El-Khosht** and F.A. Abdel-Khalak***

Physics Department, Faculty of Science, Ain-Shams University, Cairo, Egypt

* Physics Department, Faculty of Education, Cairo University, El-Fayom, Egypt

** Physics Department, Faculty of Science, Tanta University, Tanta, Egypt.

*** Physics Department, Faculty of Science, Zagazig University Zagazig, Egypt.

Received: 18-4-1992

ABSTRACT

Gamma transitions of the ^{154}Gd low lying levels of the ground state band have been investigated using HP Ge and HP Ge-NaI(T1) spectrometers. The experimental reduced transition probabilities of the 123.06, 247.93 and 346.72 keV ground state interband transitions are evaluated. The results are in excellent agreement with the calculations based on Nilsson model. Furthermore, the experimental adopted levels of the ground state band are compared with those calculated by means of a dynamic version of the collective model.

INTRODUCTION

The β^--decay of ^{154}Eu to ^{154}Gd has been studied early by several authors [1-4]. Internal conversion and Gamma ray intensity measurements were performed by Iwata et al. [5]. Angular correlation experiments were performed by Varnell et al. [6] and Lewis [7] to determine the mixing ratio of some gamma transitions.

On the other hand, the collective model [8] accounts well for the properties of the level structure of deformed nuclei. In particular, it allows us to calculate the reduced gamma ray branching ratios for transitions to different levels in the rotational band based on the ground state or a vibrational state. This model is expected to give good results in nuclei with large deformation, but its validity in regions of transitional nuclei is less certain because of the band mixing.

Many models have been given to discuss the collective states of non-spherical nuclei. The rotational model is frequently applied for strongly deformed nuclei. Also, the energy spectra of even_even actinide nuclei,with large moment of inertia and low excitation energies for high spin values, was given as higher order term angular velocity expantion [9]. The structure of transitional nuclei could be described in the frame of weakly deformed rotor using Nilsson model [10]. In the same regard, a connection between the Variable Moment of Inertia and the Interaction Boson Approximation model was given [11] to discuss the ground state band for some non-strongly deformed nuclei.

In the present work, the dynamic version of the collecti· model [12,13] is applied to describe the energy states of the ground state band of the transitional nucleus ^{154}Gd. Also, determination of the reduced transition probability for the ground state interband transitions is included.

2. EXPERIMENTAL PROCEDURE

The gamma ray spectrum has been investigated using a HP Ge detector of volume 56.4 cm^3 (FWHM = 1.8 keV at 1.33 MeV) in the singles mode. Several spectra were analysed using a MCA 4096 channel and IBM-personal computer.

A careful calibration for the energy and photopeak efficiency was carried out by means of a well known standared sources. However the gamma spectrum following the decay of ^{154}Eu to ^{154}Gd was extensively studied a great attention was taken in the present work to determine precisely the intensity of some interband transitions in the ground state band. These gamma transitions are 123.068, 247.932 and 346.723 keV. Their relative intensities are found to be 117.54 (30), 19.90(10) and 0.08(1) respectively. The intensities were normalized to 100 for the 1274.4keV γ-ray attributed to ^{154}Eu decay.

γ -γ coincidence measurements have been performed using a 3" x 3" NaI(Tl)-HP Ge fast-slow coincidence spectrometer. The time resolution of the fast coincidence pulse was about 20 ns. A triple slow coincidence pulse of 0.5 µs, was used to gate the MCA to obtain the coincidence spectra.

When the coincidence spectrometer was adjusted to select the 123.068 keV γ-peak as a gating transition, the window setting (85-130 keV) is considered. A typical coincidence spectrum for that gate is shown in fig. (1). Also, a partial decay scheme of ^{154}Eu is shown in fig.(2).

3. THE DYNAMIC VERSION OF THE COLLECTIVE MODEL CALCULATIONS

A dynamic version of the unified collective model of nuclei introduced by Zvonov and Mitroshin [12], as a universal mechanism forming quasi rotational bands in spherical, transitional and deformed nuclei, holds well for the ground state bands in even -even nuclei $40 \leqslant A \leqslant 180$. In such model the energy spectrum of vibrational states with $\bar{I}$=N is given by

$$E_N = NW^{(N)} + \frac{2\lambda + 1}{2} (W^{(N)} - W^{(1)})$$

where $W^{(N)} = W^{(1)} (1 + 2\acute{\gamma}(N-1))^{1/2}$, $W^{(1)} = E^{+}_{2_1}$,

$$\acute{\gamma} = \gamma (1 + \frac{3\ e^2 z^2}{10\pi R_o B_2} / E^2_{2_1}$$

λ is the phonon number 0,1,2,3, ... ; γ is a universal constant = 0.184 $(20 \leqslant A \leqslant 28)$ or = 5.5×10^{-2} $(40 \leqslant A \leqslant 190)$. Also, $R_o = r_o A^{1/3}$, (r_o = 1.25 fm) and $B_\lambda = \frac{3}{4\pi} \frac{mA}{\lambda} R_o^2$ where m is the nucleon mass in umits of a.m.u.

The ground state band (yrast band) of ^{154}Gd was calculate using such model, but there is a pronounced deviation from the experimental data as shown in table (1). This model was modifi [13] as follows

$$E_N = NW^{(N)} + \frac{2\lambda + 1}{2} (W^{(N)} - W^{(1)}) + \eta (W^{(N)} - W^{(1)}) (N + \frac{2\lambda + 1}{2}) \frac{2\lambda + 1}{2}$$

where η is a fitting parameter 0.068. It is found good agreement between experimental data and those calculated by means of the modified expression up to 12^+ as shown in table (1). The deviation in energy values up 12^+ state may be attributed to a slightly appearing of the backbending phenomena, usually occured in yrast (ground state) bands of deformed nuclei.

4. E2 REDUCED TRANSITION PROBABILITY WITHIN BAND

With a half life or level width measurement the total transition probability of a nuclear level is determined and consequently that of the depopulating transitions. Also, it is common to compare experimental results with theoretical predictions by giving the hindrance factor F (theoretical transition probability/ corresponding experimental transition probability).

A theoretical predictions of the transition rates in deformed nuclei are known to be obtained using the deformed potential single particle model formulated by Nilsson [14]. According to this model the reduced E2 transition probability can be written

$$B(E2) = 4.028 \times 10^{-5} A^{3/2} \left(< I_i k_i 2, k_f - k_i | I_f k_f > + b_{E2} (-1)^{I_f + k_f} < I_i k_i 2 - k_f - k_i | I_f, -k_f > \right)^2 G^2_{E2}$$

where B(E2) in units of $e^2 b^2$ and the quäntities b and G depend on the initial and final states of the transition [14,15]. The results from a comparison with this model is given in table (2), column (7), where the hindrance factor F_N is given. The values of F_N in table (2) indicate a very weak band mixing of other bands with the low lying states of the ground state band and a pure E2 multipolarity for the 123.068, 247.932 and 346.723 keV interband transitions.

The reduced transition probability given in column (6) is obtained from the following formula:

$$B(E2) = 56.4 / t_{1/2\gamma}(E2)\, E^5$$

where the partial half life $t_{1/2\gamma}$ (E2) is in seconds, E_γ in keV and B(E2) in units of $e^2 b^2$.

Using the collective model relationship,

$$B(E2)\,(I_i\ k \longrightarrow I_f\ k) = \frac{5}{16\pi} Q^2 < I_i\ k\ 20 | I_f\ k >^2$$

we obtain the electric quadrupole moments for the above mentioned interband transitions and consequently the equivalent deformation parameter as given in table (2). The results show that the 4^+ and 6^+ states of the ground state band have approximately the same deformation

5. CONCLUSION

In this work an attemnt has been made making use of a good resolution detectors to determine precisely energies and intensities of the ground state band γ-transitions. The coincidence spectrum fig.(1) includes γ-transitions attributed to such ground state band.

The experimental reduced transition probabilities of the interband transitions are determined and compares with that of the deformed single particle model given by Nilsson and an excellent agreement is obtained. This result indicates that there is no effective band mixing with the low lying levels of the ground state band. Furthermore, the dynamic version of the collective model given in references [12,13] is applied to the ground state band of ^{154}Gd. It is noticed a good agreement between experimental and theoretical calculations up to $I^{\pi} = 12^+$. The deviation in energy values for $I > 12$ may be attributed to a slightly appearing of back bending phenomena in ^{154}Gd ground state band.

Table (1): Experimental and Calculated Energy levels of the Ground state band ($K^{\pi}=0^+$) of ^{154}Gd

Experimental E(keV) Energy Level	Dynamic version of the Collective model	Modified Dynamic version of the Collective model
0.00	0.0	0.00
123.068	123.0	123.06
371.003	322.5	372.5
717.723	551.6	713.2
1144.52	804.0	1160.0
1637.20	1065.0	1683.0
2184.70	1258.5	2408.5
2777.50	1649.5	3229.0
3404.50	2081.5	4120.0
4016.30	2314.5	5144.5

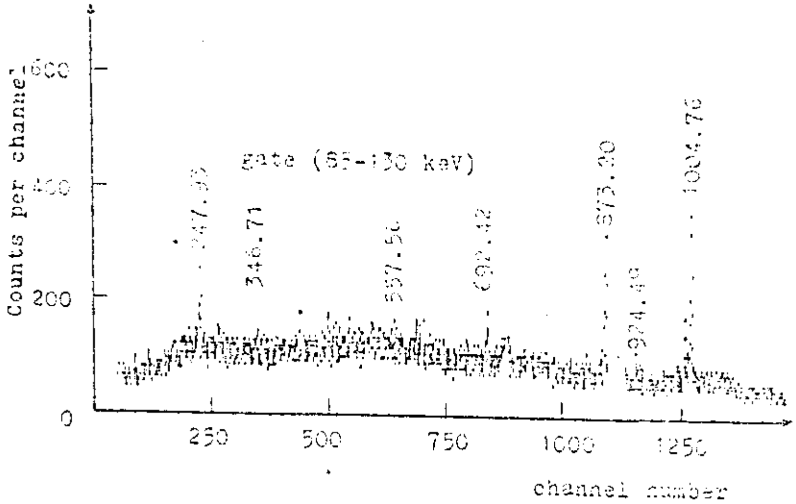
Table (2): Experimental Data and Hindrance factors F_N for low lying Ground state inter-band transitions and the equivalent deformation parameters δ of the corresponding states.

E(keV)	$t_{1/2}$(level)[a]	E_γ(keV)	I_γ	α[a]	$B(E2)^{b}_{exp.}$	F_N	δ
123.060	1.186(18) ns	123.10(8)	117.54(30)	1.2	3.70(5)	1.04	0.34(1)
371.005	45.20(150) ps	247.95(17)	19.90(10)	0.111	1.48(3)	0.963	0.24(2)
717.723	7.8(4) ps	346.72(14)	0.08(1)	0.0391	1.50(6)	1.1	0.23(2)

a) Ref. (16).

b) B(E2) in units of e^2b^2.

Fig.(1)



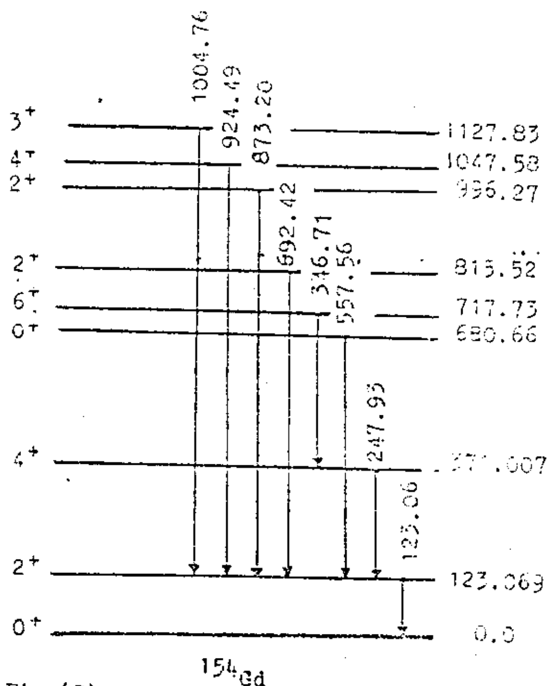


Fig.(2)

.g.(1): Coincidence spectrum for gate (85 - 130) keV of ^{154}Eu source.

Fig.(2): Partial level scheme of ^{154}Gd nucleus.

REFERENCES

1- R.A. Meyer, Phys. Rev., 170 (1968) 1089

2- Y. Yoshizawa, Y. Iwata and Y.Jinuma, Nucl. Inst. Meth., 174 (1980) 133.

3- H. Yamada, H. Hawakami, M.Koite and K. Komura, J.Phys. Soc. Jpn., 42 (1977) 1448.

4- J.B. Gupta, S.L. Gupta, J.H. Hamilton and A.V. Ramayya, Z. Phys., A 282 (1977) 179.

5- Y. Iwata, M. Yasuhara, K. Maeda and Y. Yoshizawa, Nucl. Inst. Meth., 219 (1984) 123.

6- L. Varnell, J.D. Bowman and J. Trischuk, Nucl Phys., A 127 (1969) 270.

7- G.C. Lewis, G. Mohammad, L.D. Wyly, E.T. Patronis and C.H. Braden, Nucl. Inst. Meth., 211 (1983) 371.

8- A. Bohr and B. Mottelson, Nuclear Structure, New York: W.A. Benjamin, (1969)

9- L.K. Peker, S. Pearlstein and J.H. Hamilton, Phys. Lett., 100 B (1981) 281.

10- P.C. Simms, F.A. Rickey and R.K. Pobli, Nucl. Phys. A 347 (1980) 205.

11- A. Klein, Phys. Lett., 93 (1980) 1 and Nucl. Phys., A 347 (1980) 3.

12- V.S. Zvonov and V.E. Mitroshin, Inter. Symp. On High Spin States and Nuclear Structure, Dresden, 19-24 Sep. (1977).

13- A. El-Naem and M. Morsy, Ain-Shams Univ., Private Communication.

14- S.G. Nilsson. Mat. Fys. Medd. Dan. Ved. Selsk., 29 (1955) 16.

15- O. Nathan and S.G. Nilsson, in : Alpha, Beta and Gamma Ray Spectroscopy (Edited by K. Siegbahn, Amesterdam, North-Holland Pub. Co., (1955) Chap. 10

16- R.G. Helmer, Nuclear Data Sheets, 52 (1987).

Delta J. Sci. 16 (1) 1992

التركيب الطبقى للجادولينيوم – ١٥٤

سمير يوشع الخميس– حنفى مصطفى حنفى+– محسن انور الخشت ++
فتحية عبد الرؤف عبد الخالق +++

الانتقالات الجامية بين مستويات الطاقة المنخفضة فى حزمة المستوى الارضى للجادولينيوم – ١٥٤ قد بحثت باستخدام كاشف الجرمانيوم عالى النقاوة ومطياف التطابق المتزامن والمكون من هذا الكاشف المذكور ويشاركه كاشف يوديد الصوديوم المنشط بالثاليوم وعلى هذا فقد قيم الاحتمال الانتقالى التجريبى للانتقالات الداخلية (ثنائية القطب الكهربى) لحزمة المستوى الارضى لـ ٦٠و١٢٣ ، ٩٣و٢٤٧ ، ٧٢و٣٤٦ كيلو الكترون فولت.

والنتائج التى حصلنا عليها قد جاءت فى توافق متميزة مع الحسابات التى أجريت على أساس نموذج نلسون. وكذلك مستويات الطاقة التجريبية لحزمة المستوى الأرضى التى قورنت بمثيلها المحسوب بواسطة صوره حركية لنموذج التجمع.

+قسم الطبيعة ، كلية التربية ، جامعة القاهرة ، الفيوم ، مصر.
++قسم الطبيعة ، كلية العلوم ، جامعة طنطا ، طنطا ، مصر.
+++قسم الطبيعة ، كلية العلوم ، جامعة الزقازيق ، الزقازيق ، مصر.