THE DECAY OF ^{153}Ho TO THE TRANSITIONAL N = 87 NUCLEUS ^{153}Dy

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ABSTRACT :

A preliminary ^{153}Dy level scheme, fed from the decays of ^{153}Ho and ^{153m}Ho, is presented. At both Ho isomers correspond two distinct level schemes, with respectively low and high spins. The low spin part seems very similar to the low spin scheme of the ^{151}Gd isotone, the interpretation of which suppose a small deformation. The high spin part, dominated by the strong β^+ transition (h11/2)p → (h9/2)n, can be correlated to the scheme obtained by in-beam excitations.

1. INTRODUCTION

Level schemes of neutron deficient odd Dysprosium isotopes obtained from Holmium decays, are well known for N > 89. They correspond to deformed nuclei, based on the groundstate 3/2-[521] configuration and the ^{155}Dy (N = 89) scheme can be interpreted in term of other Nilsson configurations, strongly mixed by Coriolis interactions (1). The transition between deformed and spherical shape is expected near N = 88 and, indeed, the 7/2 spin value measured by Rosen et al (2) for the ^{153}Dy groundstate corresponds to the shell model f7/2 prediction.

Schmidt-Ott et al (3) produced Ho isotopes by bombarding ^{144,147}Sm with ^{11,10}B. By using a gas jet capillary transport technique, they observed various γ transitions corresponding to two ^{153}Ho isomers : a low spin one, with a 9.3 mn half-life, and a high spin one with T1/2 = 2.0 mn. No level scheme was presented. A study of the first levels fed by the 9.3 mn isomer, obtained from spallation reactions on a tantalum target and mass separation, was made by Zuber et al (4). Their work was developped by Andréiev et al (5). They measured γ and conversion electron spectra, single or in coincidence, level half-lives, and presented a scheme with 4 excited levels at 108.8, 270.6, 500.9 and 565.8 keV. Their 108.8 keV half-life measurement give 1.35 ± 0.10 ns.

The ^{153}Dy levels, excited by (α,xnγ) reactions on Gd targets, are more precisely known after the concordant studies of Kleinheinz et al (6) and Jansen et al (7). From these works, a h11/2 band, presenting the characters of a large deformation (11/2-[505] configuration) coexists with two less developed more spherical, f7/2 and h9/2 bands. The i13/2 intrinsic state corresponds to a more complex coexistence of two ΔI = 2 bands.

The new possibility of separating Holmium isotopes at ISOCELE (8) allowed us to extend our previous systematics on odd Dysprosium level schemes. We present here some preliminary results on the ^{153}Ho decay.

2. HOLMIUM-DYSPROSIUM ON-LINE SEPARATION

Holmium isotopes have been produced by Tb(^{3}He,xn) reactions with the I.P.N.-ORSAY synchrocyclotron (^{3}He beam energy = 280 MeV). On-line separations were performed with the ISOCELE 2 facility (9). In this region, the difference between metal volatilities, correlated to the corresponding boiling points (Ho = 2695°C, Dy = 2562°C, Tb = 3123°C) is small, but the Tb-Ho difference is sufficient for using the Terbium as a target for Ho-Dy production, although supporting a small consumption. By this method, a strong mixing Ho-Dy is unavoidable, but we observed that the Holmium/Dysprosium proportion was improved by a factor up to 4 by using the Terbium target as an anode.

3. EXPERIMENTAL METHODS

The mass-separated Ho-Dy ions were implanted in the mylar tape of a tape transport system associated with various semi-conductor detectors. Coaxial and planar Ge, Ge(Li) and Si(Li) detectors were used for γ and X rays measurements. Conversion electrons were registered with a Si(Li) detector in a magnetic "selector" (10). γ-γ and e-γ coïncidence experiments (2048 x 2048 channels) were performed with these detectors and analyzed with the Orsay ARIEL IBM Computer. Discrimination between transitions issued from each Holmium isomer was obtained by systematically registering two successive 2 mn spectra after the source transport.

Pure daughter spectra (^{153}Dy = T1/2 = 6,5 h) were obtained by a final delayed counting. Single spectra were analyzed by a special program associated with an ORTEC Ultima analyzer.

4. RESULTS

Two typical single γ and conversion spectra are presented in fig. 1 and 2. A γ spectrum obtained with the Terbium target as anode and corresponding to the energies under 700 keV is shown in (1) (fig.2). As a 153 daughter spectrum, practically free of Holmium, was registered in the same conditions, a fraction of it is substracted from the first spectrum and the result is plotted above in (2), fig. 2, for facilitating the Holmium decay identification. Figure 1 shows some conversion lines at low energies. The use of a magnetic selector eliminates X rays and β^+ and most of the daughter spectrum can also be substracted, but results are not so complete than for γ spectra, due to the weak intensity of most of the transitions. In electron as in γ spectra, the presence of an intense 295.8 keV M1 transition is predominant.

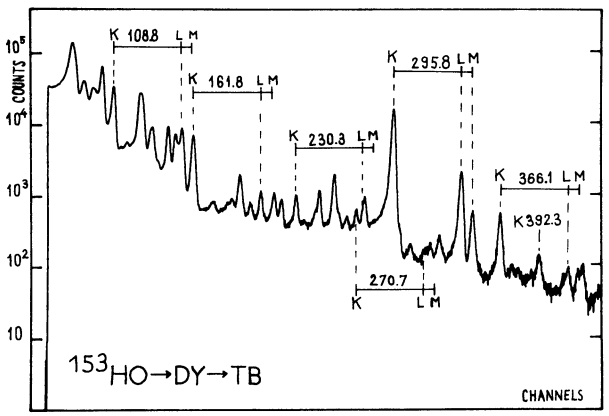

Fig.1 : Conversion spectrum registered with a magnetic "selector".

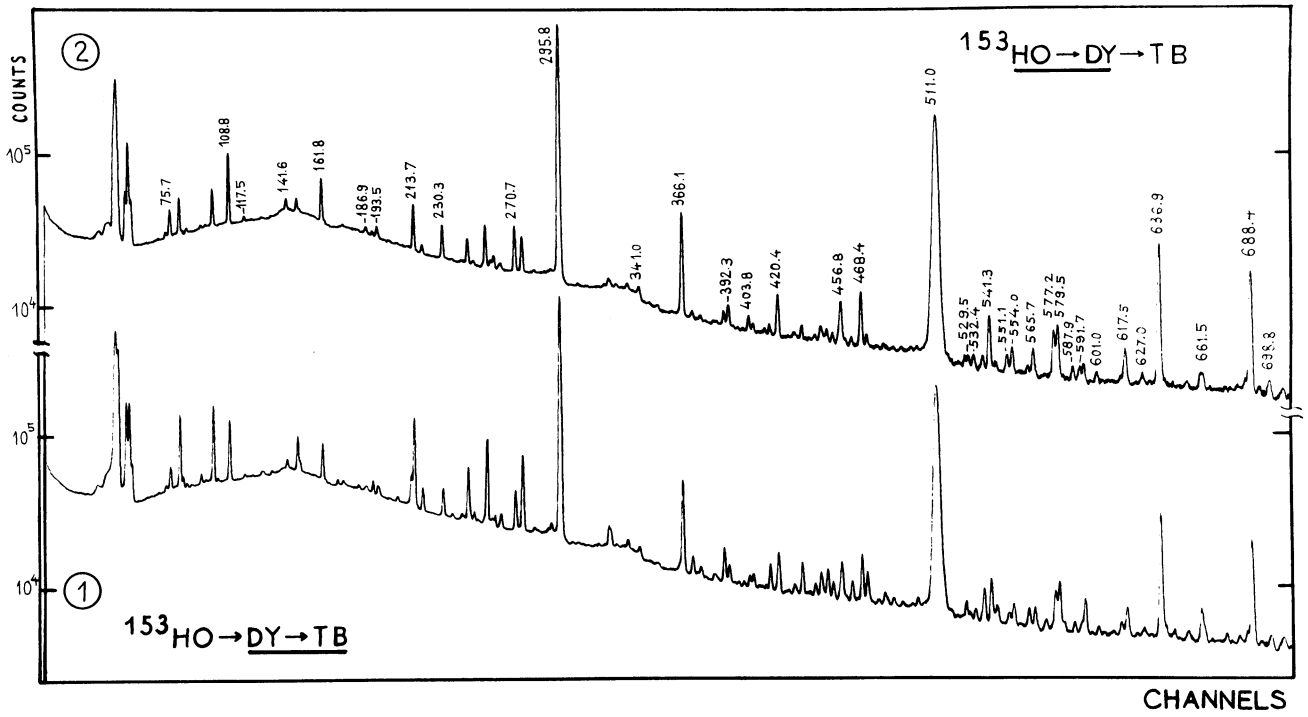

Fig. 1 : γ spectrum. Quoted energies correspond to Ho → Dy transitions.

The decay scheme built from the experimental results is presented in figure 3. Indeed, the ^{153}Dy level scheme is the juxtaposition of two very different schemes, issued from each of the 9.3 mn-low spin (left) and the 2 mn-high spin (right) Holmium isomers. The 2 mn levels with spins probably 9/2 and higher, decay by some transitions (inclined on the drawing) on the 9.3 mn levels, the spins of which seem less than 7/2. The high spins part can be correlated with levels obtained by in-beam excitation (6,7) where the 295.8, 636.9, 712.6 and 837.1 keV levels are also identified. The 9.3 mn scheme essentially confirms the Andreiev's work (5) and extends it. Multipolarity determinations are in agreement with his previous measurements but they are not sufficient to univocally determine the spins of the four first excited levels. Nevertheless, the fact that the 2 mn high spins scheme decays essentially on the 366.1 and 108.8 levels, very probably 5/2, is in favor of lower values for the other spins and the retained sequence : 7/2, 5/2, 3/2, 5/2, 1/2 of negative parity levels is strikingly similar to the one determined in the N = 87 isotone ^{151}Gd (11).

In figure 3, the transitions for which location is confirmed by γ-γ coincidence measurements are quoted with small circles. Intensities and conversion results of the scheme transitions are presented in table 1. These intensities are relative to the 295.8 one, fed by the 2.0 mn Ho isomer. As the proportion of the two Ho isomers depends of the excitation mode and owing to the decays of the 2 mn scheme on the 9.3 mn levels, the relative intensities of the 9.3 mn transitions are not completely fixed and change during the first mn of the decay time. The table 1 corresponds to the spectra registered for the two first minutes following a 4 mn collection time.

Future work is foreseen for measuring Q_β values and to precise the isomeric level position in ^{153}Ho (as no Ho X rays were seen with our Si(Li) detector, a direct transition in Holmium seems almost unexistent). But assuming the theoretical value (12) : $Q_\varepsilon \simeq 4300$ keV, we find a low log ft $\simeq 4.5$ for the 295.8 level, strongly in coincidence with the 511 keV annihilation peak. The 1381.3 and 1276.1 keV levels correspond to other low log ft values near 5.0 and the 9.3 mn levels to log ft values above 5.8.

5. DISCUSSION

As previously mentioned, the 7/2 spin measurement (2) for the Dy groundstate can be identified to the f7/2 negative parity shell model configuration and, from the conversion results, the four first "9.3 mn" excited levels have the same negative parity. Apart the f7/2, we expect the presence of the h9/2 and i13/2 configurations and, indeed, the in-beam experiments (6) identify the 295.8, 636.9 et 712.6 levels with respectively the 9/2- (h9/2), 11/2-(f7/2) and 13/2+(i13/2) configurations. The 295.8 keV level h9/2 assignment is supported by the strong β^+ allowed transition from the high spin Holmium isomer. The isomeric level existing in numerous Ho isotopes discloses the existence of the h11/2 shell, separating the d5/2 and d3/2 ones, and the 295.8 keV feeding corresponds probably to the (h11/2)p → (h9/2)n transition. The 2mn half-life Ho isomer should be 11/2 or 9/2-, more probably 11/2-, owing to the direct feeding of the 712.6, 13/2+ level (log ft ∿ 6.1). Such a configuration prohibits any transition to the 11/2-[505] deformed band, found by Kleinheinz et al. and based on a 1068 keV level. The other 9.3mn half-life Ho isomer should be in one of the d3/2, d5/2 configurations, decaying by forbidden β^+ transitions to the low spin levels.

Concerning these ones, we already noticed the analogy with the corresponding levels in the isotone ^{151}Gd (11). Hammaren et al. conclude for ^{151}Gd to the probable permanence of a deformation ($\beta > 0.12$), a pure spherical model beeing unable to explain the number of low spin levels and, especially, the existence of a 1/2-, 575.7 keV level which seems similar to the 501.1 keV level in ^{153}Dy. Further examinations are planned for interpreting this last isotope.

The 1276.1 and 1381.3 levels, decaying to number of low energy levels in both schemes, seem to be collective levels based on the f7/2 - h9/2 configurations, mixed by Coriolis interaction.

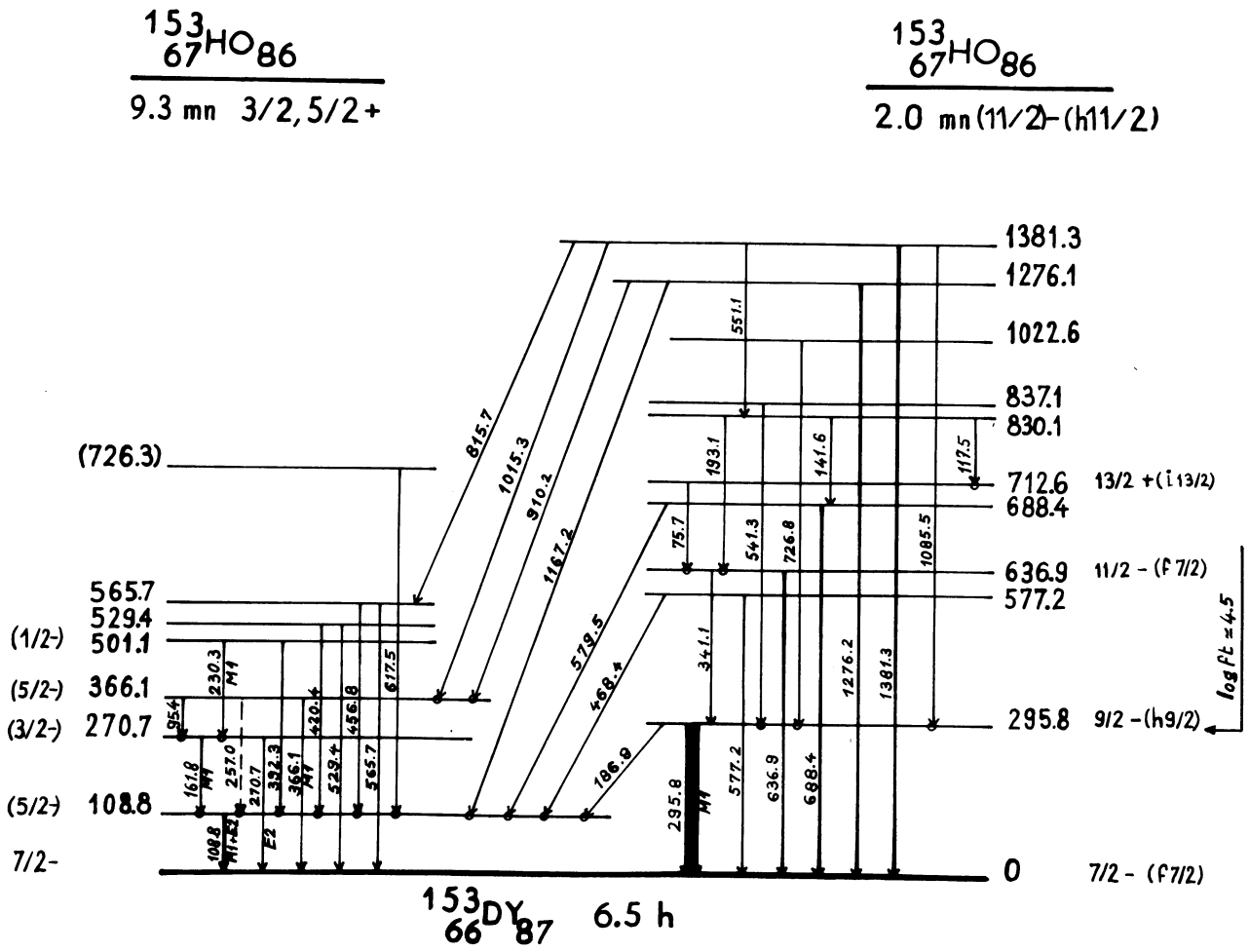

Figure 3

TABLE 1 : Principal transitions, relative intensities and conversion results.

E_γ	Ir	α_K	K/L	Multip.
75.7±.1	10			
95.4±.2	0.9			
108.8±.1	51	1.07±.2	$2.71^{+.56}_{-.46}$	M1+E2
117.5±.1	2.1			
141.6±.2	6.7			
161.8±.1	27	.66±.07	$8.03^{+2.82}_{-1.88}$	M1
186.9±.2	4.3			
193.4±.2	4.8			
230.3±.2	15	.19±.03	$8.13^{+3.27}_{-2.19}$	M1
257.0±.2	2.9			
270.7±.1	22	.050±.015	$4.11^{+1.25}_{-.92}$	(M1+)E2
295.8±.1	1000	.10*	$6.74^{+.51}_{-.48}$	M1
341.0±.3	3.7			
366.1±.1	61	.059±.006	$7.92^{+1.70}_{-1.32}$	M1

E_γ	Ir	E_γ	Ir
392.3 ± .2	6.5	636.9 ± .1	79
420.4 ± .1	13	688.4 ± .1	46
456.8 ± .1	16	726.8 ± .1	19
468.4 ± .1	18	815.7 ± .2	4.5
592.4 ± .1	2.0	910.2 ± .2	15
541.3 ± .2	14	1015.3 ± .2	19
551.1 ± .1	3.7	1085.5 ± .2	15
565.7 ± .1	6.1	1167.2 ± .2	12
577.2 ± .2	12	1276.2 ± .2	42
579.5 ± .2	15	1381.3 ± .2	33
617.5 ± .2	8.7		

* *Theoretical value (L.A.Sliv and I.M. Band (13)).*

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