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ABSTRACT.
We report here on the first study of the level structure of ^{151}Ho. High spin levels in ^{151}Ho have been populated in the ^{141}Pr + ^{16}O and ^{144}Sm + ^{12}C reactions. The level structure has been established up to 6.6 MeV energy and the spins and parities determined up to $49/2^-$. Most of the proposed level configurations can be explained by the coupling of $h_{11/2}$ protons to $f_{7/2}$ and/or $h_{9/2}$ neutrons. An isomer with 14 ± 3 ns half-life and a delayed gamma multiplicity equal to 17 ± 2 has been found. Its spin is larger than $57/2\,\hbar$ units.

NUCLEAR REACTIONS ^{141}Pr (^{16}O,6n), E = 101-131 MeV, ^{144}Sm (^{12}C,p4n), E = 82-110 MeV ; measured $\sigma(E;E_\gamma,\theta)$, γγ-coinc., γ-γ delay. ^{151}Ho deduced levels, J, π, $T_{1/2}$, γ-mixing, multiplicity. Enriched target, Ge(Li) detectors.

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1. INTRODUCTION

Many high-spin isomers associated with high gamma multiplicity have been found [1] near the doubly magic nucleus ^{146}Gd [2]. Information on odd-Z, odd-A nuclei is not very abundant in the vicinity of the Z = 64, N = 82 shell-closures and it appears interesting to study the level structure of such nuclei.

An investigation has been undertaken on the ^{151}Ho nucleus which is situated in this region and has at least one high-spin isomer found during a systematic search [3]. This nucleus was produced via ^{12}C and ^{16}O induced reactions with the hope of populating high-spin states and to have some insight on their level configurations. Moreover, comparisons with neighbouring nuclei whose structure is already rather convincingly established could be useful in the understanding of level patterns. We report here on a detailed study of ^{151}Ho for which preliminary results have been given by us previously [4] and for which only α and β-decay properties were known [5],[6],[7].

2. EXPERIMENTAL TECHNIQUES

Levels in ^{151}Ho were populated in the reactions ^{141}Pr(^{16}O, 6n) and ^{144}Sm(^{12}C,p4n) using beams delivered by the Grenoble variable energy cyclotron. Self-supporting targets of 10 mg/cm^2 ^{141}Pr and 18 mg/cm^2 ^{144}Sm were bombarded with 101, 110, 120, 131 MeV ^{16}O ions and 76, 82, 90, 98, 110 MeV ^{12}C ions, respectively.

The singles spectra were obtained by means of planar (3.5 cm^3) and coaxial (15% efficiency) Ge(Li) detectors having a resolution of 0.7 keV FWHM at 122 keV and 2.0 keV FWHM at 1.33 MeV, respectively. The energies of γ-lines were determined by recording simultaneously the γ-rays emitted by the target and standard calibration sources (^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu). The energy accuracy is better than 100 eV for strong and well resolved lines. The four dimensional γ-γ-$t_{\gamma-RF}$ -$t_{\gamma-\gamma}$ coincidence measurements were performed with two 15% efficiency coaxial detectors. The angular distribution of γ-rays was studied at six angles i.e. 90°, 100°, 115°, 125°, 140° and 150° relative to the beam with the planar detector and 40°, 47.5°, 55°, 65°, 75° and 90° with a coaxial one. Both coincidence and angular distribution measurements were made at 131 MeV ^{16}O and 110 MeV ^{12}C beam energy. Data concerning the transitions placed in the level scheme are given in table 1. A few weak lines in ^{151}Ho (350, 434, 478, 887 and 1009 keV) which were found in $\gamma\gamma$ coincidence spectra are not listed.

The linear polarization of γ-lines was measured in the reaction ^{144}Sm + ^{12}C at 98 MeV with a Compton polarimeter which consisted of five Ge(Li) detectors placed in the same cryostat [8]. In spite of the complexity of the recorded spectra, valuable data were obtained for some well resolved γ-lines.

A gamma ray multiplicity set-up consisting of fourteen 2" x 2" NaI(Tℓ) detectors operating in coincidence with a Ge(Li) counter was also used. The purpose of this set up was first of all to single out, from the radioactive background observed between the beam burst, the long delayed γ-ray cascades which would be generated from a high spin isomer. Secondly, the multiplicity filter, efficiency calibrated, yields the information about the length of the isomeric cascade even if not all the transitions of this cascade are identified. The absolute efficiency of the individual NaI detectors was determined with calibrated sources. The efficiency of the whole set-up was measured with ^{60}Co and ^{177m}Lu sources and found equal to 5.7 %.

Two methods were employed to determine the half-life of the isomer :coincidences between γ-rays from a Ge(Li) detector and the radiofrequency signal of the cyclotron, and coincidences between gammas from Ge(Li) and NaI(Tℓ) counters.

3. EXPERIMENTAL RESULTS

3.1. Identification of ^{151}Ho

The first step of our study was to identify γ-rays in ^{151}Ho. Indeed no information of this type on this nucleus was available before our investigation.

Gamma rays were attributed to ^{151}Ho on the basis of excitation functions in the ^{141}Pr + ^{16}O reaction. In the γ singles spectrum it clearly appears that the lines of $^{150-152}$Dy produced in the reactions ^{141}Pr (^{16}O, pxn) with x = 4,5,6 are strong. One also observes another family of γ-rays whose excitation functions resemble those of ^{151}Dy lines (fig. 1). The 246, 414, 486, 597, 789 and 1397 keV γ-rays are therefore assigned to an A = 151 nucleus. Singles decay spectra were also recorded immediately after the beam was cut off. The 527 keV γ-ray of ^{151}Dy clearly shows up in these radioactivity spectra and its existence confirms the production of ^{151}Ho which feeds ^{151}Dy by electron capture. Therefore, the group of γ-rays above listed (246, 414...) is assigned to ^{151}Ho.

A similar method of identification was also applied in the ^{144}Sm + ^{12}C reaction where Ho isotopes are produced after emission of one proton and several neutrons. The ^{151}Ho nucleus is therefore unambiguously identified from the results obtained in both reactions.

3.2. The level structure of ^{151}Ho

From the γ-γ coincidence spectra it appears that eleven γ-rays are always in coincidence. They are the strongest in the singles spectrum and their intensities represent more than 70% of the total intensity of the discrete lines (table 1) assigned to the ^{151}Ho exit channel in the ^{141}Pr + ^{16}O reaction. This is illustrated by figure 2 which shows the γ spectrum in coincidence with most of these strong lines in ^{151}Ho.

The three stretched E2 transitions of 789, 597 and 297 keV whose intensities are the strongest are placed at the bottom of the main cascade (fig. 3). Since the 597 and 789 keV transitions have the same intensity, their relative position is fixed by comparison with neighbouring even-even nuclei and isotones.

Because of its intensity, the 414 keV line is placed on top of the 297 keV γ-ray. This 414 keV γ-ray is rather well separated in the polarization spectra recorded in the ^{144}Sm + ^{12}C reactions. The ratio of the γ intensities taken in the perpendicular and parallel directions relative to the beam, $N_{\perp}/N_{//}$, equals 0.85 ± 0.20 which indicates (by comparison with angular distribution data) no parity change. The angular distribution of this gamma is characterized by a negative A_{22} coefficient which excludes a pure $\Delta I = 0$ transition. A pure L = 1, $I \rightarrow I + 1$ transition appears to be very improbable because of the reaction mechanism involving heavy ions and a pure L = 1, $I + 1 \rightarrow I$ would give too large an alignment ($\alpha_2 > 0.8$) compared to those of other lines in the cascade. Therefore this 414 keV line is an M1 + E2, $I + 1 \rightarrow I$ transition with a quadrupole admixture $\delta^2/(1 + \delta^2)$ in the range of 0.024 to 0.048 or 0.91 to 0.94 and a negative δ mixing ratio.

The 128.8 keV line has a weak gamma intensity and a strongly negative A_{22} coefficient typical of M1+E2, $I+1 \rightarrow I$ transitions. Though its quadrupole admixture is not evaluated precisely (from 0.04 to 0.32 or from 0.60 to 0.92), its total internal conversion coefficient (I.C.C.) α_T is estimated with a relatively good precision because the E2 and M1 total I.C.C. are comparable at this energy. The total I.C.C. for such a mixed dipole-quadrupole transition is then α_T = 1.21 ± 0.08 and the total transition intensity equals 69 ± 11 which is larger than that of the 414 keV line placed below. The intensity balance of the 2098 keV level is reequilibrat by a 307.2 keV, M1+E2 γ-ray which deexcites this state.

The angular distribution data show the 1397, 246 and 455 keV lines to be L = 2 transitions. The linear polarization data ($N_\perp/N_{//}$ = 1.13±0.24 1.40 ± 0.28 and 1.13 ± 0.18 respectively) indicate an electric character. The A_{22} experimental coefficients of the 485.8 and 308.7 keV lines are compatible with pure E2 and M1+E2, I+1 → I transitions, respectively. The ΔI = 1 transition has a quadrupole admixture $\delta^2/(1+\delta^2)$ in the range 0.03-0.31 or 0.63-0.94 and a negative δ. The 1024 keV gamma which also has a negative A_{22} coefficient is likely an M1+E2, I+1 → I transition.

The position of all these transitions can be fixed thanks to several forks in the level scheme. In the first one, the 486, 1397 and 129 keV lines deexcite the 4109.5 keV level in parallel with the 265, 275, 517, 367 and 587 keV gammas. In the second one, the main pathway made by the 1024, 309 and 455 keV transitions drains two thirds of the excitation of the 6144 keV level. Most of the lines involved in both weak parallel cascades have undetermined multipolarities because they are mixed with gammas belonging to other nuclei produced during the bombardment of the target. Their energies and intensities are extracted from γγ coincidence spectra.

As seen in table 1, all the strong transitions and especially those of the main cascade have known multipolarities which permits unambiguous determination of spin and parity of the most strongly populated levels, except for the 6144 keV level. The negative parity of this level is not firmly established. Indeed, because of the weakness of the 1024 keV transition, the statistics were poor in the polarization spectra and data relative to this line were impossible to extract.

The $47/2^-$ and $49/2^-$ spins and parities of the 5951 and 6184 keV levels, respectively, are firmly established because of the 831.1 and 232.8 keV γ-rays which have strongly negative A_{22} angular distribution coefficients typical of M1+E2 transitions.

One should mention that the 1396.8 keV transition is the cross-over of the 624.0 and 772.7 keV lines which clearly appear in γγ coincidence spectra . The spin and parity of the 2851 keV level cannot be fixed but assumptions based on level configurations will be made in section 4.

A branch which feeds the 4811 keV, $43/2^-$ level seems to be important in the level structure. It is made of the 564.6 and 1241.6 keV transitions which have no prompt component (fig. 5). This fact clearly indicates the existence of an isomer located at/or above the 6617 keV level. The point concerning the isomer will be developed in detail in the next subsection.

3.3. High spin isomer in ^{151}Ho

During our systematic search for high spin isomers in the region close to N = 82 [3] we observed that, in the reactions ^{12}C + ^{144}Sm at 98 and 110 MeV and ^{16}O + ^{141}Pr at 120 and 130 MeV bombarding energy, all the strong transitions attributed to ^{151}Ho appear in the high-fold spectra collected between the beam bursts (fig. 4). This was interpreted as evidence that a high spin isomer is excited in this nucleus.

The half-life of the isomer was determined in Ge(Li)-RF and NaI-Ge(Li) coincidence experiments. Figure 5 presents the result of the first of the mentioned experiments performed with ^{12}C + ^{144}Sm reaction at 110 MeV bombarding energy. The half-life of the isomer was deduced from the decay of transitions belonging only to ^{151}Ho. Taking into account the spread between values determined for different transitions, the adopted value of the half-life is 14 ± 3 ns. The NaI-Ge(Li) coincidence experiment gives a similar value for the half-life and, in particular, indicates that there is no longer-lived component which might falsify the Ge(Li)-RF experiment, performed in about a 60 ns time range.

From the data shown in fig. 5 the isomeric ratio was calculated to be $\sigma_{isomer}/\sigma_{ground\ state} = 0.05 \pm 0.02$. In this calculation it was assumed that the whole intensity of the isomer decays through the 597 keV transition. The cross section for the production of the $11/2^-$ ^{151}Ho ground state by the (^{12}C, p4n) reaction was determined in a separate experiment to be 260 ± 30 mb at 110 MeV bombarding energy. Therefore at this energy the cross section for the production of the isomer is 13±5 mb.

The low cross section and rather short half-life made it difficult to determine with precision the delayed gamma multiplicity $\bar{M}_d$ of transitions from the isomer decay. Different measurements with ^{16}O + ^{141}Pr and ^{12}C + ^{144}Sm reactions exhibit a rather large spread of this delayed multiplicity which is not the case for isomers observed in other nuclei [3] and produced with larger cross sections and/or having longer half-lives. Taking all measurements into account we adopted $\bar{M}_d = 17 \pm 2$ for the ^{151}Ho isomer.

The delayed multiplicity may be converted into the total angular momentum removed by the cascade of gamma rays deexciting the isomer. Considering that one yrast transition removes 1.65 ± 0.16 unit of angular momentum -this value is a mean obtained from nuclei in the region of interest [3]- the spin of the isomer is $I_{is} = I_g + 1.65\ \overline{M}_d = 67/2 \pm 5$ where $I_g = 11/2$ corresponds to the spin of the ground state.

Numerous transitions, weak in coincidence spectra during the beam burst, appear much enhanced in the prompt coincidence between the beam bursts. In particular the 1241.5 keV and 564.0 keV transitions are in coincidence between themselves and with transitions deexciting levels below 4811 keV excitation energy (fig. 3). The former has no prompt component in the time spectra as shown in fig.5 . Therefore the excitation energy of the isomer is equal to/or higher than 6617 keV (see fig. 3). A more detailed decay pattern of the (14 ± 3)ns isomer was difficult to establish due to its low feeding in the reactions studied.

Moreover, an isomer with a very short half-life could also exist in ^{151}Ho. Indeed all the γ-lines of the Yrast cascade seems to appear with a short half-life. Using the 1.7 ns in ^{150}Dy [9] as a reference and comparing the decay curve of ^{150}Dy and ^{151}Ho γ-rays obtained in γ-RF coincidences, one deduces that this short half-life in ^{151}Ho is smaller than 2 ns if it really exists.

4. DISCUSSION OF THE ^{151}Ho LEVEL STRUCTURE

Except for α and β-decay properties of two states [5] [6] in ^{151}Ho, nothing was known on its levels structure before our investigation. Tentative assignments were made : $I^\pi = 11/2^-$ and $5/2^+$ to the ground ($T_{1/2}$ = 36 s) and low-energy metastable ($T_{1/2}$ = 42 s) states, respectively. Toth et al. [7] attributed an $11/2^-$ spin to the 36-second state from the log ft value of the β-decay branch to the $h_{9/2}$ neutron state in ^{151}Dy.

Since the nucleus ^{151}Ho has 67 protons and 84 neutrons, the configurations of the low energy states will originate from $h_{11/2}$ proton, $f_{7/2}$ and $h_{9/2}$ neutron shells. These proton and neutron states are used to explain the level structure of nuclei in the region of the periodic table we are considering. This is in particular the case of ^{150}Dy whose proposed theoretical level configurations [9] appear to be very credible. We will then consider this nucleus as the even-even core of ^{151}Ho and interpret the major part of the ^{151}Ho level structure by addition of an $h_{11/2}$ proton.

The three first excited levels which have energies similar to those in the ^{150}Dy core nucleus [9] (fig. 7) are explained by the coupling of a fully aligned $h_{11/2}$ proton to the $\nu f^2_{7/2}$ core states.

The $25/2^-$, $27/2^-$ and a second $23/2^-$ levels could also be explained by the coupling of this $h_{11/2}$ proton to 7^+, 8^+ and 6^+ core states, respectively. The $27/2^-$ state exists in odd-A N = 84 isotones such as ^{147}Eu and ^{149}Tb where the $25/2^-$ and $(23/2^-)_2$ are not observed (fig. 8). These two last levels have been found in $^{151}_{65}$Tb [10] and result likely in the coupling of the $h_{11/2}$ proton with the 7^+ and 6^+ core states having the $\nu f_{7/2}\ \nu h_{9/2}$ configuration. The low-energy level structure of ^{150}Gd [11] which is the core of ^{151}Tb is much better known than the structure of ^{150}Dy, revealed by an heavy ion reaction which populates yrast states but bypasses the others. A 7^+ and several 6^+, 8^+ levels are known in ^{150}Gd. They should exist in ^{150}Dy but are still unknown.

One should mention that the $27/2^-$ level at 2227 keV could be the result of the coupling between the $10^+[(\pi h^2_{11/2})_{10}\ (\nu f^2_{7/2})\ ]$ state in ^{150}Dy and an incompletely aligned $(h_{11/2})_{7/2}$ proton. This possibility is ruled out because of the excessive energy difference between the 10^+ core state at 3062 keV and this $27/2^-$ level.

It appears then that the coupling of a fully aligned $h_{11/2}$ proton to the positive parity states of ^{150}Dy can reproduce the negative parity levels of the Yrast cascade in ^{151}Ho up to 2227 keV excitation energy.

One knows that in ^{150}Dy [9], there is a 10^+, 12^+, 14^+, 16^+ sequence whose transition energies resemble those of the 0^+, 2^+, 4^+, 6^+ ground band. It is generated from the coupling of two aligned $h_{11/2}$ protons $((\pi h^2_{11/2})_{10^+})$ with two $f_{7/2}$ neutrons. Though the basic state is difficult to establish, such a sequence equivalent to the $11/2^-$, $15/2^-$, $19/2^-$, $23/2^-$ ground band exists also in ^{151}Ho. The correspondence between the even-even core (^{150}Dy) and ^{151}Ho states is clearly shown in figure 7. In the proposed scheme, the $39/2^-$ level has a $\pi h^3_{11/2}\ \nu f^2_{7/2}$ configuration, the three $h_{11/2}$ protons being coupled to the maximum I = 27/2, i.e. the level of the odd-A nucleus ^{151}Ho is obtained by adding an $h_{11/2}$ proton (I = 7/2) to the $16^+[(\pi h^2_{11/2})_{10}\ (\nu f^2_{7/2})_6]$ ^{150}Dy core state. This assignment is strongly supported by the comparable excitation energy of these $39/2^-$ and 16^+ states but especially by the energy difference (2671 keV) between the $39/2^-$ and $23/2^-$ levels which is nearly equal to the difference in excitation (2716 keV) between the 16^+ and the 6^+ levels in ^{150}Dy (fig.7). The $27/2^-$ base state of this $\nu f^2_{7/2}\ \pi h^3_{11/2}$ band is not determined experimentaly as shown in fig. 3 but the 2851 keV level could be such a level. Indeed, in such a case, the $31/2^- \rightarrow 27/2^-$ transition would have an energy (773 keV) similar to the one of the $15/2^- \rightarrow 11/2^-$, 789 keV transition. Moreover this $27/2^-$ level would be shifted down by 175 keV relative to the 10^+ core state. Such an energy difference is very plausible as indicated in fig. 7 . The strong deexcitation of the $31/2^-$ level towards the $27/2^-$ level at 2227 keV compared to the weak one towards the 2851 keV level having the same configuration is probably due to the large energy ratio of both the E2 transitions.

Going up in energy, one reaches the $43/2^-$ state at 4811 keV for which we propose the $(\pi h^3_{11/2})_{27/2}(\nu f_{7/2}\ \nu h_{9/2})_8$ configuration. Indeed, it is situated 260 keV below the 18 corresponding core state and the $43/2^-$ and $27/2^-$ levels are separated by 2584 keV which is comparable to the 2669 energy difference between the 18^+ and 8^+ ^{150}Dy states (fig. 7).

Several yrast traps have been calculated [12] in ^{151}Ho : $39/2^+$, $43/2^-$, $47/2^-$, $55/2^-$ and $57/2^-$. Unfortunately, the level scheme of ^{151}Ho presented in fig. 3 is not enough developed to identify the $I = 67/2 \pm 5$ isomer with one of the calculated yrast traps.

A simple comparison as made in fig. 8 shows that the lower part of the ^{151}Ho level structure has strong analogies with those of neighbouring odd-A isotopes and also with ^{151}Tb where a $25/2^-$ and a second $23/2^-$ level appear.

5. CONCLUSION

A level structure has for the first time been established up to 6.6 MeV for the nucleus ^{151}Ho. Spins and parities have been determined up to a 6184 keV, $49/2^-$ level and the configurations of most of the states up to the $43/2^-$ one at 4811 keV can be understood by the coupling of $h_{11/2}$ protons with $f_{7/2}$ or/and $h_{9/2}$ neutrons.

A high spin isomer has been found which lies above 6.6 MeV. Its spin is larger than 57/2 units of angular momentum, a value deduced from the lower limit of the measured delayed gamma multiplicity. Other isomers could exist in ^{151}Ho. They could perhaps be populated by nuclear reactions involving heavier projectiles.

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FIGURE CAPTIONS

Figure 1 - Relative excitation functions of some well resolved γ-rays in A = 150, 151 and 152 nuclei from the $^{141}Pr + ^{16}O$ reaction. The γ intensities are given in arbitrary units.

Figure 2 - Spectrum of prompt in-beam coincidences with the strongest lines in the main cascade taken in the $^{12}C + ^{144}Sm$ reaction at 110 MeV. The gates are set on the 246, 414, 405,486, 597 and 789 keV γ-rays.

Figure 3 - Partial level structure of ^{151}Ho. The width of the arrows is proportional to the total intensity of the transitions. A level is indicated by a broken line when the relative positions of the feeding and depopulating transitions are uncertain.

Figure 4 - The Ge(Li) gamma-ray spectra collected between the beam bursts in 1 to 3 fold coincidence with NaI detectors for the $^{16}O+^{141}Pr$ reaction at 131 MeV incident energy. Transitions in ^{151}Ho (^{151}Dy) are indicated by black (open) circles.

Figure 5 - The time spectra of ^{151}Ho transitions observed in a Ge(Li)-RF coincidence experiment in the $^{12}C + ^{144}Sm$ reaction at 110 MeV bombarding energy. The 504 keV γ-ray belongs to ^{150}Dy produced in the same reaction.

Figure 6 - Gamma-ray spectrum of prompt coincidences taken between the beam bursts in the $^{12}C + ^{144}Sm$ reaction at 110 MeV. The gates are set on the 246, 414, 455, 486, 597, and 789 keV γ-lines.

Figure 7 - Diagram showing the relation between the level configurations in ^{151}Ho and ^{150}Dy.

Figure 8 - Comparison of low energy level structures in N = 84 isotones.

TABLE 1 : Transitions of ^{151}Ho placed in the level scheme. The γ intensities are obtained in the ^{141}Pr + ^{16}O reaction at 131 MeV.

TABLE 1

Transitions of ^{151}Ho placed in the level scheme.

The γ intensities are obtained in the ^{141}Pr + ^{16}O reaction at 131 MeV.

E_γ (keV)	I_γ(125°) relative	A_{22}^{exp}	Multipolarity	I_{total} relative	I_i^π or E_i(keV) → I_f^π or E_f(keV)
128.8	31(2)	- 0.46 (12)	M1+E2	69(6)	$27/2^-$ - $25/2^-$
232.8	12(2)	- 0.60 (22)	M1+E2	14(3)	$49/2^-$ - $47/2^-$
246.0	66(4)	+ 0.16 (14)	E2	74(5)	$39/2^-$ - $35/2^-$
257.7	16(3)	- 0.01 (14)			4613 - $39/2^-$
264.6[a]	13				$35/2^-$ - 3844
275.0[a]	10				3844 - 3569
284.5[a]	8				4898 - 4613
297.2	79(5)	+ 0.11 (5)	E2	84(5)	$23/2^-$ - $19/2^-$
307.2	24(4)	- 0.35 (13)	M1 + E2	26(5)	$25/2^-$ - $23/2^-$
308.7[b]	32(5)	- 0.44 (13)	M1 + E2	35(6)	$45/2^-$ - $43/2^-$
367.3	21(3)	- 0.28 (6)	(M1 + E2)		$(31/2^-)$ - $(29/2^-)$
404.4	10(3)				$23/2^-$ - $19/2^-$
414.1	57(4)	- 0.32 (3)	M1 + E2	59(4)	$25/2^-$ - $23/2^-$
455.5	70(5)	+ 0.17 (6)	E2	71(5)	$43/2^-$ - $39/2^-$
485.8	47(5)	+ 0.18 (4)	E2	47(5)	$35/2^-$ - $31/2^-$
516.9	17(2)	+ 0.11 (17)			3569 - $(31/2^-)$
539.9[a]	6				$35/2^-$ - 3569
543.0[a]	8				4898 - $39/2^-$
564.6[a]	6				6617 - 6053
587.1	38(4)	+ 0.23 (11)	(E2)	38(4)	$(29/2^-)$ - $25/2^-$
597.4	102(5)	+ 0.15 (3)	E2	102(5)	$19/2^-$ - $15/2^-$
624.0[a]	7				2851 - $27/2^-$
772.7[a]	8				$31/2^-$ - 2851
789.4	100(5)	+ 0.11(3)	E2	100(5)	$15/2^-$ - $11/2^-$
792[c]					3844 - $(31/2^-)$
831.1	10(2)	- 0.63(30)	M1+E2	10(2)	$47/2^-$ - $45/2^-$
917.0	10(2)	+ 0.26(5)	(E2)	10(2)	$(47/2^-)$ - $43/2^-$
919.4[a]	5				3972 - $(31/2^-)$
937.3	12(3)	- 0.03(14)		12(3)	$47/2^{(-)}$ - 5207
1024.2	26(4)	- 0.36(18)	(M1+E2)	26(4)	$47/2^{(-)}$ - $45/2^-$
1241.6	9(1)	- 0.11(19)		9(1)	6053 - $43/2^-$
1396.8	56(8)	+ 0.20(22)	E2	56(8)	$31/2^-$ - $27/2^-$

a) Energy and intensity deduced from γ-γ coincidence spectra. The angular distribution coefficients are not given because these lines are too weak or mixed in the singles spectra.

b) A weak component of roughly 309 keV is placed between the 5207 and 4898 keV levels.

c) This line appears in γγ coincidence spectra. Its characteristics cannot be given because it is situated in the high energy tail of the strong 789.4 keV γ-ray.

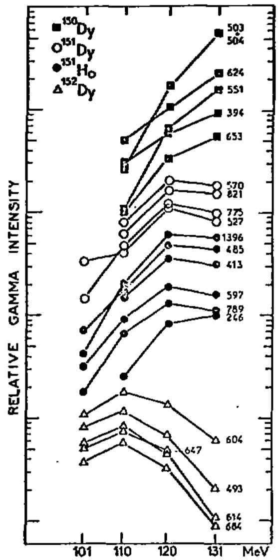


Fig.1 - Relative excitation functions of γ-rays in A = 150, 151, 152 nuclei from the ^{16}O + ^{141}Pr reaction at 131 MeV. The γ intensities are given in arbitrary units.

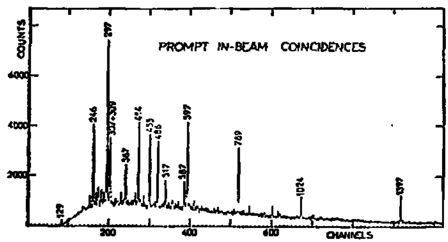


Figure 2 - Spectrum of prompt in-beam coincidences with the strongest lines in the main cascade taken in the ^{12}C + ^{144}Sm reaction at 110 MeV. The gates are set on the 246, 414, 405,486, 597 and 789 keV γ-rays.

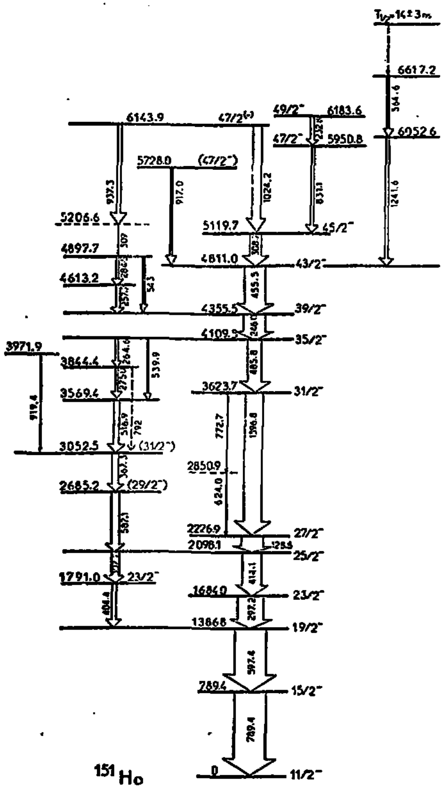


Figure 3 - Partial level structure of ^{151}Ho. The width of the arrows is proportional to the total intensity of the transitions. A level is indicated by a broken line when the relative positions of the feeding and depopulating transitions are uncertain.

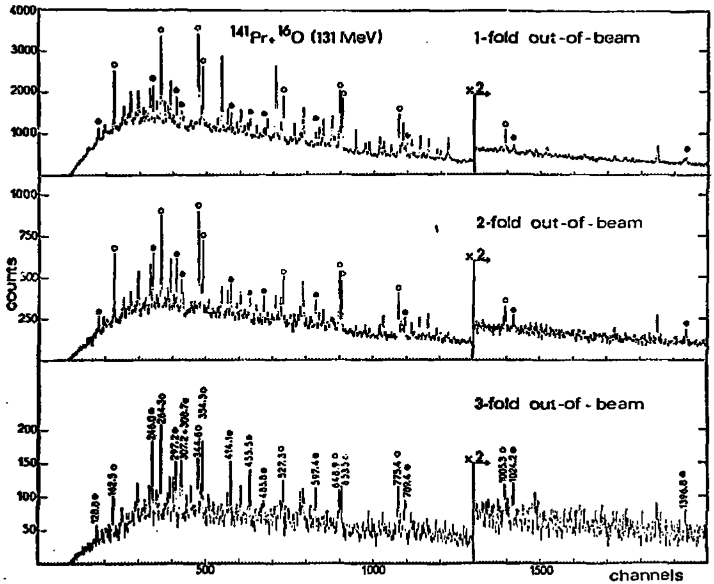
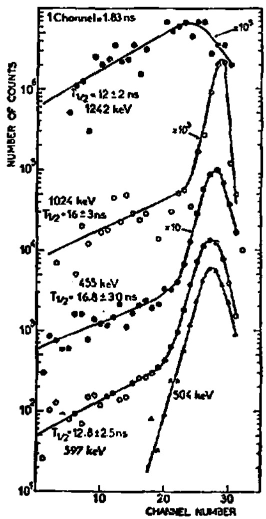


Figure 4 - The Ge(Li) gamma-ray spectra collected between the beam bursts in 1 to 3 fold coincidence with NaI detectors for the $^{16}O+^{141}Pr$ reaction at 131 MeV incident energy. Transitions in ^{151}Ho (^{151}Dy) are indicated by black (open) circles.



<u>Figure 5</u> - The time spectra of ^{151}Ho transitions observed in a Ge(Li)-RF coincidence experiment in the ^{12}C + ^{144}Sm reaction at 110 MeV bombarding energy. The 504 keV γ-ray belongs to ^{150}Dy produced in the same reaction.

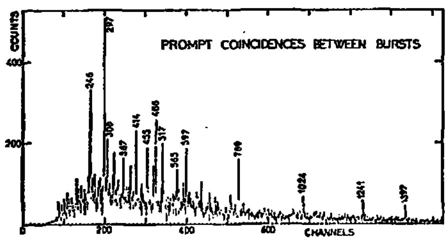


Figure 6 - Gamma-ray spectrum of prompt coincidences taken between the beam bursts in the ^{12}C + ^{144}Sm reaction at 110 MeV. The gates are set on the 246, 414, 455, 486, 597, and 789 keV γ-lines.

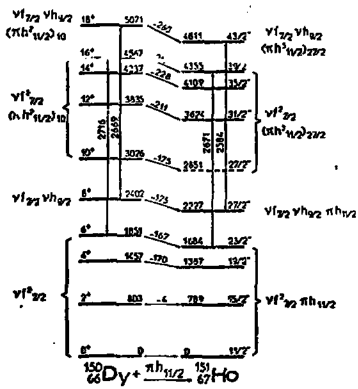


Figure 7 - Diagram showing the relation between the level configurations in ^{151}Ho and ^{150}Dy.

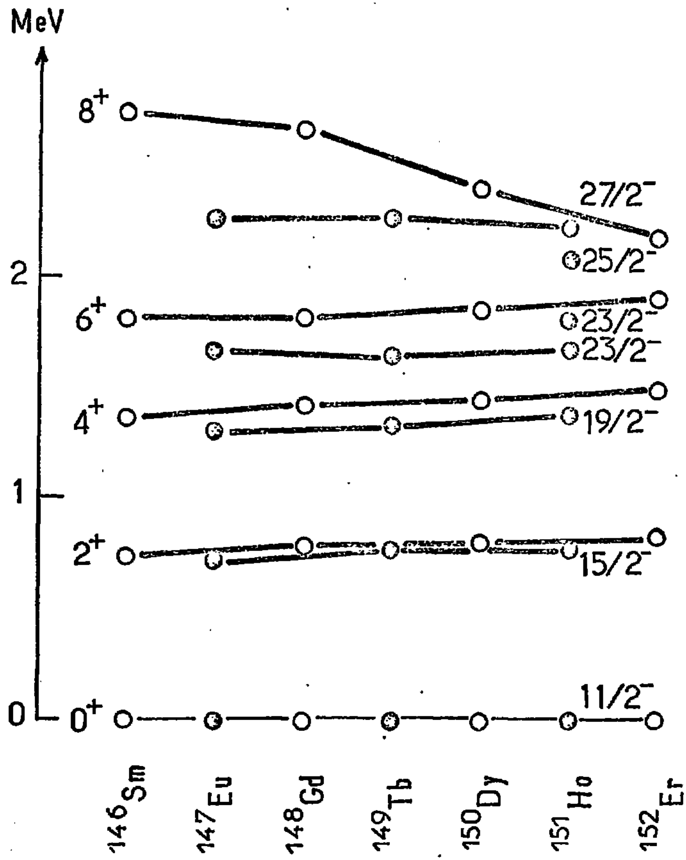


Figure 8 - Comparison of low energy level structures in N = 84 isotones.