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DECAY OF ORIENTED ^{149}Nd AND LOW-LYING LEVELS IN THE N=88 ^{149}Pm NUCLEUS

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1. INTRODUCTION

The nuclear structure investigations of N = 88 isotopes with Z ≈ 64 suggest the coexistence of both the deformed and non-deformed states, which reflect the effect of the Z = 64 closed proton core as well as a tendency to deformation. Our present knowledge of the excited levels in ^{149}Pm and γ-transitions linking them were obtained from the investigation of the γ-rays [1] and conversion electrons [2] following the decay of ^{149}Nd, non-perturbed [3,4] and perturbed [4] γ-γ directional correlation as well as from (^{3}He,d), (α, t) [5], ($\vec{t}$, α) [6] reactions and in-beam measurement using the ^{150}Nd(p,2nγ) reaction [7]. The most complete bibliographies on this isotope are contained in the compilation of ref. [8]. Recently the ^{149}Pm nucleus has been studied in the γ-γ directional correlation measurement [9]. In those experiments about fifty excited states were observed.

Regardless of the variety of the experimental information, the spins of several low-lying states in ^{149}Pm have not been unambiguously determined at present. In addition, the information on multipole mixing ratios of the most of γ-transitions in ^{149}Pm primarily comes from ICC data. To provide both the missing unambiguous data on nuclear spin and new information on the multipole character of γ-rays in ^{149}Pm, we studied the decay of parent ^{149}Nd polarized at low temperatures in the gadolinium host. Having new experimental information, especially on nuclear spins and multipole mixing ratios, we have discussed our results in the light of the axial-quasiparticle-rotor model. The preliminary results of this investigation have been reported earlier [10].

2. EXPERIMENTAL METHODS

Radioactive nuclei ^{149}Nd ($T_{1/2}$ = 1.72(1) h) were generated by the thermal neutron irradiation of neodymium oxide (enriched to 93.2% by the ^{148}Nd isotope). The ^{149}Nd$\underline{Gd}$ sample was prepared by applying a melting procedure similar to that of ref. [11]. The sample was cooled by using a top-loading ^{3}He:^{4}He dilution refrigerator of the SPIN facility [11]. The temperature of the ^{149}NdGd system in this refrigerator, determined from independent measurements using a ^{54}MnNi nuclear thermometer, was ≤ 16 mK. The γ-ray spectra were measured by means of two coaxial Ge(li) detectors with sensitive volumes 33 cm^3 both and resolution ≈ 3 keV at 1332 keV. Detectors were placed at angles of 0° and 90° to the direction of an external magnetic field (1.3 T). The γ-ray spectra recorded at a sample temperature ≈ 1 K were employed for normalization of the observed γ-ray intensities to the unity for a randomly oriented sample. Two ^{149}NdGd samples were prepared consecutively and two measurements were performed by the described procedure.

3. DATA ANALYSIS AND RESULTS

From the measured normalized intensities the $A_2U_2B_2$ - and $A_4U_4B_4$ - terms of the angular distribution functions were extracted. All the 4th order terms are either equal to zero within the experimental errors or small within comparatively large errors and hence don't yield useful information. In Tab-

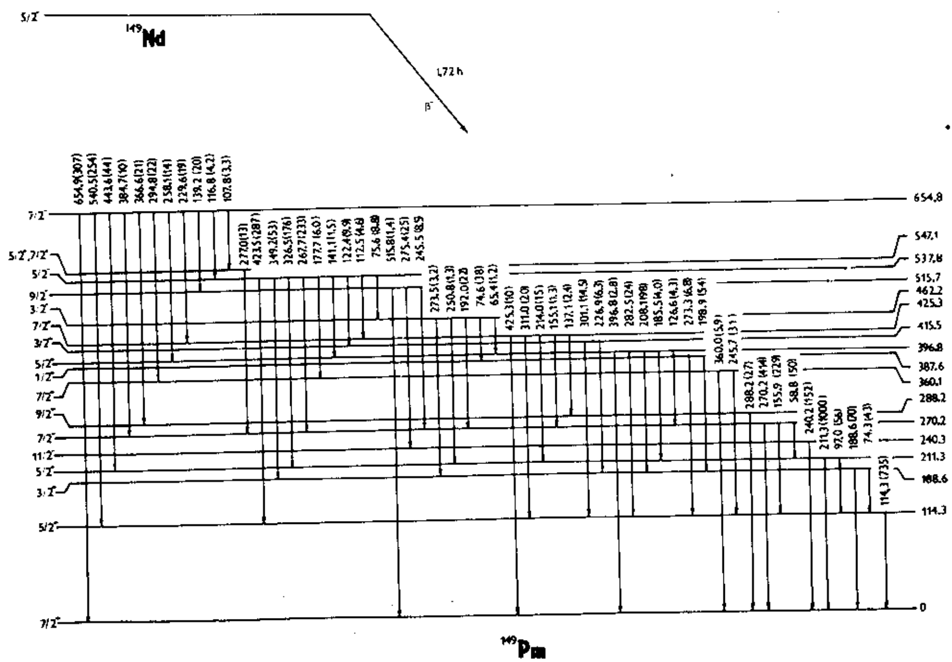

Fig.1. A portion of the ^{149}Nd *decay scheme.*

le 1 the measured $A_2U_2B_2$ - terms from two measurements are summarized. The analysis of the data was performed by assuming the placement of γ-transitions following the ^{149}Nd decay scheme of ref.[1] complemented by the results of refs.[2,4-7]. The part of this scheme, used for the present data analysis, is shown in fig.1. The factors of deorientation by preceding β- and γ-radiations, U_2, were evaluated considering the allowed β-transitions to be of the Gamow-Teller type. The multipolarities of the γ-ray transitions suggested by the ICC data[2] were taken into account in the calculation of U_2 coefficients and, if it was possible, the data obtained in the present work, too. The uncertainties of U_2 coefficients were deduced from the uncertainties in branching ratios[1] and γ-ray multipolarities, too.

3.1. Determination of orientation parameter B_2

The spin of the ground state of the ^{149}Pm nucleus was experimentally determined to be 7/2 /12/, with positive parity[8]. From the negative sign of the anisotropy of the intensive 654.8 keV ground state transition, its non-stretched character can be deduced, and the spin 7/2 of the 654.8 keV level unambiguously confirmed. This transition was established as electric-dipole one with the less than 2% M2 admixture allowed[2]. The level at 654.8 keV is populated via a direct - transition from the ^{149}Nd ground state, while the beta-gamma cascade feeding being negligible.

Owing to these properties, the measured anisotropy of the 654.8 keV transition was used for evaluation of the nuclear orientation parameter of the ^{149}Nd ground state. It should be noted that the anisotropy of the non-stretched transition is considerably less sensitive to the given amount of M2/E1 mixing than the anisotropy of the stretched one and that our evaluation is independent of the 4th term, since $A_4 = 0$ for the E1 transition. The experimental values of $B_2 = 0.504(44)$ and of $B_2 = 0.696(52)$ were deduced for two samples employed.

The level at 240.3 keV has a long half-life $T_{1/2} = 35$ ms. Substantial attenuation of the anisotropy of the 240.3 keV ground state transition can therefore be expected. Assuming its pure M2 character[2], the analysis of the anisotropy of this stretched transition, by using the above-mentioned values of B_2 and the calculated U_2 coefficients, gave the attenuation factor $G_2 = 0.50(15)$.

3.2. Multipolarity and spin assignments

The angular distribution coefficients A_2 have been deduced by means of the measured values of $B_2U_2A_2$-terms together with the above B_2 and calculated U_2 coefficients. The average values of A_2-coefficients from two independent measurements, together with their mean-square deviations, are summarized in the 4th column of Table 1.

The spin assignments of five levels at 654.9, 537.8, 270.2, 211.3 and 114.3 keV, known from the earlier works as $7/2^-$, $5/2^-$, $7/2^-$, $5/2^+$ and $5/2^+$ [2,4-7], respectively, were unambiguously confirmed in our work from the sign of the A_2-coefficients of intensive 654.9, 540.5, 423.5, 326.5, 270.2 and 155.9 γ-transitions. The E1 character of these transitions was established earlier [2]. The spin-assignments of several other levels, discussed below, are derived from the experimental anisotropy of the γ-ray transitions linking these five levels.

Analysis of the γ-ray multipole mixing ratios $\delta(L = 2/L=1)$ was carried out by combining the present A_2-values with the available internal conversion data [2] applying a procedure based on the maximum likelihood principle, as suggested in ref. [3]. The resulting inference about the γ-values is summarized in Table 2.

The 188.6 keV level. The level at 188.6 keV was assigned earlier as $3/2^+$ [2] on the basis of measured E2/M1 and E2 multipolarity of the 74.3 keV and 188.6 keV transitions, respectively. This suggestion is in agreement with the new reaction data [5-7]. In the same manner assignment of $1/2^+$ was made for 387.6 keV level from measured multipolarity of the 198.9 keV transition.

The present zero anisotropy of the 198.9 keV γ-ray confirms the spin 1/2 for the 387.6 keV level. The stretched character of the E1 349.2 keV γ-transition [2], unambiguously established from the present positive value of its A_2 coefficient, implies the $3/2^+$ or $7/2^+$ assignments for 188.6 keV level. However, the M1 198.9 keV transition to the 188.6 keV level rules out spin 7/2. The value of $A_2 = -0.19(8)$ coefficient of the 188.6 keV ground-state transition is in agreement with the theoretical one $A_2 = -0.143$ for the pure E2 stretched transition from the 3/2 state.

The 288.2 keV level. This level has been earlier assigned as $(9/2)^+$ [1] and $(7/2, 9/2)^+$ [7], new γ-γ correlation data prefer spin 7/2 [9]. The positive sign of the A_2-coefficient of the 366.6 keV transition, the electric-dipole multipolarity of which was established in ref. [2], unambiguously confirms

Table 1. The experimental $U_2A_2B_2$-terms from β-decay of ^{149}Nd

E_γ (keV)	$U_2A_2B_2$ 1st sample	$U_2A_2B_2$ 2nd sample	A_2
114.3	0.089(12)	0.115(11)	0.30(4)
155.6	0.107(16)	0.128(15)	0.26(3)
188.6	−0.05(4)	−0.07(3)	−0.19(8)
192.0	−0.18(11)	−0.21(11)	−0.42(17)
198.9	0.00(3)	−0.00(3)	
208.1	−0.02(2)	0.02(2)	0.047(31)
211.3	−0.125(6)	−0.143(7)	−0.35(3)
229.6	−0.38(10)	−0.41(11)	−0.74(15)
240.2	−0.08(2)	−0.11(2)	
267.7	0.18(2)	0.22(2)	0.50(7)
270.1	−0.13(2)	−0.17(2)	−0.34(3)
275.4	0.30(16)	0.31(16)	0.71(26)
282.4	−0.33(12)	−0.31(5)	−0.70(11)
288.2	−0.28(6)	−0.41(6)	−0.71(9)
294.8	−0.19(6)	−0.22(10)	−0.34(9)
301.1	0.01(14)	−0.06(12)	−0.10(30)
311.0	−0.01(8)	−0.12(5)	−0.08(11)
326.5	−0.158(16)	−0.149(8)	−0.36(6)
349.2	0.13(4)	0.13(4)	0.29(4)
360.0	0.15(25)	0.29(25)	0.66(49)
366.6	0.04(6)	0.05(6)	0.09(8)
384.7	−0.25(15)	−0.08(12)	−0.24(18)
423.5	−0.158(14)	−0.169(11)	−0.40(5)
443.6	0.15(4)	0.27(5)	0.35(6)
540.5	0.18(1)	0.21(1)	0.370(25)
555.9+556.8	−0.082(38)	−0.130(20)	
654.8	−0.194(17)	−0.265(19)	≡ −0.436

Table 2. *The multipole mixing ratios of some γ-rays in* ^{149}Pm

E_{Lev} (keV)	I_i^π	E_γ (keV)	I_f^π	$\delta(L+1/L)$ [a]	$Q=\delta^2/(1+\delta^2)$
114.3	$5/2^+$	114.3	$7/2^+$	0.14(5)	(0.8–3.5)% E2
188.6	$3/2^+$	188.6	$7/2^+$	E2	
211.3	$5/2^+$	211.3	$7/2^+$	$-0.44^{+0.08}_{-0.11}$	(12–23)% E2
270.2	$7/2^-$	270.1	$7/2^+$	$-0.074^{+0.052}_{-0.041}$	(0.1–1.3)% M2
		155.9	$5/2^+$	0.032(32)	(0.0–0.4)% E1
288.2	$9/2^+$	288.1	$7/2^+$	$0.74^{+0.31}_{-0.13}$ [b]	(27–53)% E2
				or 2.0(6) [b]	(65–87)% E2
396.8	$5/2^+$	282.4	$5/2^+$	0.77(72)	(0–70)% E2
		208.1	$3/2^+$	0.17(3)	(2–4)% E2
425.3	$7/2^+$	311.0	$5/2^+$	0.22(13)	(0–11)% E2
				or $\delta < -8.6$ or $\delta > 8.0$	E2
462.2	$3/2^-$	192.0	$7/2^-$	E2 [c]	
537.8	$5/2^-$	423.5	$5/2^+$	$-0.025^{+0.093}_{-0.022}$	(0.0–1.1)% M2
		349.2	$3/2^+$	0.044(38)	(0.2–0.7)% M2
		326.5	$5/2^+$	−0.07(6)	(0–2)% M2
		267.7	$7/2^-$	0.28(7)	(4–11)% E2
654.8	$7/2^-$	654.8	$7/2^+$	≡ E1	≡E1
		540.5	$5/2^+$	−0.23(28)	(0–21)% M2
		366.6	$9/2^+$	−0.04(11)	(0–2)% M2
		294.8	$7/2^+$	$-0.11^{+0.25}_{-0.19}$	(0–8)% M2
		229.6	$7/2^+$	$0.06 \le \delta \le 1.1$	(0–55)% M2

a) The emission matrix elements and sign convention introduced by Krane and Steffen[14] *are used in our work. The errors are within the 95% confidence level.*

b) Evaluated only from the present A_2*-value.*

c) Theoretical value for pure E2 transition $A_2 = -0.14$.

the $9/2^+$ assignment. Then multipolarity of the 288.2 keV ground-state transition was deduced as $\delta = 0.74^{+0.31}_{-0.13}$ or 2.0(6).

The 360.1 keV level. The negative value of the A_2-coefficient of the 294.8 keV transition, established as E1 in ref.[2] unambiguously determines the $7/2^+$ assignment for 360.1 keV level.

The 425.3 keV level. The assignments $7/2^+$, $(5/2)^+$ [1] and $(5/2, 7/2)^+$ [7] of this level were reported earlier. New γ-γ angular correlation data[9] prefer the $7/2^+$ assignment. On the basis of the negative value of the A_2-coefficient of E1[2] 229.6 keV transition, depopulating the $7/2^-$ level at 654.9 keV, we can unambiguously assign the 425.3 keV level as $7/2^+$. Then, the multipolarity of the 311.0 keV γ-ray transition is M1+(1-11)% E2 or E2.

The 462.2 keV level. The nuclear spin of this level has been determined as $3/2^-$ [1,7]. However, in the $(\vec{t}, \alpha)$ reaction the $(7/2)^+$ level at ≈ 462 keV has been populated[6]. From a rather large negative value of the A_2-coefficient of the 192.0 keV transition, multipolarity of which is known as E2[2], we unambiguously confirm the $3/2^-$ assignment of this level.

The 396.8, 415.5 and 515.7 keV levels. Accepting the assignments $5/2^+$, $3/2^+$ and $9/2^-$, made for these levels in ref.[1,7,9], we have determined the multipole mixing ratios of the 208.1, 282.5 and 301.1 keV γ-ray transitions.

The 275.4 and 277.0 keV transitions were detected as an unresolved doublet in our γ-spectra. To assume the E1 multipolarity of the 277.0 keV γ-ray, we can evaluate E2/M1 mixing ratio of the major part of the doublet - of the 275.4 keV γ-rays. Its value is only weakly dependent on the ambiguous spin assignment of the 547.1 keV level.

4. DISCUSSION

The transitional character of the ^{149}Pm nuclei allows many approaches. The interpretations of low-lying levels in terms of the intermediate coupling model were made in refs.[1,7,9] The interacting-boson aproximation has been applied to the odd-A Pm isotopes in ref.[15] . Kortelahti et al.[7] have shown that the low-lying states in ^{149}Pm, especially many positive-parity states, can be qualitatively described by using the axial quasiparticle rotor model (QRM). The quasiparticle rotor model with a variable moment of inertia was used by Bhattacharya et al.[16] for the description of the isotopes ^{149}Pm, ^{151}Eu and ^{153}Tb. Recently the properties of low-lying states in ^{149}Pm have been discussed by Iimura et al. in ref.[9]. The results of the theoretical studies of the structure of low-lying levels in ^{149}Pm and ^{151}Eu isotones are systemized in our previous study[17].

To bring to light discrepancies between the results of some theoretical investigations[7,9], as well as to show the possible rotational structure of the low-lying states in ^{149}Pm, we have re-examined the existing experimental information available on ^{149}Pm and discussed it in the light of QRM calculations.

The Hamiltonian of the model used can be written in the form: $H = H_{qp} + H_{q\,rot}$, where H_{qp} describes the intrinsic motion of the quasiparticle in the deformed Saxon-Woods potential and $H_{q\,rot}$ is the rotational part associated with the adiabatic rotor and the Coriolis interaction. The intrinsic part H_{qp} consists of these contributions: the single particle, pairing and recoil terms. Details of the model applied are described in ref.[18].

The parameters of the axially-deformed Saxon-Woods potential were taken from Solovjev's monography[19] and abjusted to reproduce the lowest quasiparticle energies in ^{149}Pm:

$$R_o = 1.25 \text{ fm},\ V_o = 59.4 \text{ MeV},\ \kappa = 0.35 \text{ fm}^2,\ \alpha = 1.63 \text{ fm}^{-1},$$

$$\beta_{20} = 0.09,\ \beta_{40} = -0.02.$$

Small quadrupole and hexadecapole deformations can be compared with the values of $\beta_{20} = 0.10$, $\beta_{40} = 0.00$[7,9] and $\beta_{20} = 0.10 - 0.15$, $\beta_{40} \simeq -0.04$[20] used for ^{149}Pm and ^{151}Eu, respectively.

During the diagonalization process the intrinsic energies of the 15 quasiparticle states originating from $d_{3/2}$, $d_{5/2}$, $g_{7/2}$ and $h_{11/2}$ orbitals together with the attenuation factors, reducing the Coriolis interaction, were optimized. The electromagnetic probabilities B(E2), B(M1) and B(E1) were calculated by using the parameters[7,9,21]:

$$g_R = 0.35,\ g_S = 5.586,\ g_L = 1.0,\ Q_0 = 450 \text{ e}^2\text{fm}^4.$$

The parameters of inertia A = 35 keV and A = 20 keV were fixed for the positive and negative parity states, respectively.

The experimental transition probabilities were used in the classification of the states. Their values, calculated from both the multipole mixing ratios and the compiled half - lives[8], are compared with the results of our QRM calculations in Tables 4, 5. Table 3 summarizes the experimental and calculated multipole mixing ratios δ. Figure 2 shows the calculated bands together with the experimental levels.

Our QRM calculations reproduce well the transition rates between positive parity states: The large experimental B(E2) probability of the $3/2^+_1 \to 5/2^+_1$ transition indicates the similar structure of these two states. Another strong E2 transition $5/2^+_2 \to 7/2^+_1$ can be explained by the Coriolis coupling of the $7/2^+[404]$ and $5/2^+[413]$ states. On the other hand, the small experimental B(E2) probabilities of the $5/2^+_1 \to 7/2^+_1$, $3/2^+_1 \to 7/2^+_1$ and $5/2^+_2 \to 5/2^+_1$ transitions are well reproduced in our calculations by assuming them to be extra shell transitions.

It should be noted that in recent study /9/ the states from $d_{3/2}$ shell are not assumed. However, the low-lying intruder-hole states from $s_{1/2}$, $d_{3/2}$ and $h_{11/2}$ shells are well known for odd-proton nuclei /22/.

The structures of the negative parity low-lying states in ^{149}Pm are less clearly understood. The rather pure experimental information available on the transition probabilities makes it difficult to interprete the existing incomplete data. An attempt to systemize the negative parity states of ^{149}Pm in relation to ^{151}Eu and ^{153}Tb isotones is made in ref. /1/.

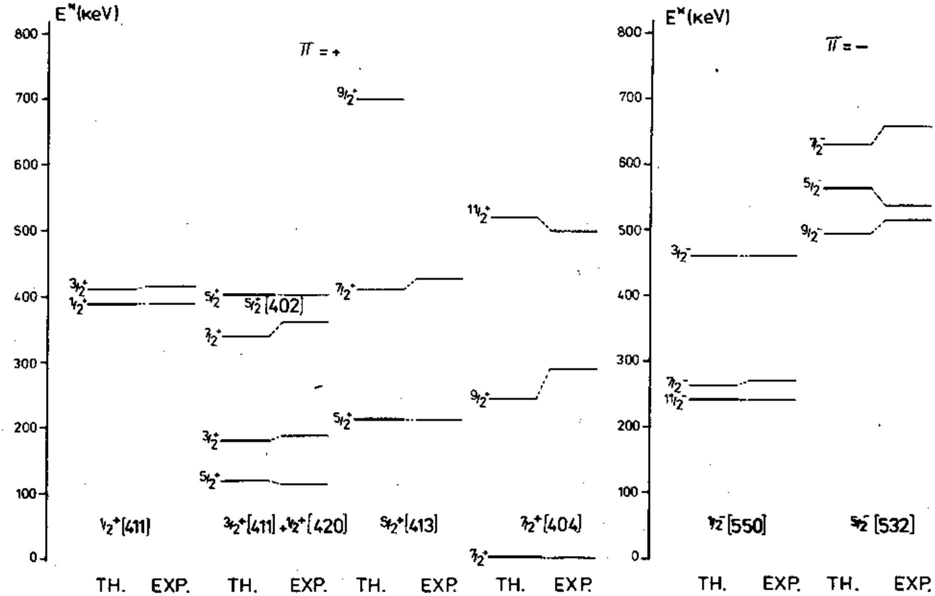

Fig. 2. Experimental levels of ^{149}Pm compared with predictions from QRM calculation.

Table 3. Experimental and calculated multipole mixing ratios of some γ-rays in ^{149}Pm

E_{lev} (keV)	I_i^{π}	E_{γ} (keV)	I_f^{π}	δ^{exp}	δ^{calcul}
114.3	$5/2^+$	114.3	$7/2^+$	0.14(5)	−0.21
188.6	$3/2^+$	74.3	$5/2^+$	$\lvert\delta\rvert = 0.71(6)$ [a]	0.11
211.3	$5/2^+$	211.3	$7/2^+$	$-0.44^{+0.08}_{-0.11}$	−0.30
		97.0	$5/5^+$	$\lvert\delta\rvert < 0.14$ [a]	−0.04
288.2	$9/2^+$	288.1	$7/2^+$	$0.74^{+0.31}_{-0.13}$	
				or 2.0(6)	
360.1	$7/2^+$	245.7	$5/2^+$	$\lvert\delta\rvert < 1.1$ [a]	1.02
387.6	$1/2^+$	198.6	$3/2^+$	$\lvert\delta\rvert < 0.50$ [a]	0.01
396.8	$5/2^+$	282.4	$5/2^+$	0.77(72)	7.15
		208.1	$3/2^+$	0.17(3)	0.00
415.5	$5/2^+$	301.1	$5/2^+$	$\lvert\delta\rvert > 0.3$ [a]	−0.01
425.3	$7/2^+$	311.0	$5/2^+$	0.22(13)	−1.15
				or $\delta < -8.6$ or $\delta > 8.0$	
		214.0	$5/2^+$	$\lvert\delta\rvert > 0.9$ [a]	0.90
515.7	$9/2^-$	275.4		$\lvert\delta\rvert > 0.5$ [a]	
537.8	$5/2^-$	267.7	$7/2^-$	0.28(7)	0.24
		75.6	$3/2^-$	$\lvert\delta\rvert < 0.8$ [a]	−0.02
654.8	$7/2^-$	116.8	$5/2^-$	$\lvert\delta\rvert = 0.5^{+1.1}_{-0.3}$ [a]	−0.05

a) *Deduced from the ICC data* /8/ .

Table 4. Experimental and calculated electromagnetic transition rates B(E2) and B(M1)

E_{lev} (keV)	I_i^π	E_γ (keV)	I_f^π	B(E2) (e^2fm^4) Theory	Exp.	B(M1) ($10^{-3}\mu_N^2$) Theory	Exp.
114.3	$5/2^+$	114.3	$7/2^+$	90	106(50)	1.9	4.9(5)
188.6	$3/2^+$	188.6	$7/2^+$	22	150(20)		
		74.3	$5/2^+$	5800	3310(45)	177	2.5(5)
211.3	$5/2^+$	211.3	$7/2^+$	1060	2020(95)	37	33(10)
		97.0	$5/2^+$	140	< 800	67	22(6)
288.2	$9/2^+$	288.1	$7/2^+$	6200		13	
360.1	$7/2^+$	245.7	$5/2^+$	5200		21	
387.6	$1/2^+$	273.3	$5/2^+$	10	550(20)		
		198.6	$3/2^+$	30	< 650	440	5.0(15)
		176.2	$5/2^+$	0	140(4)		
396.8	$5/2^+$	282.4	$5/2^+$	2200		0.2	
		208.1	$3/2^+$	0.3		600	
415.5	$5/2^+$	301.1	$5/2^+$	6		600	
425.3	$7/2^+$	311.0	$5/2^+$	145		0.8	
		214.0	$5/2^+$	5200		21	
515.7	$9/2^-$	275.4	$11/2^-$			420	
537.8	$5/2^-$	267.7	$7/2^-$	2500	> 300	220	> 12
		75.6	$3/2^-$	1000	≈ 20000	1300	> 12
654.8	$7/2^-$	116.8	$5/2^-$	3500	> 50	1000	> 0.5

In agreement with our interpretation, the log ft values of the β-transitions to the 654.8 and 537.8 keV levels [1] reveal the similar structure of these levels. The experimental value of the B(E2) ≈ 20000 e^2fm^4 of the $5/2^-_1 \to 3/2^-_1$ transition is connected with a rather large value of the δ coefficient evaluated from the ICC data [8].

Table 5. Experimental and calculated electromagnetic transition rates B(E1)

E_{lev} (keV)	I_i^π	E_γ (keV)	I_f^π	B(E1) ($10^{-5} e^2 fm$) Theory	Exp.
270.2	7/2⁻	270.2	7/2⁺	1	3.5(5)
		155.9	5/2⁺	14	10(1)
		58.8	5/2⁺	0.1	41(8)
537.8	5/2⁻	423.5	5/2⁺	56	> 48
		349.2	3/2⁺	3.2	> 15
		326.5	5/2⁺	0.01	> 60
		177.7	7/2⁺	45	> 12
		141.1	5/2⁺	144	> 7
		122.4	3/2⁺	7	> 70
		112.5	7/2⁺	7	> 45
654.8	7/2⁻	654.9	7/2⁺	24	> 4
		540.5	5/2⁺	4	> 5
		443.6	5/2⁺	0.01	> 1.8
		366.6	9/2⁺	0.01	> 1.5
		294.8	7/2⁺	54	> 3
		258.1	5/2⁺	37	> 3
		229.6	7/2⁺	0.05	> 2.5

5. SUMMARY

Although the structure of the transitional weakly deformed nuclei is more complex than the simple approach used by us, the present calculations indicate the possible rotational structure of the most low-lying levels in ^{149}Pm. Our interpretation of the QRM gives better results as compared with the earlier QRM calculation /7,9/ While the experimental transition probabilities B(E2) and B(M1) are reasonably well described in our calculations, the multipole mixing ratios and B(E1) values are not reproduced so satisfactorily.

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REFERENCES

1. Schneider E.W. et al. - Z.Phys., 1979, A291, p.77.
2. Backlin A., Malmskog S.G., Solhed H. - Ark.Fys., 1967, 34, p.495.
3. Copinathan K.P. - Phys.Rew., 1966, 141, p.1185.
   Swensson A.G., Bostrom L., Joshi M.C. - Nucl.Phys., 1966, 89, p.348.
   Begzhanov R.B., Gaffarov D., Solichbajev K.T. - Pisma v Zhurnal Eksperimental'noj i Teoreticheskoj Fiziki, 1969, 9, p.413.
4. Seo T., Hayashi R., Aoki A. - Nucl Phys., 1970, A159, p.494.
5. Straume O., Lovhoiden G., Burke D.G. - Nucl. Phys., 1976, A266, p.390.
   Lee I.S. et al. - Nucl. Phys., 1981, A371, p.111.
6. Straume O. et al. - Z.Phys., 1979, A293, p.75.
7. Kortelahti M. - Nucl.Phys., 1979, A332, p.422.
   Kortelahti M. - Dep. of Physics, Univ. of Jyvaskyla, Research Report No. 10/1979.
8. Szucs J.A., Johns M.W., Singh B. - Nucl.Data Sheets., 1985, 46, p.1.
9. Iimura H., Seo T., Yamada S. - J.Phys.Soc.Jap., 1986, 55, p.1108.
10. Šimeček P. et al. - Hyp.Int., 1987, 34, p.123.
    Preceedings of The VIIth Conference on HI, 8.-12.9.1986, Bangalore, India.
11. Finger M. et al. - Hyp.Int., 1984, 22, p.461.
12. Lederer C.M., Shirley V.S. (editors): App. VII in Table of Isotopes, 7-th edition J.Wiley Sons, 1977.
13. Dzhelepov B.S. - Sovremennyje metody jadernoj spectroskopii. 1983, Leningrad, Nauka, 1984, p.164.

14. Krane K.S., Steffen R.M. - Phys.Rev., 1970, C2, p.724.
15. Scholten O., Ozzello T. - Nucl. Phys., 1984, A424, p.221.
16. Bhattacharya S., Sen S., Guchhait R.K. - Phys.Rev., 1985, C32, p.1026.
17. Šimeček P. et al. - JINR, P6-87-161, Dubna, 1987.
18. Baznat M.I., Pjatov N.I., Tcherniej M.I. - Elementarnye Chastitsy i Atomhye Yadra, 1973, No.4/4, p.941.
19. Solovjev V.G. - Structura atomnogo yadra, Nauka, Moskva, 1971.
20. Dracoulis G.D., Leigh R.J. - J.Phys., 1976, G2, L87.
21. Alikov B.A. et al. - Izv. Akad. Nauk SSSR, ser. fiz., 1984, 48, p.875.
22. Meyer R.A., Meadows J.W.T., Macias E.S. - J.Phys., 1982, G8, p.1413.

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