Nuclear g-Factors of the 1229 and 2911 keV Isomers in 143Nd

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I. 7. Nuclear g-Factors of the 1229 and 2911 keV Isomers in ^{143}Nd

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In N=83 nuclei with even Z from Ba to Gd, low-lying $13/2^+$ states are observed systematically in the range of excitation from 1540 keV in ^{139}Ba to 997 keV in ^{147}Gd. These energies are quite consistent with an interpretation of the $\nu i_{13/2}$ single-particle excitations, but the measured half-lives indicate the B(E3) enhancement for the transition from the $13/2^+$ state to the $7/2^-$ ground state in comparison with the single-particle estimate. It has been therefore attributed to an admixture of collective 3^- excitation built on the $f_{7/2}$ ground state in the $i_{13/2}$ state,[1-3] because the 3^- octupole states in N=82 nuclei have been systematically found in even isotones from ^{136}Xe to ^{146}Gd with excitation energies decreasing monotonically with Z, and behavior of the energies of the $13/2^+$ states is qualitatively similar to those of the 3^- states.

A clear evidence on the admixture of the octupole excitation was found in the 997 keV $13/2^+$ isomer in ^{147}Gd by measurements of the nuclear g-factor[4,5], which indicated that the dominant component of the isomer was ($\nu f_{7/2} \otimes 3^-$) configuration rather than $\nu i_{13/2}$.

In the present work we have measured the g-factor of the 1229 keV $13/2^+$ isomer in ^{143}Nd by the time-integral perturbed angular distribution(TIPAD) method for in-beam γ-rays to investigate an adjacent nucleus of ^{147}Gd. The 2911 keV $21/2^+$ state having a half-life of 482 ps[3] precedes the $13/2^+$ state, therefore we also investigated the 2912 keV isomer and determined the main configuration.

The levels in ^{143}Nd (shown in Fig. 1) were excited by the ^{142}Ce(α,3n)^{143}Nd reaction. An enriched ^{142}Ce target was prepared by depositing $^{142}CeO_2$ powder of 11 mg/cm^2 thickness.on a mylar foil. The target was placed in an external magnetic field of 1.80 T applied perpendicularly to the beam-detector plane with an electromagnet (PAD magnet), and was bombarded by a 36 MeV α-particle beam from the Tohoku University CYRIC cyclotron. The change of position and direction of the beam due to the PAD-magnet field is compensated by active magnetic channels (AMC)[7], together with a beam steering magnet upstream. The residual beam deflection achieved in this system is estimated to be within $\pm 0.1°$.

The TIPADs of in-beam γ-rays were measured with a 230 cm^3 HPGe detector at seven angles between 64° and 130°. The γ-ray yields at different angles were normalized by another HPGe detector fixed at -90° as a monitor. Three times of measurements have been performed. In one measurement each run took 10 min and the number of runs at an angle was about 30. Fig. 2 shows typical examples of the TIPADs of γ-rays de-exciting the 1229 keV and the 2911 keV states.

The data were fitted to an expression:

$$W(\theta;\pm B_{eff}) = A_0+\Sigma A_n G_n P_n(\cos[n(\theta \mp \Delta\theta_n)]); \qquad (n = 2 \text{ and } 4),$$

where $\Delta\theta_n$ is the angular shift due to the Larmor precession,.and given by the Larmor angular velocity ω and mean life τ as

$$\Delta\theta_n= (1/n)\arctan(n\omega\tau); \quad (n=2 \text{ and } 4).$$

The results of the least-squares fitting are shown in Fig. 2. Mean values of the ωτ of the three-times measurements are listed in table 1. The effect of the precession of the upper levels was corrected for the 1229 keV level, while for 2911 keV level it was neglected.

The nuclear g-factor is deduced from the Larmor angular velocity ω and the effective perturbation field B_{eff} as

$$g = -\hbar\omega/\mu_N B_{eff},$$

where μ_N is the nuclear magneton. In the rare earth region, the effective magnetic field at the site of the nucleus B_{eff} is quite different from the external field B_{ext} by the large paramagnetic effect[8)]. The B_{eff} is written as

$$B_{eff} = ß\ B_{ext},$$

where ß is the paramagnetic correction factor. We used

$$ß\ (\text{Nd in } CeO_2)= 1.71(20):$$

a value obtained for Nd ions in the CeO_2 target[9)].

The mean-life of the state must be known to deduce the g-factor from the observed rotation angle $\Delta\theta_n$ of the TIPAD. Since the previous reports on the mean-life of the 1229 keV state are not compatible[2,3)], we have measured the lifetime by the beam-γ timing method using the HPGe detector. A background-subtracted time spectrum is shown in Fig. 3 together with a result of a least squares fit. The present result of the half-life of the 1229 keV level is to be

$$T_{1/2} = 6.79(2)\text{ ns},$$

which is in agreement with the value of ref. 2). The lifetimes and the final results for the g-factors are listed in table 1.

The present result of

$$g(13/2^+) = +0.058(5)$$

for the 1229 keV 13/2+ level indicates an obvious admixture of collective component because of the positive g-factor, comparing with the g-factor[10)] of about -0.15 for the $i_{13/2}$ neutron orbital. If only the ($\nu f_{7/2} \otimes 3^-$) and $\nu i_{13/2}$ configurations are considered as the main components of the 1229 keV state, the g-factor of the 13/2+ state can be written by the additivity relation as

$$g(13/2^+) = a^2[7g(f_{7/2})+6g(3^-)]/13+(1-a^2)g(i_{13/2}),$$

where a is the amplitude of the component of the octupole admixture. The value of a^2 is evaluated to be a^2=0.76(2) by using the effective g-factors for each component listed in table 2. The predominance of the ($f_{7/2} \otimes 3^-$) configuration in the 1229 keV level is clear and is quite similar to the case of the 977 keV 13/2+ level[4,5)] in ^{147}Gd. The g-factors of the 997 keV level in ^{147}Gd reported by Hausser et al.[4)] and Dafni et al.[5)] are not in agreement with each other; the former was a negative value, while the latter positive, however both the values lead to a result of the large octupole admixture in the 997 kev level.

The spin of the 2911 keV 21/2+ level is assigned by several studies[2,3,6,11)], and the parity is determined by Caussyn et al.[6)]. Burde et al.[3)] suggested the $\{\nu f_{7/2} \otimes \pi[g_{7/2}^{-1}h_{11/2}]_{7^-}\}_{21/2^+}$ configuration as the main component of the state, and Aziz et al.[11)] considered one more configuration of $\{\nu i_{13/2} \otimes 4^+\}_{21/2^+}$ as well as for the 3024 keV 21/2 level. If we take into account only these two components, the g-factor of the 21/2+ state can be written in the same manner as the 13/2+ state:

$$g(21/2^+) = a^2[g(f_{7/2})+2g(7^-)]/3 + (1-a^2)[13g(i_{13/2})+8g(4^+)]/21.$$

Using the present result of

$$g(21/2^+) = +0.69(12)$$

and the effective g-factors in table 2, we obtain a value of a^2=0.89(29). This shows that the 2911 keV level has almost pure ($\nu f_{7/2} \otimes 7^-$) configuration.

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Table 1. Experimental results and g-factors.

Isomer(keV, J^{π})	$\omega\tau$ (rad)	τ (ns)	g
1229 $13/2^+$	-0.0869(34)[a]	9.80(3)[b]	+0.058(5)
2911 $21/2^+$	-0.0684(92)	0.695(40)[c]	+0.69(12)

[a] Corrected for the effect of rotations of the upper levels.
[b] Present work.
[c] Ref. 3).

Table 2. Effective g-factors for components.

component	g-factor	reference
3^- state	+0.62(12)	^{146}Gd(derived from 9^- in ^{148}Gd)[12]
4^+ state	+1.08(3)	^{140}Ce[13]
7^- state	+1.25(2)	^{146}Gd[13]
$\nu f_{7/2}$	-0.304(2)	^{143}Nd[13]
$\nu f_{7/2}$	-0.15(2)	isotopes of lead and mercury[10]

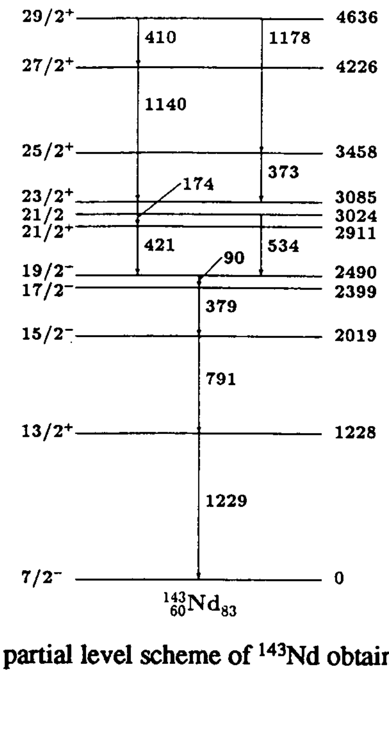

Fig. 1. A partial level scheme of ^{143}Nd obtained in in-beam spectroscopic study[6].

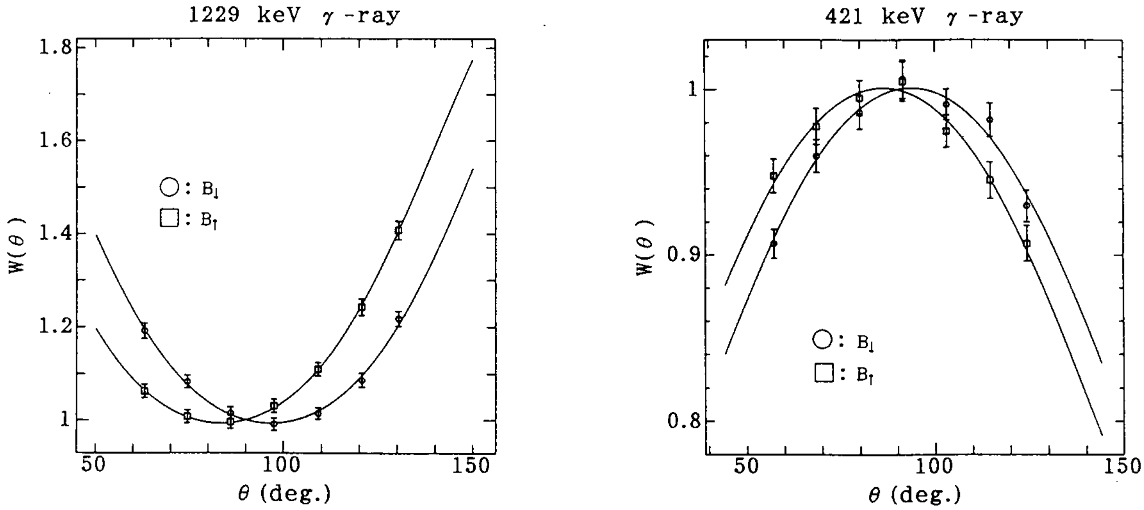

Fig. 2. Typical examples of the TIPAD results of the 1229 and 472 keV γ rays.

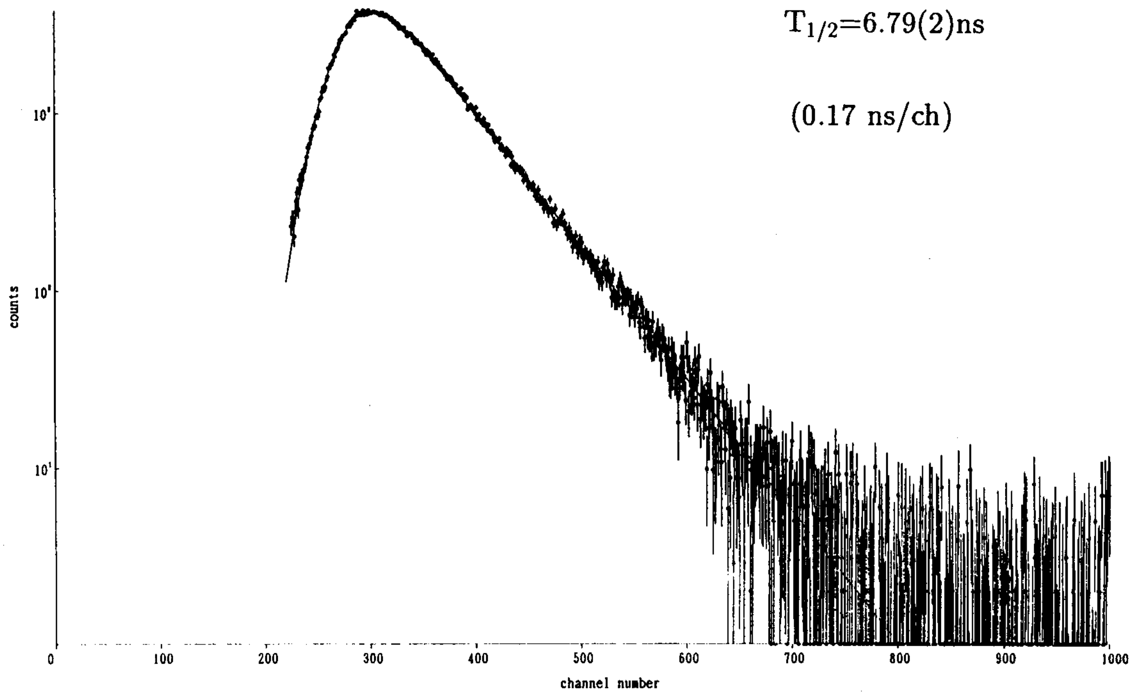

Fig. 3. RF-γ time spectrum of the 1229 keV γ ray.