Nuclear g factor of the 2972 keV isomeric state in ^{130}Xe

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The g factor of the 2972 keV isomer in ^{130}Xe was measured with the time-integral perturbed angular distribution method to be $g=-0.158\pm0.021$. The lifetime of this state was revised to be $T_{1/2}=5.17\pm0.11$ ns. These results determined the $\nu h^2_{11/2}$ configuration for the isomer, in agreement with the interacting boson approximation calculation including the fermion degrees of freedom.

I. INTRODUCTION

In a recent systematic study of even-mass Xe isotopes[1] the backbending of the yrast levels was found to occur in the lighter Xe isotopes ($A\leq 126$) at $J^\pi=12^+$, but in the heavier Xe isotopes ($A\geq 128$) at $J^\pi=10^+$. This observation, together with the systematic trend of excitation energies, has suggested that the yrast 10^+ levels in the Xe isotopes are collective states for $A\leq 126$, while they are two-neutron quasiparticle states of $\nu h^2_{11/2}$ for $A\geq 128$ (Ref. 1). Measurement of the g factor should provide conclusive data in verifying such a suggestion; we have a notable example of the 10^+ level in ^{144}Gd, of which the configuration was determined to be $\pi d^{-2}_{5/2}\,\nu h^2_{11/2}$ by the g-factor measurement,[2] contrary to the $\nu h^{-2}_{11/2}$ configuration expected from the energy systematics.

The 2972 keV level in ^{130}Xe is an isomeric state having a half-life of 5 ns and decays to the first 8^+ level at 2697 keV (Refs. 1 and 3). This isomeric state has been assigned as a level with $J^\pi=8^+$ or 10^+ by Goettig *et al.*,[3] and as the lowest (yrast) 10^+ level by Kusakari *et al.*[1] In order to determine the configuration we have measured the g factor and remeasured the half-life of this isomer.

II. EXPERIMENTS AND RESULTS

The 2972 keV isomer was populated through the ^{130}Te(α,4n)^{130}Xe reaction using a 48 MeV α beam from the Tohoku University cyclotron. The target (4 mg/cm^2) was prepared by depositing isotopically enriched ^{130}Te powder on a thin Mylar backing. The time-integral perturbed angular distribution (TIPAD) of the 275 keV γ ray deexciting the isomer was measured, applying an external magnetic field of $B=\pm(20.40\pm0.07)$ kG in the direction perpendicular to the reaction plane. The deflection of the beam due to the magnetic field was compensated by means of an active magnetic channels system[4] to be within $\pm0.6°$ for both directions of the field. The angular distribution was measured with a high-purity Ge detector at seven angles between 60° and 132°. Another Ge(Li) detector was placed at $-90°$ for normalizing the γ-ray yields obtained at different angles. The result of TIPAD measurement is shown in Fig. 1 together with the least-squares fittings to the expression

$$W(\theta,\pm B)=b_0+\frac{b_2}{[1+(2\omega\tau)^2]^{1/2}}\cos 2(\theta\mp\theta_2)+\frac{b_4}{[1+(4\omega\tau)^2]^{1/2}}\cos 4(\theta\mp\theta_4)\ ,$$

where ω is the Larmor angular velocity and τ is the mean

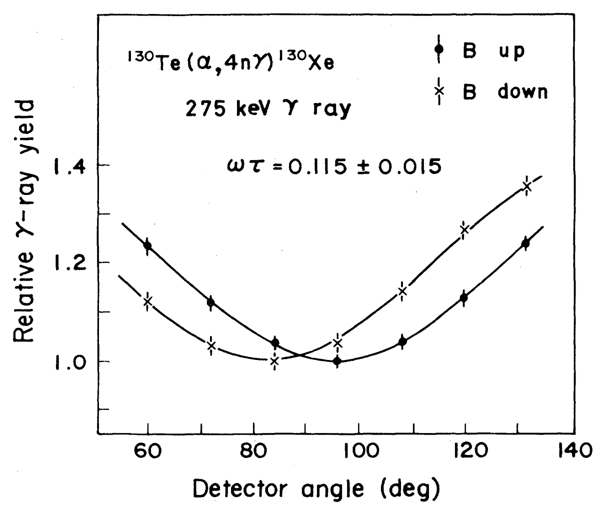

FIG. 1. The time-integral perturbed angular distribution of the 275 keV γ ray deexciting the 2972 keV level in ^{130}Xe. The curves indicate least-squares fittings.

life of the isomer, and $\theta_n=(1/n)\arctan n\omega\tau$. The value of $\omega\tau$ was obtained as $\omega\tau=0.115\pm0.015$ rad, where the error (one σ) contains the ambiguity of the beam direction (±0.011 rad) as well as the statistical error.

Since the previous measurement of τ for the 2972 keV isomer had a considerable error, we have remeasured the lifetime by the beam-γ delayed-coincidence method. The 2972 keV level was populated by the $^{130}Te(\alpha,4n)^{130}Xe$ reaction using a 48 MeV α beam from the Institute for Nuclear Study cyclotron. The time resolution of the Ge(Li) detector used in the measurement was 5.5 ns (FWHM) for E_γ around 300 keV. The decay curve of the 275 keV transition to the 8^+ level is shown in Fig. 2. The half-life of the 2972 keV level was obtained as

$$T_{1/2}=5.17\pm0.11 \text{ ns} .$$

The error (one σ) contains the statistical one (±0.07 ns) and the systematic one (±0.09 ns). It is noted that the time spectrum of the 721 keV transition feeding the 2972 keV isomer showed a prompt pattern. The present value of $T_{1/2}$ is consistent with the previous ones reported by Goettig *et al.*[3] (4.8 ± 0.5 ns) and by Kusakari *et al.*[1] (5.9 ± 0.8 ns). From the present value the reduced $E2$ transition probability is also revised to be $B(E2;$ 275 keV$)=1.63\pm0.04$, in Weisskopf units, provided the 275 keV transition is of $E2$ character (see Sec. III).

Using the present values of $\omega\tau$ and τ $(=1.443T_{1/2})$ in the formula $\omega\tau=-g\mu_N B\tau/\hbar$, the g factor of the 2972 keV isomer was obtained as

$$g(2972 \text{ keV})=-0.158\pm0.021 .$$

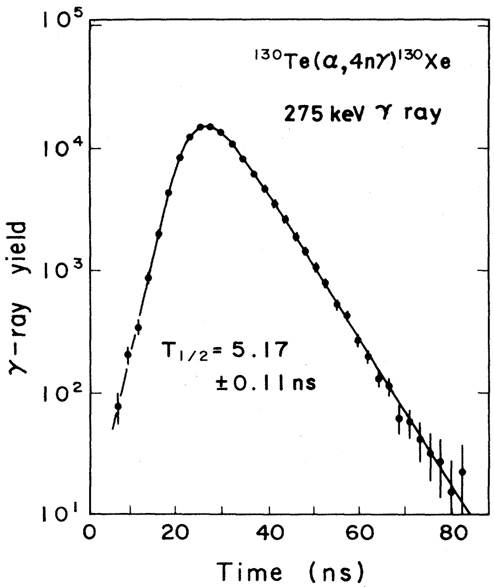

FIG. 2. The decay curve of the 275 keV γ ray deexciting the 2972 keV level in ^{130}Xe with respect to the cyclotron radiofrequency signal.

III. DISCUSSION

The value of the g factor obtained above clearly supports the expected $\nu h_{11/2}$ quasiparticle nature of the isomer as discussed in the following. The g factors of the $\frac{11}{2}^-$ isomers systematically appearing in odd-mass Xe isotopes were successfully reproduced[5,6] by configuration-mixing calculations following Arima and Horie[7,8] assuming the $\nu h_{11/2}$ configuration for these states; $g_{\text{exp}}=-0.154\pm0.005$ (^{129}Xe), -0.145 ± 0.018 (^{131}Xe), and -0.158 ± 0.022 (^{133}Xe) (Refs. 5 and 9). These values essentially coincide with the present value of $g(2972$ keV$)$. Therefore the most probable configuration of the 2972 keV isomer is considered to be $\nu h_{11/2}^2$. The systematic trend[1] of excitation energies of the even-mass Xe isotopes, together with the small $B(E2;$ 275 keV$)$ of this isomer (1.63 ± 0.04 W.u.), supports such a consideration.

Adopting a weighted mean value of the experimental g factors for the $\nu h_{11/2}$ quasiparticle states as $g(\nu h_{11/2})=-0.154\pm0.005$, we can estimate the purity of the $\nu h_{11/2}^2$ configuration in the 2972 keV isomer of ^{130}Xe as follows. Assuming possible admixtures of a collective state and a state of the $\pi h_{11/2}^2$ configuration, we have with a good approximation

$$g(2972 \text{ keV})=(1-\alpha^2-\beta^2)g(\nu h_{11/2}) + \alpha^2 g(\text{coll})+\beta^2 g(\pi h_{11/2}) ,$$

where α and β are the mixing amplitudes, and the additivity of the g factor is implied. Using the experimental values of $g(2972$ keV$)$ and $g(\nu h_{11/2})$ given above, $g(\text{coll})=0.288\pm0.032$ taken from the first 2^+ state in ^{130}Xe (Refs. 10 and 11) and $g(\pi h_{11/2})=1.4$ from the 536 keV $\frac{11}{2}^-$ state in ^{133}La (Ref. 12), we get the result as $1-\alpha^2-\beta^2\geq97\%$. Thus the 2972 keV isomer in ^{130}Xe is concluded to be essentially a pure two-quasiparticle state of $\nu h_{11/2}^2$.

Recently a calculation[13] for the excited states of the even-mass Xe isotopes has been performed on the basis of the extended interacting-boson approximation[14] (extended IBA), which includes the fermion degrees of freedom, in this case, the $(\nu h_{11/2}^2)_J$ configuration as well as the neutron and proton bosons. The possibility of an 8^+ assignment to the 2972 keV isomer can be excluded on the basis of the following theoretical consideration: According to the extended IBA calculation the second 8^+ level with the $\nu h_{11/2}^2$ configuration (at $E_x\approx3$ MeV) has a theoretical half-life of 29 ps and a theoretical γ-ray branching ratio of

$$I_\gamma(8_2^+\to6_1^+)/I_\gamma(8_2^+\to8_1^+)=1.2 ,$$

which are incompatible with the experimental values of $T_{1/2}=5.17\pm0.11$ ns and

$$I_\gamma(2972 \text{ keV}\to6_1^+)/I_\gamma(2972 \text{ keV}\to8_1^+)\approx0 ,$$

respectively. On the other hand, this calculation gives the probability of the $(\nu h_{11/2}^2)_{10}$ configuration of 92% for the *yrast* 10^+ level in ^{130}Xe which is predicted at an excitation energy around 3 MeV (Ref. 13). It is noted that this calculation also predicts the second 10^+ level of boson type in ^{130}Xe at an excitation energy 1 MeV higher than the yrast 10^+ level.

On the basis of the experimental and theoretical information, we conclude that the 2972 keV isomer in ^{130}Xe has the predominant configuration of $\nu h^2_{11/2}$ and that it can be identified as the yrast 10^+ level.

For clarifying the systematic properties of the first 10^+ levels in the Xe isotopes, measurements of the g factors of the 10^+ levels of ^{126}Xe and ^{128}Xe are highly desirable.

Note added in proof. Recently, Gorbachëv *et al.*[15] reported for the 2972 keV level of ^{130}Xe $g_{exp} = -0.204 \pm 0.014$, not in agreement with our value (-0.158 ± 0.021); they measured the time-differential perturbed angular distribution of the 275 keV γ ray using NaI(Tl) detectors.

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