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Proton-neutron configurations in ^{236g,m}Am and its EC-decay daughter ^{236}Pu

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Abstract. The EC decay of ^{236}Am has been studied using a gas-jet coupled on-line isotope separator. A half-life analysis revealed that there are two EC-decaying states in ^{236}Am: the 5^- state with $T_{1/2} = 3.6(2)$ min and the (1^-) state with $T_{1/2} = 2.9(2)$ min. The 1185.5 keV level in ^{236}Pu was found to be the K isomer with $K^\pi = 5^-$ and $t_{1/2} = 1.2(3)$ μs. EC transitions from ^{236g,m}Am to the 1185.5, 1311.5, and 1340.8 keV levels in ^{236}Pu show small $\log ft$ values of 4.9, 5.3, and 4.8, respectively, indicating that the $\pi5/2^+[642] \rightarrow \nu5/2^+[633]$ transition largely contributes to these transitions, and thus, the populated levels should be the $\pi5/2^-[523]\pi5/2^+[642]$ two-quasiparticle states. The $K^\pi = 0^-$ octupole band established in ^{236}Pu is located at higher energy than those in ^{238,240}Pu, which implies that the octupole correlations become weak at ^{236}Pu.

PACS. 23.20.Lv γ transitions and level energies – 23.40.-s β decay; double β decay; electron and muon capture – 27.90.+b $220 \leq A$

1 Introduction

It is challenging for both experiments and theories to reveal the nuclear structure of heavy actinide and transactinide nuclei. Experimentally, in-beam γ-ray spectroscopy and decay spectroscopy are extensively used to study the level structure of unstable nuclei. However, for short-lived transuranium nuclei, those experimental data are very scarce because of the small production cross-sections and severe contamination of γ-ray spectra. For EC decays of short-lived Am isotopes, no γ transition has been observed in previous experiments using chemical separation techniques [1–4]. In this work, we have studied the EC decay of ^{236}Am through γ-ray spectroscopy using an on-line isotope separator (ISOL), and established level structure and proton-neutron configurations in ^{236}Pu and ^{236}Am.

The decay of ^{236}Am was observed for the first time by Hall [1]. He produced Am isotopes by bombarding ^{237}Np with 33–39 MeV ^{3}He ions, and observed Pu K X-rays in chemically purified Am fractions. A preliminary half-life of 3.73(28) min was obtained for ^{236}Am. In our early experiment using the ISOL [5], Pu K X-rays originating from the EC decay of mass-separated ^{236}Am were observed successfully. However, no γ transition was found in the decay of ^{236}Am because of low statistics. The α decay of ^{236}Am was also studied with the ISOL, and the α energy and its intensity were determined to be 6150 keV and 0.004%, respectively [6]. Excited states in ^{236}Pu were established via the α decay of ^{240}Cm, β^- decay of ^{236}Np, and in-beam electron and γ-ray spectroscopy using the ^{235}U$(\alpha, 3n)^{236}$Pu reaction and a few-nucleon transfer reaction [7–10]. Only the ground-state band with spins up to 24^+ has ever been established.

2 Experiments

The nucleus ^{236}Am was produced by the ^{235}U(^{6}Li, $5n$)^{236}Am reaction at the JAERI tandem accelerator facility. A stack of twenty-one ^{235}U targets set in a

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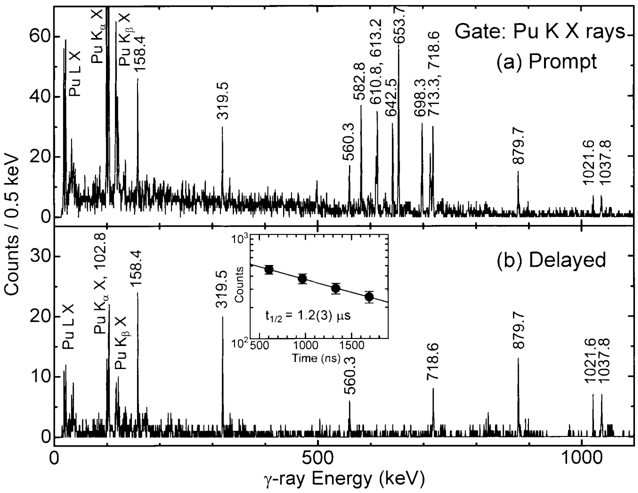

Fig. 1. Gamma-ray spectra in coincidence with Pu K X-rays observed in the mass-236 fraction. The time window was set (a) on the prompt part of the γ-γ time spectrum and (b) at the range of 0.4–1.9 μs from the prompt peak. The inset shows a decay curve of K X-γ delayed coincidence counts which contain all the γ- and X-ray counts in coincidence with Pu K X-rays.

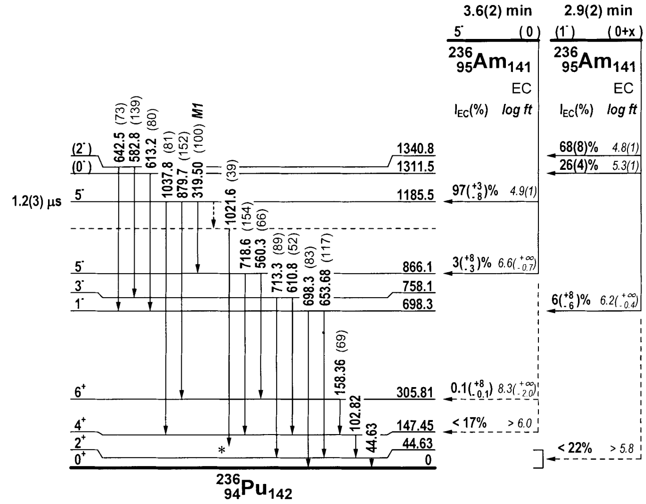

Fig. 2. Decay scheme of $^{236\mathrm{g,m}}$Am. The final state of the 1021.6 keV transition is either the 2^+ or the 4^+ state which could not be identified.

multiple-target chamber with 5 mm spacings was bombarded with a ^{6}Li beam of 43–48 MeV on targets with an average intensity of 440 particle-nA. Each target was electrodeposited on a 0.8 mg/cm^2 thick aluminum foil with an effective target thickness of about 100 μg/cm^2. Reaction products recoiling out of the targets were stopped in He gas loaded with PbI_2 clusters, and transported into an ion source of the ISOL by a gas-jet stream through an 8 m long capillary. Atoms ionized in the surface ionization-type thermal ion source were accelerated with 30 kV and mass-separated with a resolution of $M/\Delta M \sim 800$ [11].

The separated ions were implanted into an aluminum-coated Mylar tape in a tape transport system, and periodically transported to a measuring position at 500 s intervals. The measuring position was equipped with a short coaxial Ge detector (ORTEC LOAX) and a 35% n-type Ge detector (ORTEC GMX) placed on both sides of the tape in a close geometry. The detectors were shielded with 100 mm thick lead bricks and 5 mm thick copper inner plates. Gamma-ray singles and γ-γ coincidence events were recorded event by event together with time information. The data were accumulated during 21 h. Gamma-ray energy was calibrated using a ^{152}Eu source before and after the on-line experiment and also using background γ lines observed in on-line spectra. The efficiency of the detectors was measured using a mixed γ-ray standard source.

3 Results

Figure 1(a) shows a γ-ray spectrum in coincidence with Pu K X-rays observed in the mass-236 fraction. The time window was set on a prompt part of the γ-γ time spectrum. Fourteen γ transitions were attributed to the EC decay of ^{236}Am. Figure 1(b) shows a K X-γ delayed coincidence spectrum obtained by setting the time window at the range of 0.4–1.9 μs from the prompt peak. Apparently, this spectrum is different from the prompt one, indicating the existence of an isomeric state in ^{236}Pu with a $\sim \mu$s lifetime. The half-life of this isomer was determined to be 1.2(3) μs from the K X-γ delayed coincidence analysis whose decay curve is given in the inset in fig. 1(b). On the basis of the γ-γ coincidence relationships, the decay scheme of ^{236}Am has been established as shown in fig. 2. The 1185.5 keV level was assigned to be isomeric. Energies and relative intensities of γ rays derived from γ-ray singles spectra are summarized in table 1. Coincidence summing effects with cascade γ, K X-, and L X-rays were taken into account in the intensity analysis. All the possible combinations of γ-γ coincidence relationships in the decay scheme were clearly observed except for those with the 44.63 and 102.82 keV transitions.

The first 2^+ and 4^+ states in ^{236}Pu were previously established at 44.63 and 147.45 keV, respectively [7]. In the present experiment, the 44.63 keV $2^+ \rightarrow 0^+$ transition was not observed because this $E2$ transition has a large total internal conversion coefficient of $\alpha_T = 760$ [12]. The 102.82 keV $4^+ \rightarrow 2^+$ transition also has a large conversion coefficient ($\alpha_T = 14.1$ [12]), and this γ line overlaps with the intense 103.7 keV Pu K_{α_1} X-ray line. Thus, the 102.82 keV γ line was not distinguished in singles and γ-γ coincidence spectra, but only seen in the K X-γ delayed coincidence spectrum. The level energies of the first 2^+ and 4^+ states were taken from ref. [7].

The placement of the 1021.6 keV γ transition remains ambiguous. Since the 1021.6 keV γ-ray was observed in the K X-γ delayed coincidence spectrum, the initial state of this transition should be located below the 1185.5 keV level and fed by a transition from the 1185.5 keV level. The final state is either the 44.63 keV or the 147.45 keV level, that is, the initial state of this transition is the 1066.2 keV level fed by the 119.3 keV transition, or the 1169.1 keV

Table 1. Energies and relative intensities of γ-rays originating from the EC decay of 5^- and (1^-) states in ^{236}Am. The relative intensity of the Pu $K_{\alpha 2}$ X-ray observed in this experiment is 230(34).

E_γ (keV)	I_γ from ^{236}Am(5^-)[a]	I_γ from ^{236}Am(1^-)[b]
44.63[c]	[d]	[d]
102.82[c]	[d]	[d]
158.36(10)	69(10)	
319.50(11)	100(15)	
560.3(2)	66(13)	
582.8(2)		139(21)
610.8(3)		52(10)
613.2(2)		80(13)
642.5(2)		73(12)
653.68(12)		117(18)
698.3(2)		83(13)
713.3(2)		89(15)
718.6(2)	154(24)	
879.7(2)	152(22)	
1021.6(3)	39(7)	
1037.8(2)	81(12)	

([a]) For I_γ per 100 decays of ^{236}Am(5^-), multiply by 0.20(4).
([b]) For I_γ per 100 decays of ^{236}Am(1^-), multiply by 0.27(6).
([c]) Taken from ref. [7].
([d]) Not observed.

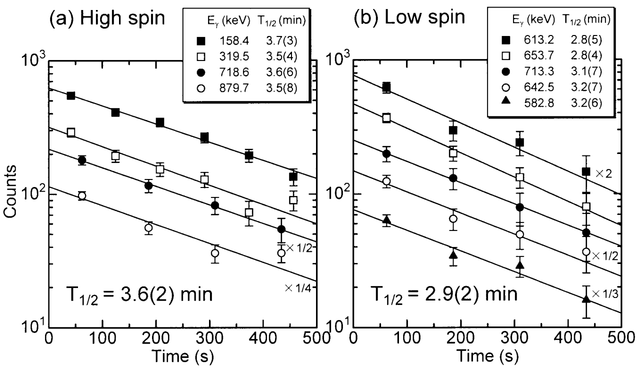

Fig. 3. Decay curves of γ-rays following the EC decay of ^{236g,m}Am (a) via the 866.1 and 1185.5 keV levels in ^{236}Pu and (b) via the 698.3, 758.1, 1311.5, and 1340.8 keV levels.

level fed by the 16.4 keV transition. We could observe neither the 16.4 keV nor the 119.3 keV γ-ray probably due to their large internal conversion coefficients. Note that if the 119.3 keV transition has an $E1$ multipolarity, this γ-ray should be observable. Thus, the $E1$ multipolarity is excluded for the 119.3 keV transition. The relative intensity of the 1021.6 keV γ-ray observed in the K X-γ delayed coincidence spectrum was the same as that in the singles spectrum within experimental uncertainties, indicating that there is little direct EC feeding to the initial state of the 1021.6 keV transition.

EC-transition intensities to excited states in ^{236}Pu revealed that most of the EC transitions concentrate on the 1185.5, 1311.5, and 1340.8 keV levels whose spin-parities are 5^-, (0^-), and (2^-), respectively, as discussed later. The EC transitions to both the 5^- and (0^-) states suggest that there are two EC-decaying states in ^{236}Am with high spin and low spin. Figures 3(a) and (b) show decay curves of γ-rays following the EC decay of ^{236}Am via (a) the 1185.5 keV level and (b) the 1311.5 and 1340.8 keV levels. Weighted averages of these half-life values exhibit the existence of two distinct EC-decay half-lives in ^{236}Am: 3.6(2) min for the high-spin state and 2.9(2) min for the low-spin state, which is a direct evidence for the existence of the EC-decaying isomer.

4 Discussions

The 698.3, 758.1, and 866.1 keV levels are evaluated to be the 1^-, 3^-, and 5^- members of the $K^\pi = 0^-$ octupole band, because the energy spacings among these levels are in excellent agreement with the rotational band energies $E(I) = E_0 + I(I+1)\hbar/2\mathcal{J}$ with spins $I = 1, 3$, and 5. The $K^\pi = 0^-$ octupole band typically appears at low excitation energy in light actinide nuclei [7]. $B(E1)$ ratios of the γ transitions from these levels to the ground-state band are in reasonably agreement with those of the $K^\pi = 0^-$ octupole band in ^{238,240,242}Pu as well as those of the Alaga rule prediction [13] for $K^\pi = 0^-$, not for $K^\pi = 1^-$, as summarized in table 2.

Gamma transitions from the 1185.5 keV level to the 4^+, 5^-, and 6^+ states are strongly hindered despite the existence of higher-spin states of 8^+, 10^+, and 12^+ below the 1185.5 keV level. This fact indicates that the 1185.5 keV level is not the isomer arising from large spin differences, but the "K isomer" with a spin-parity of 4^+, $5^\pm$, or 6^+. Since the $M1$ multipolarity is assigned to the 319.5 keV transition as described in the following paragraph, the spin-parity of 5^- has been identified to the 1185.5 keV level.

The K internal conversion coefficient of the 319.5 keV transition is derived from the K X-to-γ intensity ratio observed in the K X-γ delayed coincidence spectrum displayed in fig. 1(b) which contains only transitions depopulating the 1185.5 keV level and does not include K X-rays associated with the EC. Since the K electron binding energy of Pu is 121.8 keV, seven γ transitions of 158.4, 560.3, 718.6, 319.5, 879.7, 1021.6, and 1037.8 keV yield K X-rays. Multipolarities of the 158.4, 560.3, and 718.6 keV transitions are $E2$, $E1$, and $E1$, respectively. Those of the last three are unknown, but these high-energy transitions have small K internal conversion coefficients, thus their contributions are small. The K X-ray intensity associated with these six transitions is calculated using the observed γ-ray intensities and theoretical conversion coefficients [12]. By subtracting this calculated intensity from the measured one, the K internal conversion coefficient of the 319.5 keV transition is determined to be $\alpha_K = 0.87(21)$. Theoretical α_K values of the 319.5 keV transition are 0.029, 0.868,

Table 2. $B(E1)$ ratios for transitions from the 1^-, 3^-, and 5^- states in the $K^\pi = 0^-$ octupole band to levels in the $K^\pi = 0^+$ ground-state band in $^{236-242}$Pu, compared with the Alaga rule predictions.

	Present	Ref. [7]			Alaga rule [13]	
	^{236}Pu	^{238}Pu	^{240}Pu	^{242}Pu	$K^\pi = 0^-$	$K^\pi = 1^-$
$\frac{B(E1;1^-\to0^+)}{B(E1;1^-\to2^+)}$	0.58(13)	0.57(3)	0.50(6)	0.44	0.50	2.00
$\frac{B(E1;3^-\to2^+)}{B(E1;3^-\to4^+)}$	1.07(28)	0.88(7)	0.57(4)		0.75	1.33
$\frac{B(E1;5^-\to4^+)}{B(E1;5^-\to6^+)}$	1.10(28)		0.62(4)		0.83	1.20

and 0.070 for $E1$, $M1$, and $E2$ multipolarities, respectively [12], which allows us to assign the $M1$ ($E2 < 26\%$) multipolarity to the 319.5 keV transition.

Relative intensities of EC transitions to excited states are calculated from intensity imbalances of γ transitions. The intensity of missing EC transitions including the transitions to the first 0^+, 2^+, and 4^+ states is calculated through the comparison between the observed Pu K X-ray intensity and the calculated one based on the proposed decay scheme, where theoretical K internal conversion coefficients [12], K fluorescence yield, and K electron capture ratios [7] are used. The missing intensity is deduced to be $1(^{+8}_{-1})\%$ relative to the total EC-transition intensity from both $^{236\text{g,m}}$Am. Since the 1% intensity is negligibly small to deduce $\log ft$ values, we assume here that the missing EC-transition intensity is zero, and evaluate the absolute γ- and EC-transition intensities as shown in table 1 and fig. 2.

In fig. 2, we summarize the $\log ft$ values calculated using the measured half-lives, EC-transition intensities, $\log f$ tables [14], and Q_{EC} value of 3.17(11) MeV evaluated from the measured α-particle energy [6,15] and the atomic masses of ^{232}Np and ^{236}Pu [16]. The energy of the isomeric state in ^{236}Am is unidentified. However, *e.g.*, ± 200 keV difference in Q_{EC} value induces merely ± 0.1 uncertainty in $\log ft$ values. Such a small uncertainty would not influence the following discussions. Thus, we deduced the $\log ft$ values for both the high- and low-spin states using the same Q_{EC} value of 3.17(11) MeV. It was found that the EC transitions from $^{236\text{g,m}}$Am to the 1185.5, 1311.5, and 1340.8 keV levels show small $\log ft$ values of 4.9(1), 5.3(1), and 4.8(1), respectively.

Sood and Sheline [17] surveyed $\log ft$ values of EC and β^- transitions in $A \geq 228$ nuclei, and found that only a few specific transitions show $\log ft < 5.5$, which allows us to assign proton and neutron configurations involved in the transitions. Around neutron-deficient Am nuclei, the transitions with $\log ft < 5.5$ are identified to be the $\pi5/2^+[642] \leftrightarrow \nu5/2^+[633]$ transition [17,18]. Although the transitions of $\pi7/2^+[633] \leftrightarrow \nu7/2^+[624]$ and $\pi7/2^+[633] \leftrightarrow \nu5/2^+[633]$ may also show small $\log ft$ values of < 5.5 [17], these transitions would not be observed in the EC decay of neutron-deficient Am nuclei, because the occupation probability of the $\pi7/2^+[633]$ orbital in the ground states of the Am nuclei would be small; the $\pi7/2^+[633]$ orbital is estimated to lie at several hundred keV above the Fermi surface. Therefore, the small $\log ft$

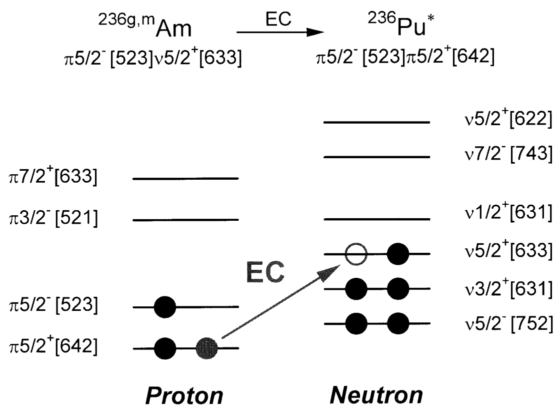

Fig. 4. Schematic drawing of the EC transitions from $^{236\text{g,m}}$Am to the 1185.5, 1311.5, and 1340.8 keV levels in ^{236}Pu which exhibit small $\log ft$ values of 4.9, 5.3, and 4.8, respectively. Energy spacings and order of the Nilsson single-particle states drawn in the figure are roughly estimated from the systematics in $Z = 95$ isotopes and $N = 141$ isotones.

values of 4.9, 5.3, and 4.8 in $^{236\text{g,m}}$Am indicate that the $\pi5/2^+[642] \to \nu5/2^+[633]$ transition largely contributes to these transitions, and thus, the proton-neutron configuration of $^{236\text{g,m}}$Am must include either the $\pi5/2^+[642]$ or the $\nu5/2^+[633]$ orbital. Besides, since the transition to the 1185.5 keV 5^- state is an allowed transition, the EC-decaying high-spin state has a spin-parity of 4^-, 5^-, or 6^-, and its configuration must include an odd-parity orbital.

It is known that the 95th proton of the ground state of $^{235,237-243}$Am occupies the $\pi5/2^-[523]$ orbital [7,18], and the $\pi5/2^+[642]$ orbital lies close to the Fermi surface; the $\pi5/2^+[642]$ hole state is located at 187, 206, and 84 keV in ^{239,241,243}Am, respectively [7]. Other orbitals are separate from these orbitals. On the other hand, the 141st neutron of the ground state of odd-mass $N = 141$ nuclei ^{229}Ra, ^{231}Th, ^{233}U, and ^{235}Pu occupies the $\nu5/2^+[633]$ orbital [7,18,19]. Excitation energies of other Nilsson states are shown in fig. 4 of ref. [18], exhibiting the large energy spacings of 150–300 keV between the $\nu5/2^+[633]$ ground state and other lowest-lying Nilsson states in ^{231}Th, ^{233}U, and ^{235}Pu. The locations of proton and neutron orbitals around the Fermi surface of ^{236}Am are schematically drawn in fig. 4. These systematics strongly suggest that the ground state of ^{236}Am

Table 3. Reduced transition probabilities of γ-rays depopulating the 1185.5 keV $K^\pi = 5^-$ isomer in ^{236}Pu compared with those of the 1309 keV $K^\pi = 5^-$ isomer in ^{240}Pu, both of which have the same $\pi 5/2^-[523]\pi 5/2^+[642]$ configuration.

$I_\mathrm{i} \to I_\mathrm{f}$		^{236}Pu		^{240}Pu [7]	
		E_γ (keV)	B (W.u.)	E_γ (keV)	B (W.u.)
$5^- \to 5^-$	$M1$	319.5	$1.2(3) \times 10^{-7}$	566.3	$2.0(2) \times 10^{-7}$
$5^- \to 6^+$	$E1$	879.7	$7(2) \times 10^{-11}$	1014.4	$2.3(6) \times 10^{-12}$
$5^- \to 4^+$	$E1$	1037.8	$2.2(6) \times 10^{-11}$	1167.1	$3.3(3) \times 10^{-11}$

would have the $\pi 5/2^-[523]\nu 5/2^+[633]$ configuration, which includes both an odd-parity orbital and either the $\pi 5/2^+[642]$ or the $\nu 5/2^+[633]$ orbital. Although the configurations of $\pi 5/2^+[642]\nu 5/2^-[752]$, $\pi 5/2^+[642]\nu 7/2^-[743]$, and $\pi 3/2^-[521]\nu 5/2^+[633]$ also includes these orbitals, they are expected to lie at higher excitation energy. As a consequence, we conclude that the EC-decaying high-spin state is the $(\pi 5/2^-[523]\nu 5/2^+[633])_{5^-}$ state, and this 5^- state is considered to be the ground state according to the Gallagher and Moszkowski coupling rule [20]. The candidate for the low-spin isomer is the 0^- state or its signature partner 1^- state with $K^\pi = 0^-$ and the $\pi 5/2^-[523]\nu 5/2^+[633]$ configuration.

Since the $^{236\mathrm{g,m}}$Am have the $\pi 5/2^-[523]\nu 5/2^+[633]$ configuration and occupied $\pi 5/2^+[642]$ orbital, the $\pi 5/2^+[642] \to \nu 5/2^+[633]$ transition generates the $\pi 5/2^-[523]\pi 5/2^+[642]$ configuration as shown in fig. 4, hence the 1185.5, 1311.5, and 1340.8 keV levels in ^{236}Pu should have the $\pi 5/2^-[523]\pi 5/2^+[642]$ configuration. The $\pi 5/2^-[523]\pi 5/2^+[642]$ two-quasiparticle states are reported in ^{240}Pu at 1309, 1411, and 1438 keV with spin-parities of 5^-, 0^-, and 2^-, respectively [7]. The 1309 keV level is the $K^\pi = 5^-$ isomer, and the 1411 and 1438 keV levels are interpreted as the $K^\pi = 0^-$ $(\pi 5/2^-[523]\pi 5/2^+[642])_{0^-}$ state and its 2^- rotational band member, respectively [21]. The energy spacings among the 1185.5, 1311.5, and 1340.8 keV levels and γ branching ratios depopulating the 1311.5 and 1340.8 keV levels in ^{236}Pu are similar to those of the 5^-, 0^-, and 2^- states in ^{240}Pu [7]. If the 1311.5 and 1340.8 keV levels in ^{236}Pu correspond to this 0^- state and its 2^- rotational band member, respectively, the spin-parity of $^{236\mathrm{m}}$Am should be 1^-, because the EC transitions from $^{236\mathrm{m}}$Am to these levels are allowed transitions. The intensity ratio between the EC transitions from $^{236\mathrm{m}}$Am to the 1311.5 and 1340.8 keV levels is consistent with the Alaga rule intensity ratio [13]: $ft(KI;01 \to 02)/ft(KI;01 \to 00) = 0.5$. This fact supports the above spin-parity and K-number assignments for $^{236\mathrm{m}}$Am as well as for the 1311.5 and 1340.8 keV levels in ^{236}Pu.

The 1185.5 keV level in ^{236}Pu and the 1309 keV level in ^{240}Pu have long half-lives of 1.2 μs and 165 ns, respectively, both of which are the K isomer with the $K^\pi = 5^-$ to $K^\pi = 0^\pm$ transitions. In table 3, reduced transition probabilities for the transitions depopulating these K isomers are summarized. The transitions show large hindrances, and the hindrance factors in ^{236}Pu and ^{240}Pu are in the same order. This result strongly supports the present K-number assignments for the excited states in ^{236}Pu.

Wiedenhöver *et al.* [22] and Saleem *et al.* [10] recently established high-spin states in the ground-state band in $^{236-244}$Pu as well as the octupole band in $^{238-244}$Pu via unsafe Coulomb excitations and a few-nucleon transfer reactions, and revealed that the octupole correlations become the strongest at $^{238-240}$Pu among those Pu isotopes. Sheline and Riley [23] pointed out the relation between the strength of the octupole correlations and the energy of the first 1^- state, which suggests the higher first 1^- state in ^{236}Pu than those in ^{238,240}Pu, corresponding to the weaker octupole correlations in ^{236}Pu. Energies of the first 1^- states in ^{236,238,240,242}Pu are found to be 698, 605, 597, and 780 keV, respectively, which confirms that the octupole correlations become weak at ^{236}Pu.

5 Conclusions

The EC decay of ^{236}Am has been studied using the on-line isotope separator. The half-life analysis revealed that there are two EC-decaying states in ^{236}Am. One is the $(\pi 5/2^-[523]\nu 5/2^+[633])_{5^-}$ state with $K^\pi = 5^-$ and the 3.6(2) min half-life which is considered to be the ground state. The other is the (1^-) state having the 2.9(2) min half-life and the $\pi 5/2^-[523]\nu 5/2^+[633]$ configuration with $K^\pi = 0^-$. The small $\log ft$ values of the EC transitions from $^{236\mathrm{g,m}}$Am to the 1185.5, 1311.5, and 1340.8 keV levels indicate that the $\pi 5/2^+[642] \to \nu 5/2^+[633]$ transition largely contributes to these transitions, and thus, the populated levels should be the $\pi 5/2^-[523]\pi 5/2^+[642]$ two-quasiparticle states. The 1185.5 keV $(\pi 5/2^-[523]\pi 5/2^+[642])_{5^-}$ state is the K isomer with $K^\pi = 5^-$ and $t_{1/2} = 1.2(3)$ μs. The 1311.5 and 1340.8 keV levels are the $K^\pi = 0^-$ $(\pi 5/2^-[523]\pi 5/2^+[642])_{0^-}$ state and its 2^- rotational band member, respectively. The higher level energy of the first 1^- state in the $K^\pi = 0^-$ octupole band in ^{236}Pu than those in ^{238,240}Pu implies that the octupole correlations become weak at ^{236}Pu.

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