Level structure in the transitional nucleus ^{195}Au

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Excited states in ^{195}Au have been studied experimentally via the ^{192}Os(^{7}Li, 4n) reaction at a beam energy of 44 MeV. Based on the γ-γ-t coincidence measurement, a level scheme consisting of 15 new transitions and 10 new levels is established for ^{195}Au. The triaxial shape-polarizing effect of the high-j $h_{11/2}$ proton hole was studied by total Routhian surface calculations. By comparing with the level structures in the odd-A Au isotopes and the even-even core Hg nuclei, configurations are proposed to the rotational bands and three-quasiparticle states observed in ^{195}Au.

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The neutron-deficient Au nuclei are expected to be soft with respect to γ deformation, and the shape-polarizing effects arising from the valence proton are significant. In the odd-A Au isotopes, the ground-state deformation evolves from prolate shape to triaxial shape while increasing the neutron number [1–3]. In the odd-A Au nuclei with $A \geqslant 187$, the rotational bands associated with the $h_{11/2}$ proton hole were generally observed experimentally, and three-quasiparticle isomers were identified [3–7]. These $h_{11/2}$ bands are interpreted as resulting from the coupling of the $h_{11/2}$ proton hole to the corresponding Hg core [8,9]. In contrast to the rather stable oblately shaped Hg neighbors, the triaxial shapes were suggested for the ^{191,193}Au nuclei [3,6]. Therefore, the high-j $h_{11/2}$ quasiparticle should play an important role in driving the odd-A Au nuclei toward a triaxial shape [3,6]. The present work aims at extending the level scheme of ^{195}Au and studying the systematic features of the rotationally aligned $h_{11/2}$ bands in the odd-A Au nuclei.

The excited states of ^{195}Au were populated via the ^{192}Os(^{7}Li, 4n) reaction. The ^{7}Li beam was provided by the HI-13 Tandem Accelerator at China Institute of Atomic Energy in Beijing (CIAE). The target was an isotopically enriched 1.7 mg/cm^2 ^{192}Os metallic foil with a 1.1 mg/cm^2 carbon backing to stop the recoiling nuclei. The excitation function was measured at beam energies of 34, 38, 42, 44, and 46 MeV, and the optimum beam energy to produce ^{194,195}Au was determined to be 44 MeV. X-γ-t and γ-γ-t coincidence measurements were performed at the optimum energy with a detector array consisting of 12 Compton-suppressed high-purity germanium (HPGe) detectors and two low-energy photon spectrometer detectors. For the 12 HPGe detectors, 5 of them were placed at 40°, 2 at 152°, and 5 at 90° with respect to the beam direction. The energy and efficiency calibrations were made using ^{60}Co, ^{133}Ba, and ^{152}Eu standard sources. Typical energy resolutions were about 2.0–2.5 keV at full width at half maximum for the 1332.5-keV line. To search for the possible isomeric states, the coincidence time window was set to be 400 ns in the measurement. A total of about 9×10^7 γ-γ-t events were accumulated and sorted into a $4k \times 4k$ matrix for off-line analysis. To obtain multipolarity information for γ rays deexciting the oriented states, the coincidence data were sorted into two asymmetric matrices whose x axis is the γ-ray energy deposited in the detectors at any angles and y axis is the γ-ray energy deposited in the detectors at 40° (152°) and 90°, respectively. By gating on the x axis with suitable γ rays, two spectra measured at the two angle positions were obtained. After correcting for the overall detection efficiency of the detectors at each of the two angles and normalizing the two spectra with respect to each other, γ-ray anisotropy $R_{\text{ADO}}(\gamma)$ was deduced from the intensity ratio in the two spectra. In the present geometry, stretched quadrupole transitions are adopted if $R_{\text{ADO}}(\gamma)$ values are larger than unity [an average value of $R_{\text{ADO}}(\gamma) = 1.15 \pm 0.15$ was obtained for the known $E2$ transitions in ^{194,195}Au and ^{194}Pt] and dipole transitions assumed if $R_{\text{ADO}}(\gamma)$ values are less than 1.0.

In the previous work [8], the 318.5-keV $11/2^-$ and 1813.0-keV $21/2^+$ isomers were identified in ^{195}Au, and the 388.0-keV $15/2^- \rightarrow 11/2^-$, 388.0-keV $21/2^+ \rightarrow 19/2^-$, 718.5-keV $19/2^- \rightarrow 15/2^-$, and 659.2-keV $(17/2^-) \rightarrow 15/2^-$ transitions were observed. This provides an important basis for the present work. Assignments of the observed new γ rays to ^{195}Au were based on the coincidences with the known γ rays [8]. A gated spectrum was produced for each of the γ rays assigned to ^{195}Au, and selected coincidence spectra are shown in Fig. 1. Based on the analysis of γ-γ coincidence relationships, a level scheme consisting of 15 new transitions and 10 new levels is established and shown in Fig. 2. The properties of the transitions assigned to ^{195}Au are presented in Table I.

In the present work, the decoupled $\pi h_{11/2}^{-1}$ band is extended up to $I^\pi = 27/2^-$. The weak 282.3-keV transition is in coincidence with the 388.0-, 718.5- and 819.6-keV transitions.

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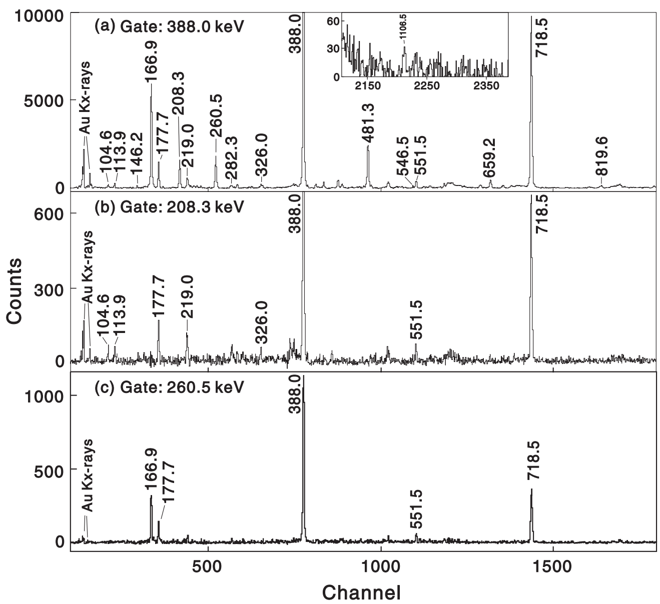

FIG. 1. The γ-ray spectra gated by (a) the 388.0-, (b) 208.3-, and (c) 260.5-keV transitions.

We could not deduce a reliable angular distribution of grays deexciting the oriented states (ADO) ratio for the 282.3-keV transition owing to its weakness, and its $E2$ character is proposed from the systematics of level structure in neighboring nuclei [3,5,6]. The 1106.5-keV transition is found to be in coincidence with the 388.0- and 166.9-keV transitions but not with the 718.5-keV transition. We note that the energy difference between the 1813.0-keV $21/2^+$ and the 706.5-keV $15/2^-$ states is 1106.5 keV, and high-energy $E3$ transitions between the $21/2^+$ and the $15/2^-$ states were observed in the odd-A ^{191,193,197}Au isotopes [7,8]. Therefore, we would assign the weak 1106.5-keV transition as the $21/2^+ \rightarrow 15/2^-$ $E3$ transition. Above the $21/2^+$ isomer, the locations of the 166.9-, 260.5-, 146.2-, 113.9-, 208.3-, 104.6-, and 219.0-keV transitions are firmly established on the basis of the coincidence and energy sum relationships of the transitions involved. The measured $R_{\mathrm{ADO}}(\gamma)$ values indicate that the 166.9-, 260.5-, and 551.5-keV transitions have quadrupole characters. In the odd-A Au isotopes, long-lived $31/2^+$ isomers were generally

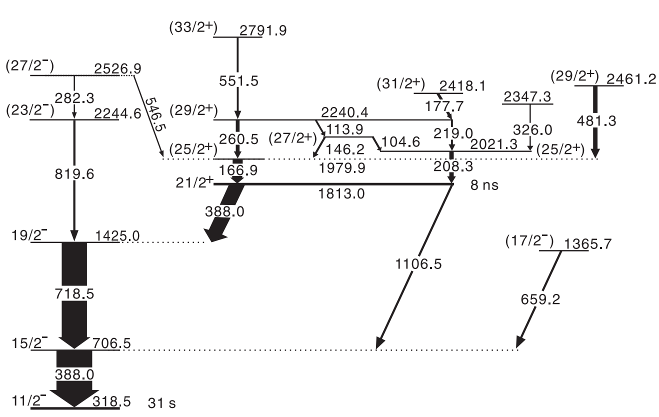

FIG. 2. Level scheme of ^{195}Au deduced from the present work. The widths of the arrows indicate the relative transition intensities.

TABLE I. The γ-ray transition energies, relative intensities, and ADO ratios in ^{195}Au. The ADO ratios for some transitions could not be measured because of their weak intensities.

E_γ(keV)[a]	I_γ[b]	E_i (keV)	$J_i^\pi \rightarrow J_f^\pi$	R_{ADO}
104.6	13	2126.1	$(27/2^+) \rightarrow (25/2^+)$	
113.9	6	2240.4	$(29/2^+) \rightarrow (27/2^+)$	
146.2	2	2126.1	$(27/2^+) \rightarrow (25/2^+)$	
166.9	100	1979.9	$(25/2^+) \rightarrow 21/2^+$	1.16(16)
177.7	24	2418.1	$(31/2^+) \rightarrow (29/2^+)$	0.79(9)
208.3	25	2021.3	$(25/2^+) \rightarrow 21/2^+$	1.16(12)
219.0	11	2240.4	$(29/2^+) \rightarrow (25/2^+)$	1.17(24)
260.5	30	2240.4	$(29/2^+) \rightarrow (25/2^+)$	1.11(11)
282.3	4	2526.9	$(27/2^-) \rightarrow (23/2^-)$	
326.0	3	2347.3		
388.0	>350	706.5	$15/2^- \rightarrow 11/2^-$	1.06(11)
388.0	>126	1813.0	$21/2^+ \rightarrow 19/2^-$	
481.3	52	2461.2	$(29/2^+) \rightarrow (25/2^+)$	1.09(10)
546.5	2	2526.9	$(27/2^-) \rightarrow (25/2^+)$	
551.5	9	2791.9	$(33/2^+) \rightarrow (29/2^+)$	1.36(16)
659.2	17	1365.7	$(17/2^-) \rightarrow 15/2^-$	0.92(12)
718.5	336	1425.0	$19/2^- \rightarrow 15/2^-$	1.14(12)
819.6	10	2244.6	$(23/2^-) \rightarrow 19/2^-$	1.21(15)
1106.5	<2	1813.0	$21/2^+ \rightarrow 15/2^-$	

[a]Uncertainties between 0.1 and 0.5 keV.
[b]Uncertainties between 5% and 30%.

observed [3,5,6]. Based on the structure systematics, we would expect that the state depopulated by the 177.7-keV transition might be the analogous isomer in ^{195}Au. However, the isomeric half-life could not be deduced in the present work owing to its weak population.

To gain an insight into the shape-polarizing effect of the high-j $h_{11/2}$ proton, we have performed total Routhian surface (TRS) calculations using the nonaxial deformed Woods-Saxon potential in the three-dimensional deformation β_2, β_4, and γ space [10]. Figure 3 shows the TRS results for the lowest (−, −1/2) configuration in $^{189-197}$Au at $\hbar\omega = 0.127$ MeV. The minima in TRS plots should correspond to the $\pi h_{11/2}^{-1}$ bands. As shown in Fig. 3, the $\pi h_{11/2}^{-1}$ bands are soft with respect to triaxial and quadrupole deformations, and they prefer negative γ deformation. The calculations indicate that the quadrupole deformation slightly decreases and the triaxial deformation evolves toward oblate shape as the mass number increases. It should be noted that the ground state in the even-even Hg core nuclei tends to have a near oblate shape.

The partial level structures in the odd-A $^{189-195}$Au isotopes are shown in Fig. 4, from which we can see the remarkable similarities. The $\pi h_{11/2}^{-1}$ bands in the odd-A nuclei were systematically observed experimentally, and the low-lying level spacings are very similar with those of the ground-state bands in the corresponding even-even Hg core nuclei [11,12]. Therefore, the $15/2^-$, $19/2^-$, and $23/2^-$ yrast levels in ^{195}Au should be formed by coupling an $h_{11/2}$ proton hole to the 2^+, 4^+, and 6^+ states in the oblately deformed ^{196}Hg core [12]. As shown in Fig. 4, the level spacing between the $27/2^-$ and $23/2^-$ states is quite small, and this might indicate a structure change likely associated with the alignment of $i_{13/2}$ neutron pair or $h_{11/2}$ proton pair. The g factor of the 10^+

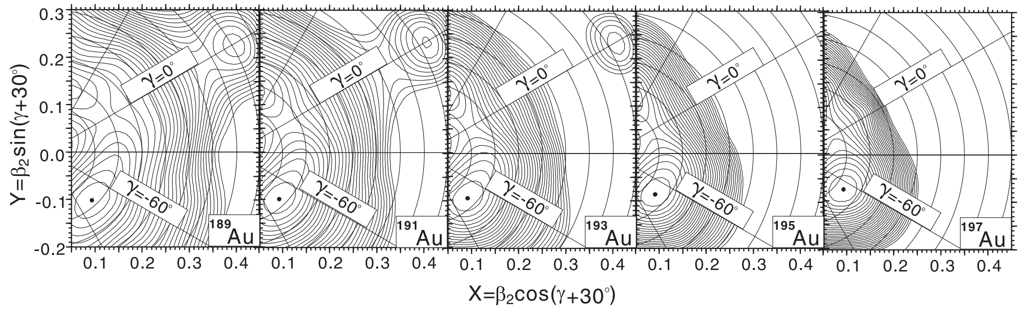

FIG. 3. Total Routhian surfaces at $\hbar\omega = 0.127$ MeV calculated for the lowest $(\pi, \alpha) = (-, -1/2)$ configurations in $^{189-197}$Au. The energy difference between neighboring contours is 100 keV.

state in ^{190,194,196}Hg was measured in the previous work, and the result is in agreement with that expected for the $\nu i_{13/2}^{-2}$ configuration [13–15]. The $27/2^-$ states in the odd-A Au isotopes might be formed by coupling an $h_{11/2}$ proton hole with the 8^+ and 10^+ core states, and therefore have the $\pi h_{11/2}^{-1} \otimes \nu i_{13/2}^{-2}$ configuration.

In the even-even Hg nuclei [11,12], semidecoupled bands built on the 5^- state were systematically observed experimentally. The intrinsic structure of the 5^- state was proposed to be dominated by the two-quasiparticle configuration $\nu i_{13/2}^{-1} \nu j$ (j originating from $p_{3/2}$ or $f_{5/2}$), the high-j quasiparticle being decoupled from the rotational core and the low-j one being strongly coupled to the core. The rotational band built on the $21/2^+$ state, which was formed by coupling an $h_{11/2}$ proton hole to the 5^- state in the neighboring even-even Hg nucleus, has occurred systematically in the odd-A Au nuclei [3,5,6]. As shown in Fig. 4, the band built on the $21/2^+$ state in ^{195}Au follows closely the systematics of the rotational bands based on the $21/2^+$ state in the odd-A Au nuclei [3,5,6]. Therefore, we propose that this band is associated with the $\pi h_{11/2}^{-1} \otimes \nu i_{13/2}^{-1} \nu j$ configuration.

The $31/2^+$ state in ^{189,191,193}Au was identified as a long-lived isomer, and the $\pi h_{11/2}^{-1} \otimes \nu i_{13/2}^{-1} \nu h_{9/2}^{-1}$ configuration was proposed to it [3,5,6]. The excitation energy and decay pattern of the $31/2^+$ state in ^{195}Au fits well into the systematics observed in the odd-A Au nuclei (see Fig. 4), and therefore we propose that this state might be an isomeric state with the configuration of $\pi h_{11/2}^{-1} \otimes \nu i_{13/2}^{-1} \nu h_{9/2}^{-1}$.

In summary, the transitional nucleus ^{195}Au has been produced in the bombardment of the ^{192}Os target with the ^{7}Li projectiles. The previously known level scheme has been extended up to an excitation energy of about 2.8 MeV and spin of $33/2\hbar$. The TRS calculations suggest that the $\pi h_{11/2}^{-1}$ bands in the odd-A nuclei would have triaxial deformations. In comparison with the level structures in the odd-A Au isotopes, configurations have been proposed to the rotational bands and three quasiparticle states observed in ^{195}Au.

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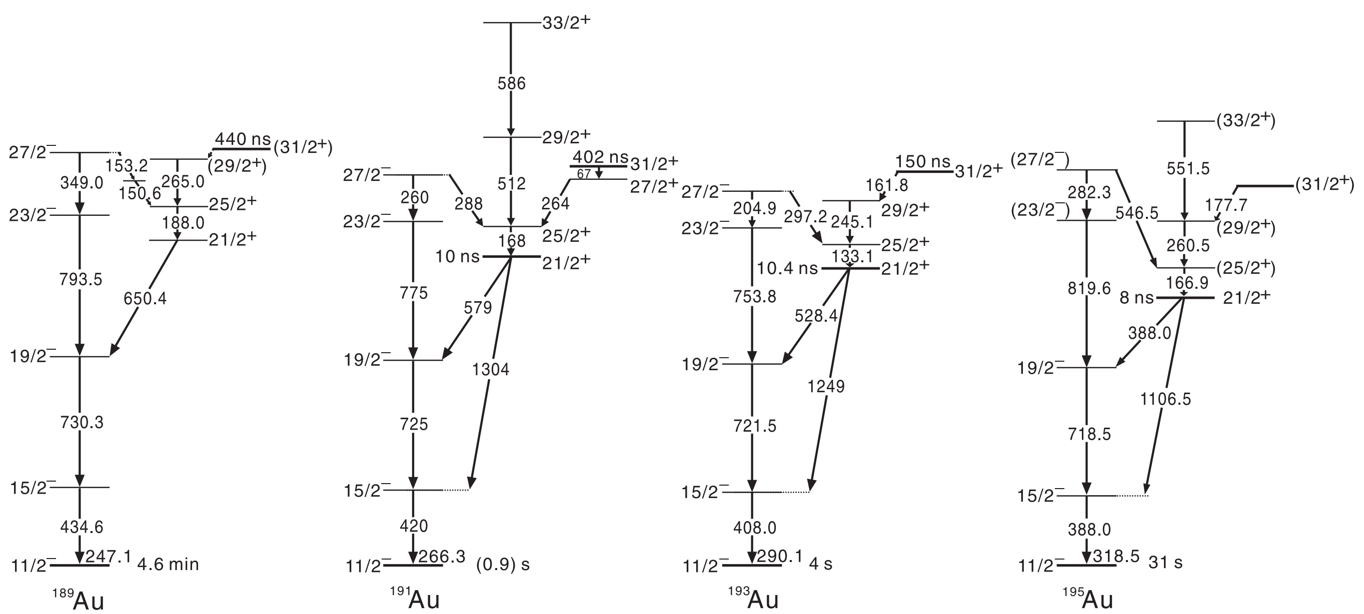

FIG. 4. Partial level schemes of ^{189}Au, ^{191}Au, ^{193}Au, and ^{195}Au. Data are taken from Refs. [3,5,6] and the present work.

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