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Short note

High spin structure of ^{117}I

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Abstract. High-spin states in ^{117}I have been studied via the ^{103}Rh(^{18}O, 4n) reaction at a beam energy of 85 MeV. Many deformed rotational bands built on the proton $h_{11/2}$, $g_{7/2}$, and $g_{9/2}$ orbitals have been identified. Among them, an unfavoured rotational band and a quasi-gamma band based on the $h_{11/2}$ state have been newly observed. Moreover, positive-parity states above $I^\pi = 35/2^+$ reported in the previous work have been rearranged. Several energetically favoured states have been assigned to noncollective oblate states based on various quasiparticle configurations with $\beta_2 \approx 0.18$–0.19 and $\gamma = 60°$.

PACS. 21.10.Re Collective levels – 27.60.+j $90 \leq A \leq 149$

In the light odd-mass I (Z = 53) nuclei (A < 121), the yrast states at low spins follow the systematics of even-mass Xe core states rather than those of Te ones. At higher spins, however, behaviour of the structure exhibits more complexity showing shape coexistence of collective and noncollective states due to competition between collective quadrupole bands and quasiparticle aligned configurations. Indeed, A yrast noncollective oblate state, where the nuclear spin is made up completely from single-particle angular momentum contributions, have been commonly observed at $43/2^-$ in the odd-mass I [1–3]. Such energetically favoured noncollective states have also been seen at various spins in Te nuclei [4,5]. In addition, other interesting properties have been found in ^{119}I [3], which are a well-developed quasi-γ rotational band based on the $h_{11/2}$ orbital and a vibrational band coupled to the even-mass Te core states. Such diversity of structure in ^{119}I inspired us also carry out the present experiment, although high-spin structures of ^{117}I were previously investigated by Waring et al. [2] and Paul et al. [6,7]. In the work, we present new experimental results for the excited states and their properties in ^{117}I.

The level structure has been studied with the ^{103}Rh(^{18}O, 4n) ^{117}I reaction at a beam energy of 85 MeV. The beam was provided by the 12UD tandem accelerator at the University of Tsukuba. The target of ^{103}Rh was a self-supporting foil of 6.8 mg/cm^2 in thickness. The γ-ray spectra were taken with 7 high-purity (HP) Ge detectors with BGO anti-Compton shields. Data were written onto 8-mm tapes (EXABYTE) for events in which two or more HP Ge detectors registered in prompt coincidence. Approximately 120 million events were collected. Multipolarity information was extracted from the data using the method of directional correlation of oriented states (DCO ratios). To this end, the coincidence events were sorted into an asymmetric matrix with energies of γ rays detected in 3 detectors at 37° (or 143°) along one axis and energies of γ rays detected in 4 detectors at 79° (or 101°) along the other axis. The level scheme of ^{117}I deduced from the present work is shown in Fig. 1 together with relative γ-ray intensities. One can see that several new bands have been established in the present work as compared to those in the previous works [2,6,7].

We have identified four decoupled negative-parity bands built on the $11/2^-$ state, which are bands 1–4. Band 1 has been already known in the previous works and at low spins interpreted as resulting from the coupling of an $h_{11/2}$ proton to the neighboring even-mass Xe core states. High spin states greater than $I^\pi = 31/2^-$ have been associated with three quasiparticle states due to the alignment of an $h_{11/2}$ neutron pair. It is noted that the crossings of the two neutrons in $h_{11/2}$ orbital has been delayed that may be interpreted as due to the different deformation driving force between the proton and the neutron $h_{11/2}$ orbitals.

Band 2 was interpreted as coming from from the coupling of the $h_{11/2}$ proton orbital to the γ vibration of the γ–soft even-mass core [2]. In the present work. we suggest that band 2 should be associated with the coupling of the $\pi h_{11/2}$ orbital to the ground band of even-mass Te nuclei. Indeed, this band shows a similar pattern of that seen in the neighboring Te nuclei that have a vibrational structure at low-lying states. Moreover, we observed a new

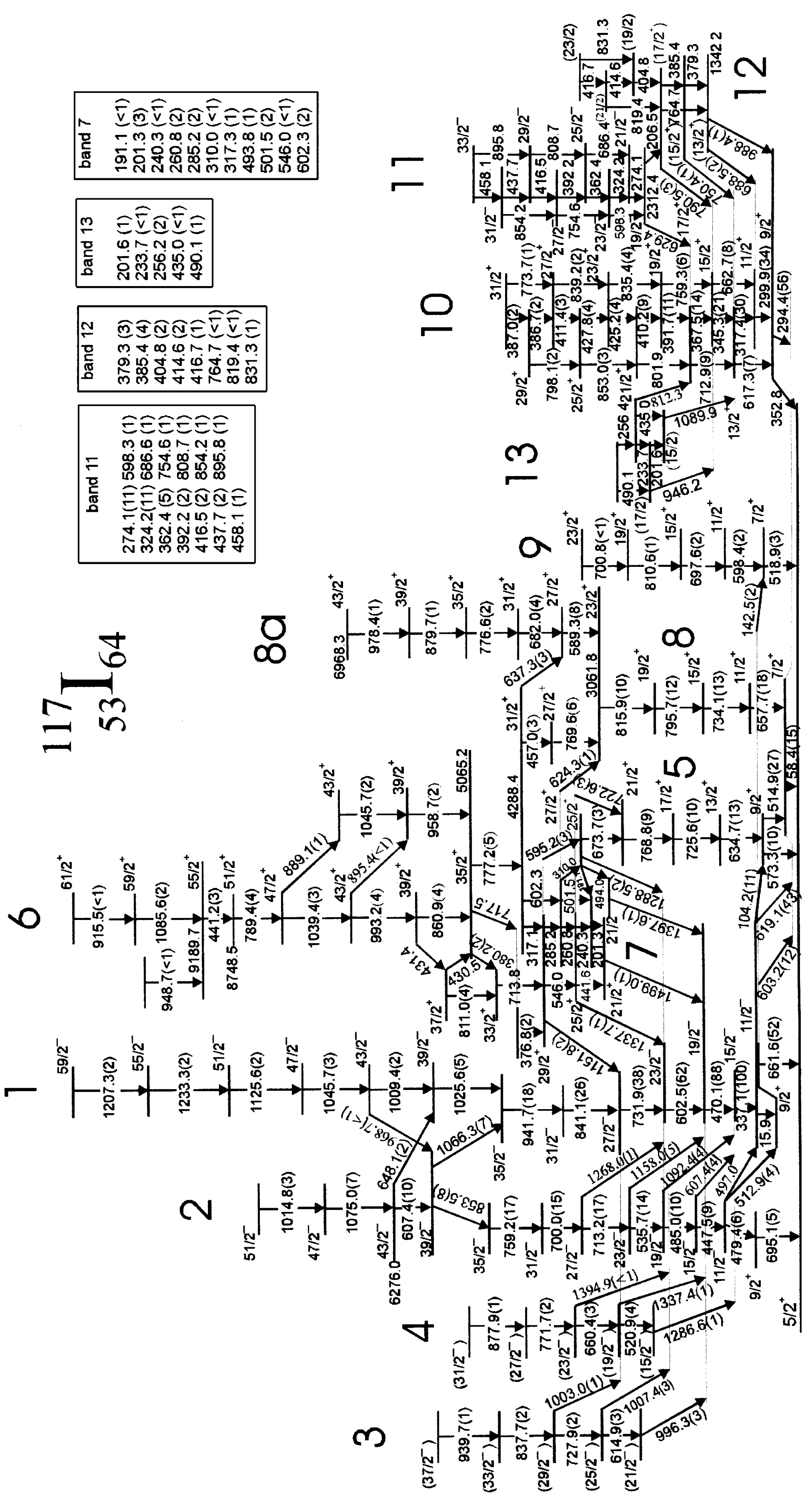

Fig. 1. Level scheme of ^{117}I deduced from the $^{103}Rh(^{18}O, 4n)$ ^{117}I reaction at a beam energy of 85 MeV. γ-ray and excitation energies are given in keV. A number in parenthesis of transition energy is the γ-ray intensity relative to the 337 keV transition. γ-ray energies are accurate to ± 0.2 keV for the transitions with $I_\gamma > 5$ rising to ± 0.4 keV for the weaker transitions. Errors for intensities are estimated to be less than 5% for the transitions with $I_\gamma > 10$ and less than 25% for the weaker transitions

band labelled 4 that can be associated with the quasi-γ rotational band built on the vibrational 2^+ state in the even-mass Xe core. Our result that band 2 should be associated with the coupling of a proton in the $h_{11/2}$ orbital to the Te core states can be supported from the same explanation regarding a similar band seen in ^{119}I [3]. One can see that the $43/2^-$ state in band 2 is drastically lowered in excitation energy comparing to the neighboring states. In order to investigate such energetically favoured states seen in ^{119}I, we performed deformation self–consistent calculations based on the TRS formalism [8,9]. The TRS calculations for $I^\pi = 43^-$ predict a noncollective oblate shape with $\beta_2 \approx 0.18$ and $\gamma = 60°$ based on the fully aligned $\pi[h_{11/2}(g_{7/2})^2]_{23/2^-} \otimes \nu[(h_{11/2})^2]_{10^+}$ configuration. The $39/2^-$ state observed below the $43/2^-$ state may be associated with a partially aligned $\pi[h_{11/2}(g_{7/2})^2]_{23/2^-} \otimes \nu[(h_{11/2})^2]_{8^+}$ configuration. A similar behaviour has also been observed in ^{119}I [3]. Meanwhile, in ^{117}Te and ^{119}Te, such an unusually low-lying state has been found at $I^\pi = 39/2^-$ that has been interpreted as a noncollective oblate state based on the $\pi[(g_{7/2})^2] \otimes \nu[(h_{11/2})^3]$ configuration [4]. It is evident that the $51/2^-$ state in band 2 is energetically favoured as showing a noncollective state. The TRS calculations for this spin predict a noncollective oblate shape with $\beta_2 \approx 0.19$ and $\gamma = 60°$ based on the $\pi[h_{11/2}(g_{7/2})^2]_{23/2^-} \otimes \nu[(h_{11/2})^2(g_{7/2})^2]_{14^+}$ configuration.

Band 3, which was newly observed in the present work, shows a typical rotational structure that transition energies are very close those in the ground band 1. We suggest that this band is the unfavoured signature of the $\pi h_{11/2}[550]1/2^-$ configuration, i.e., signature partner of low-lying states of band 1. The cranked shell model (CSM) calculations [10,11] predict a large signature splitting in $\pi h_{11/2}$ orbital that is consistent with the present experimental result. Such an unfavoured state based on the $\pi h_{11/2}$ orbital in the odd-mass I isotopes was firstly identified in ^{119}I [3].

Band 4 was also newly identified in the present work. As mentioned earlier, this band may be attributed to the coupling of an $h_{11/2}$ proton to the γ bands seen in the neighboring even-mass Xe nuclei. The same structure was also seen in ^{119}I [3].

Band 6 starting at $I^\pi = 35/2^+$ is characterized by a complicated pattern of single- and collective levels connected by quadrupole transitions. The present results for the assignments of transitions and excitation energies are quite different from those obtained by Waring et al. [2]. Considering the coincidence relationship and the γ–ray intensity, our result is more reliable. It can be seen that the $55/2^+$ state is especially low in energy comparing to that of neighboring states. Such unusually low-lying $55/2^+$ state is predicted by the TRS calculations as a noncollective oblate shape with $\beta_2 \approx 0.19$ and $\gamma = 60°$ based on the $\pi[h_{11/2}(g_{7/2})^2]_{23/2^-} \otimes \nu[(h_{11/2})^3 g_{7/2}]_{16^-}$ configuration. The calculations also predict the noncollective oblate state at $I^\pi = 39/2^+$ and $37/2^+$ for the configurations of $\pi[h_{11/2}(g_{7/2})^2]_{23/2^-} \otimes \nu[h_{11/2}g_{7/2}]_{8^-}$ and $\pi[h_{11/2}(g_{7/2})^2]_{23/2^-} \otimes \nu[h_{11/2}g_{7/2}]_{7^-}$, respectively.

Bands 5 and 8 are signature partners build on the $7/2^+$ state. The properties of these bands could be understood if a $g_{7/2}$ proton is coupled to the deformed Xe core states, which is easily explained by the presence of the Fermi energy at or near the $[422]3/2^+$ orbital of the $g_{7/2}$ proton shell. Band 8 has been extended to high spin through a backbend. For the deformation parameter of $\beta_2 \approx 0.18$ and $\gamma = 10°$, which is predicted by the TRS for $\pi g_{7/2}$ ($\alpha = -1/2$) configuration, the cranked shell model calculations indicate a level crossing at $\hbar\omega \approx 0.34$ MeV for the neutron $h_{11/2}$ orbitals. In the plot of experimental spin alignment for bands 8 and 8a as a function of rotating frequency (not shown), we found a sharp crossing at $\hbar\omega \approx 0.34$–0.37 MeV. So band 8a can be interpreted as coming from the three-quasiparticle $\pi[g_{7/2}] \otimes \nu[(h_{11/2})^2]$ configuration. Band 9 built on the $7/2^+$ state was also newly identified in this work. This band may be associated with the favoured signature based on the $\pi[402]1/2^+$ Nilsson orbital.

Band 10 is the strong coupled rotational band that can be interpreted as arising from the excitation of a $g_{9/2}$ proton across the Z = 50 closed shell, namely, two-particle-one-hole (2h-1h) excitation based on the $[\pi(g_{7/2})^2 \otimes \nu(g_{9/2})^{-1}]$ configuration. Band 11 built on the $19/2^-$ state is also the $\Delta I = 1$ coupled rotational band. This band was identified as a positive parity band starting at $I^\pi = 21/2^+$ in the previous work [2], where the 630-keV γ-ray decaying to the $17/2^+$ state in band 10 was assigned to E2 transition. In the present analysis, however, this transition is found to be stretched dipole character. Moreover, we observed a new transition of 206.5 keV with dipole character decaying to band 12. We propose that band 11 should be associated with the $\pi[(g_{7/2})^2(g_{9/2})^{-1}] \otimes \nu[h_{11/2}d_{5/2}]$ configuration. Band 12, in the previous work [2], was assigned to the negative-parity states that could be interpreted as a collective oblate shape with the high-K $h_{11/2}$ configuration. However, the present spin-parity assignment of $I^\pi = 13/2^+$ for this band-head rules out such an explanation. Instead, we suggest that this band should be associated with the coupling of a $g_{9/2}$ proton-hole to the γ vibration. It is noted that similar structures for the above strongly coupled bands 10–12 have also been found in ^{119}I [3].

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