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High-resolution (p,t) study of low-spin states in Pu 240: Octupole excitations, α clustering, and other structure features

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Abstract

© 2018 American Physical Society. Background: Many nuclear-structure features have been observed in actinides in recent decades. In particular, the octupole degree of freedom has been discussed lately after the successful measurement of the BE3;01+→31- reduced transition strength in Ra224. Recent results stemming from γ-spectroscopy experiments and high-resolution (p,t) experiments suggested that strong octupole correlations might be observed for some positive-parity states of actinide nuclei. Purpose: This work completes a series of (p,t) experiments on actinide nuclei by adding the data on Pu240. The (p,t) experiments allow us to study low-spin states up to Jπ=6+. Besides two-nucleon transfer cross sections, spin and parity can be assigned to excited states by measuring angular distributions, and several rotational bands are recognized based on these assignments. Methods: A high-resolution (p,t) experiment at Ep=24 MeV was performed to populate low-spin states in the actinide nucleus Pu240. The Q3D magnetic spectrograph of the Maier-Leibnitz Laboratory (MLL) in Munich (Germany) was used to identify the ejected tritons via dE/E particle identification with its focal-plane detection system. Angular distributions were measured at nine different Q3D angles to assign spin and parity to the excited states based on a comparison with coupled-channel distorted-wave Born approximation calculations. Results: In total, 209 states have been excited in Pu240 up to an excitation energy of 3 MeV. Many previously known states have also been observed and their spin-parity assignments were confirmed. However, many of the populated states have been seen for the first time, e.g., 15 new and firmly assigned Jπ=0+ states. In addition, all low-spin one-octupole phonon excitations, i.e., Kπ=0-,1-,2-,3-, could be observed and a new candidate for the K=3 projection is proposed. Furthermore, the double-octupole or α-cluster structure of the 02+ state in Pu240 has been studied in more detail. It is shown that the 02+ state in Th230 has a distinctly different structure. In addition, strongly excited 1- states have been observed at 1.5 and 1.8 MeV in Pu240. The present study suggests that similar states might be observed in Th230. Conclusions: At least two different and distinct structures for Jπ=0+ states are present in the actinides. These are pairing states and states with enhanced octupole correlations. We have shown that it is crucial to consider negative-parity single-particle states being admixed to some Kπ=02+ rotational bands to understand the α-decay hindrance factors and enhanced E1-decay rates. Based on our analysis, we have identified the double-octupole or α-cluster Kπ=0+ candidates from Ra224 to Pu240.

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