Properties of the β-delayed proton decay of ^{146}Ho*

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Abstract The proton-rich isotope ^{146}Ho was produced via the fusion-evaporation reaction ^{92}Mo (^{58}Ni, 3p1n). The β-delayed proton decay of ^{146}Ho was studied by proton-γ coincidence measurements using a He-jet tape transport system. The γ-transitions in ^{145}Tb following the proton emissions were observed, and the β-delayed proton branching ratios to the final states in the grand-daughter nucleus ^{145}Tb were determined. According to the relative branching ratios, the ground-state spin of ^{146}Ho has been proposed and the possible configuration discussed.

Key words He-jet tape transport system, coincidence measurement, β-delayed proton decay

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The very neutron-deficient isotope ^{146}Ho was identified by S. Z. Gui et al. in 1982 [1]. Although the β^++EC decay properties of ^{146}Ho were well investigated experimentally, its ground-state spin and parity has not been determined. For the near spherical odd-odd nuclide ^{146}Ho with a proton number of 67 and a neutron number of 79, the ground state is expected to be formed by coupling the valance proton in the $1h_{11/2}$ orbital with the neutron in the $2d_{3/2}$ or $1h_{11/2}$ orbital. Based on the analysis of the β^++EC decay spectrum [1], the spin and parity of 9^+, 10^+ or 11^+ was proposed to be the ground state of ^{146}Ho. By fitting the measured energy spectrum of β-delayed protons with a statistical-model [2], 6^- was suggested to be the ground state of ^{146}Ho. Moreover, Möller et al. [3] predicted the spin and parity of 1^- for the ground state of ^{146}Ho. Therefore, the spin and parity of the ground state in ^{146}Ho is uncertain. As we know, for the β-delayed proton decay precursor ^{Z}A, the proton decay branching ratios to the final states in the grand-daughter nucleus $^{Z-2}A-1$ can provide important information about the ground state spin and parity of the precursor ^{Z}A. In this paper, it is our aim to study the β-delayed proton decay of ^{146}Ho, and to determine the ground state spin and parity.

The nuclide ^{146}Ho was produced via the ^{92}Mo (^{58}Ni, 3p1n) reaction. The ^{58}Ni^{18+} beam was provided by the Sector-Focusing Cyclotron at the Institute of Modern Physics, Lanzhou, China. The beam energy of 383 MeV, at which energy the yields of ^{146}Ho were large, was chosen. Two self-supported isotopically-enriched ^{92}Mo targets of 2.0 mg/cm^2 thickness each were used. The target chamber was filled with helium gas at a pressure of about 100 kPa. The two targets were uniformly mounted on a copper wheel surrounded by a cooling device. The target wheel rotated 180° once every 10 min. The ^{58}Ni^{18+} beam passed through a 2.18 mg/cm^2 thick Havar window and 4.0 cm of helium gas, and then bombarded the targets. The beam intensity was about 0.5 eμA. We used a He-jet in combination with a tape transport system to move the radioactivity into a shielded counting place for proton-$\gamma(x)$-$\gamma(x)$-t coincidence measurements periodically. The irradiation

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time, tape moving time, waiting time and accumulation time were 2.04, 0.16, 0.04, and 2.0 s, respectively. $PbCl_2$ was used as an aerosol at 425 ℃. Two HPGe detectors were used for $\gamma(x)$ measurements, and located on opposite sides of the tape. Protons were detected by a 350 μm thick totally depleted silicon surface barrier detector, which was placed between the tape and one of the HPGe detectors.

The precursor ^{146}Ho was identified by the coincidence between the β-delayed protons and the γ transitions depopulating the low-lying states in the grand-daughter nuclide ^{145}Tb. The low-lying transitions in ^{145}Tb were well known experimentally [4]. The measured γ-ray spectrum gated on protons with energies from 2.2 to 6.5 MeV is shown in Fig. 1. All of the evident transitions shown in Fig. 1, except for the 511 keV γ peak, should originate from the β-delayed proton decays [5–7]. These transitions are associated with the respective β-delayed proton decay precursors, as indicated in Fig. 1 [1, 4, 8–10].

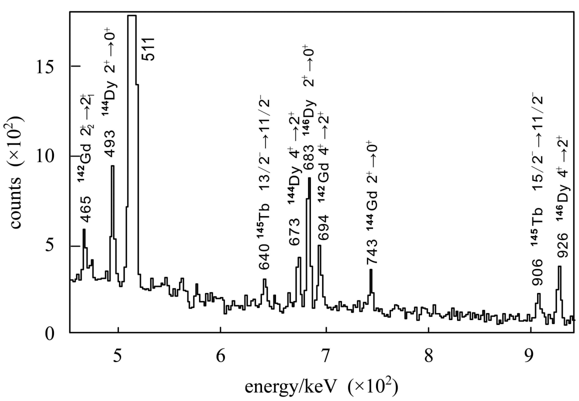

Fig. 1. The γ spectrum gated on the delayed protons with energies from 2.2 to 6.5 MeV.

The 640 keV and 906 keV γ peaks were assigned to the $13/2^- \to 11/2^-$ and $15/2^- \to 11/2^-$ transitions in the daughter nucleus ^{145}Tb [4] of the proton emitter ^{146}Dy produced via the EC/β^+ decay of ^{146}Ho. The decay scheme of ^{146}Ho, deduced from the present work, is shown in Fig. 2. The proton energy spectrum gated on the 640 keV line and the time spectrum of the 640 keV transition gated by protons are shown in Fig. 3(a) and Fig. 3(b), respectively. The component with energy lower than 2.2 MeV in the spectrum was attributed to the pileup of positrons in the silicon detector. The mean proton energy of the spectrum is about 4.0 MeV. The half-life of ^{146}Ho deduced in the present work was (2.8±0.5) s. This value is consistent with the results of (3.1±0.5) s by Wilmarth et al. [2, 11], (3.6±0.3) s by K. S. Toth et al. [12] and (3.9±0.8) s by S. Z. Gui et al. [1].

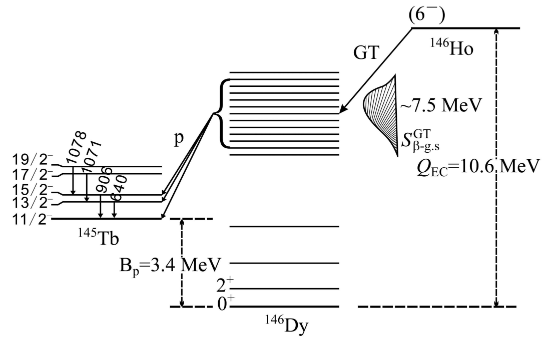

Fig. 2. Schematic representation of β-delayed proton decay of ^{146}Ho. The γ transitions are labeled with their energies in keV.

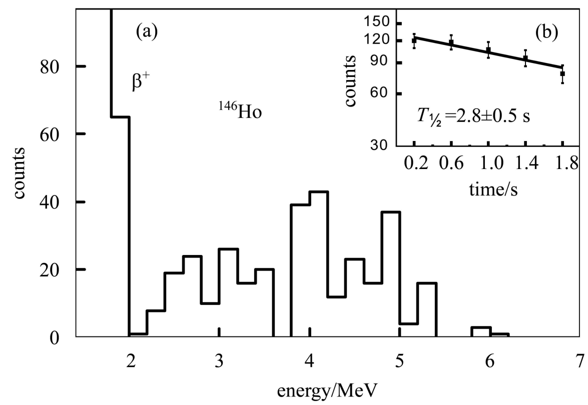

Fig. 3. (a) The energy spectrum of β-delayed protons gated on the 640 keV γ peak. (b) The time spectrum of the 640 keV transition gated by protons.

In this mass region, β-delayed proton decays mainly from the states populated by the allowed Gamov-Teller transitions of the precursor, and the relative proton branching ratios to the different states in the grand-daughter nuclide, are sensitive to the ground-state spin of the precursor. The relative proton branching ratio to the $13/2^-$ and $15/2^-$ in ^{145}Tb was determined to be about 0.9. We have not observed the $17/2^- \to 13/2^-$ and $19/2^- \to 15/2^-$ transitions in ^{145}Tb, and the branching of β-delayed proton decays to the $17/2^-$ and $19/2^-$ states in ^{145}Tb should be very small. Therefore, the observed relative branching ratios to the different states in ^{145}Tb favor the spin assignment of 6^- by Wilmarth [2], other than 10^+ or 1^- [1, 3]. In this case, the ground-state of ^{146}Ho might be associated with the configuration of $\pi h_{11/2} \otimes \nu d_{3/2}$. The states in the $|\,\pi h_{11/2} \otimes \nu d_{3/2};\, J\rangle$ multiplet are two-quasiparticle states with their energies and energy spacings determined by the interaction between the $h_{11/2}$ proton particle and the $d_{3/2}$ neutron hole. The particle-hole interaction follows the $J_{\max} - 1$ rule [13–15]. The 7^- state, the highest-spin member in this multiplet, is located generally higher in energy than the other states. The 6^- state, which has the next to highest spin in the $\pi h_{11/2} \otimes \nu d_{3/2}$ multiplet, is low in energy. Therefore, the ground-state in ^{146}Ho might have the spin and parity of 6^-.

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