β decays of the heaviest $N = Z - 1$ nuclei and proton instability of ^{97}In[†]

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Interesting nuclear structure phenomena can be observed at the limits of neutron or proton binding, providing sensitive probes of shell evolution and/or collective behaviors. Studies have found the doubly magic ^{100}Sn to be stable against proton emission, confirming the robustness of the N, $Z = 50$ shells. Searches for even more neutron-deficient nuclei below ^{100}Sn resulted in a discovery of new isotopes, while also reaching the proton dripline for Rh and Ag isotopes.[1)]

From a decay spectroscopy experiment at the RIBF, half-lives, β-decay endpoint energies, and β-delayed proton emission branching ratios of $N = Z - 1$ nuclei ^{91}Pd, ^{95}Cd, ^{97}In and ^{99}Sn were measured with the wide-range active silicon strip stopper array for β and ion detection[2)] (WAS3ABi). The results, summarized in Table 1, are consistent with β decays of mirror nuclei containing a mixture of Gamow-Teller and Fermi decay components.

The apparent stability of ^{97}In against proton emission was investigated. Based on the deficit in the β-decay amplitude of the parent nucleus, an isomeric state in ^{97}In decaying to ^{96}Cd via one-proton emission was proposed. Although this decay branch has not been detected directly, the observation of a γ-ray transition belonging to the β decay of ^{96}Cd was a supporting evidence for the proton-emitting isomer. The missing proton events were hypothesized to have occurred in a time range between the ions' flight through the BigRIPS and ZeroDegree separators (~600 ns) and the 600-μs deadtime of WAS3ABi.

From the shell model perspective, ^{97m}In is formed by promoting a $\pi 1p_{1/2}$ proton into the $\pi 0g_{9/2}$ orbital, leaving an unpaired proton in the $\pi 1p_{1/2}$ orbital and resulting in a spin-parity of $(1/2^-)$. The large spin difference and parity change suppress a γ-ray decay branch to the $(9/2^+)$ ground state. Experimental half-life limits on the isomer were converted into a hypothetical proton energy range through a theory on proton emission.[3)] As shown in Fig. 1, the lower angular momentum barrier for proton emission from the $\pi 1p_{1/2}$ orbital compared to the $\pi 0g_{9/2}$ orbital would facilitate proton emission from the isomer. This result is consistent with a few mass models which predict ^{97}In to undergo β decay as opposed to proton emission.

Table 1. Half-lives, β-decay endpoint energies, log ft values and β-delayed proton emission branching ratios of ^{91}Pd, ^{95}Cd, ^{97}In and ^{99}Sn.

Nucleus	$T_{1/2}$ (ms)	Q_{EC} (MeV)	log ft	$b_{\beta p}$ (%)
^{91}Pd	32(3)	11.8(22)	3.4(5)	$3.0^{+1.1}_{-0.9}$
^{95}Cd	32(3)	10.2(17)	3.1(5)	$4.5^{+1.2}_{-1.0}$
^{97}In	28(5)	10.0(30)	3.0(9)	$1.7^{+1.7}_{-0.8}$
^{97m}In	1.3–230 μs			
^{99}Sn	24(4)	14.7(36)	3.8(7)	$3.9^{+3.4}_{-1.7}$

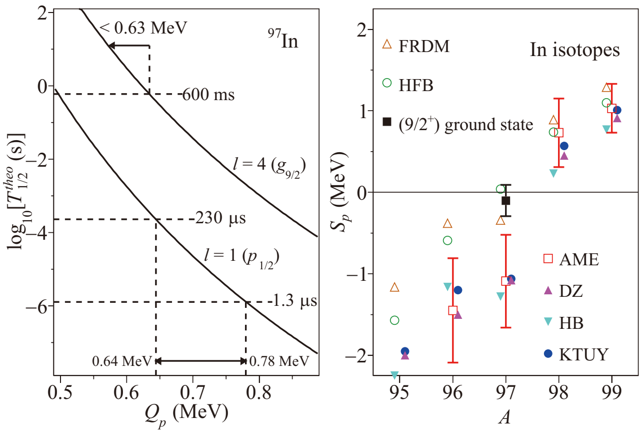

Fig. 1. Left: theoretical $T_{1/2}$ as a function of emitted proton energy Q_p and orbital angular momentum l. Right: experimental proton separation energy S_p of the ground state of ^{97}In compared with different mass predictions.[4–9)]

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