Discovery of ^{72}Rb: A nuclear sandbank beyond the proton drip line†

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We have discovered two new isotopes, ^{72}Rb and ^{77}Zr, around the proton drip line by using the BigRIPS separator at the RIKEN RI Beam Factory. ^{73}Rb, which is an unbound nuclide, was not observed. The observation of ^{72}Rb, which is an odd-odd nuclide and beyond the unbound nuclide ^{73}Rb, shows the diffuseness of the proton drip line and a possibility of "sandbanks" beyond it.

Proton-rich radioactive isotopes (RI) with atomic numbers Z = 35–40 were produced from a 345-MeV/nucleon 30–35 pnA ^{124}Xe^{52+} beam impinging on a 4-mm-thick Be target by projectile fragmentation. We performed the particle identification (PID) by deducing Z and the mass-to-charge ratio, A/Q, of the fragments based on the TOF-$B\rho$-ΔE method[1] using the standard detectors in the second stage of the BigRIPS and F11IC.

The Z vs A/Q PID plot is shown in Fig. 1. One event of ^{77}Zr and 14 events of ^{72}Rb were clearly observed, while ^{73}Rb was not observed. Assuming yield systematics of the neighboring nuclei around ^{73}Rb and its TOF value, the upper limit of the half life was deduced to be 81 ns, which is consistent with the previous result in Ref. 2). The half life of ^{72}Rb was deduced to be 103(22) ns.

The energies of the emitted protons, E_p, were estimated from the half lives of these proton decays by using the formalism of proton emission from deformed nuclei in Refs. 5, 6). In the ^{72}Rb case, a $5^+ \rightarrow 5/2^-$ proton decay with E_p = 800–900 keV was suggested, assuming mirror symmetry in the spin-parity. However, we cannot explicitly exclude the possibility of a transition of the $9^+ \rightarrow 9/2^+$ isomeric state with a broken mirror symmetry. The upper limit of the half life of ^{73}Rb leads to $E_p > 600$ keV, assuming a $3/2^-$ ground state from the mirror nuclide. These E_p values agree well with the values predicted from the atomic mass evaluation.[7,8]

We have estimated the contribution of ^{73}Rb to the two-proton bypass of ^{72}Kr, which is a waiting point in the rapid-proton process in an X-ray burst. From $E_p > 600$ keV in ^{73}Rb, no two-proton capture occurs, implying that ^{72}Kr is a strong waiting point in this nucleosynthetic network.

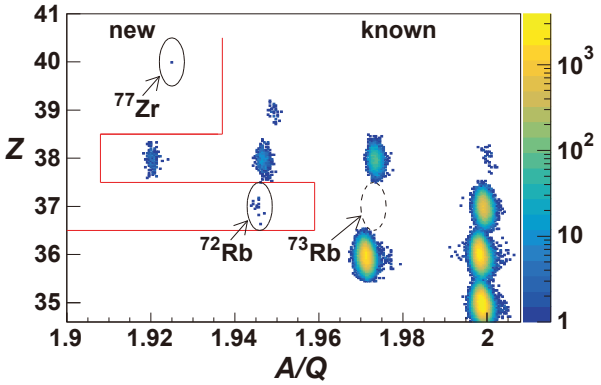

Fig. 1. Z versus A/Q PID plot. The solid lines indicate the limits of known isotopes as of September 2017. ^{73}Rb was evaluated to be a known isotope.[3] A proton-unbound excited state was observed by a beta-delayed proton decay of ^{73}Sr.[4]

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