Precision mass measurements of proton-rich nuclei in A ∼ 60−80 region with the multireflection time-of-flight mass spectrograph

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Nuclear masses of nuclei near the proton drip line up to ^{100}Sn are crucial in determining the *rp*-process pathway which drives explosive astronomical phenomena called type I X-ray bursts (XRB). In order to compare different XRB models meaningfully, the relative mass uncertainties must be improved. Precisions of the order of $\delta m/m \lesssim 10^{-7}$ are necessary for current *rp*-process calculations[1)]. Half lives of the key nuclei in the *rp*-process are of the order of several tens to several hundreds of milliseconds. The multireflection time-of-flight mass spectrograph (MRTOF) satisfies the experimental requirements for these conditions[2)].

We performed mass measurements of the proton-rich nuclei in the A ∼ 60−80 region by utilizing the MRTOF combined with a gas-filled recoil ion separator GARIS-II[3)] via a gas-cell and an ion transport system. To produce the proton-rich nuclei the fusion-evaporation reaction ^{nat}S(^{36}Ar,X) was used. In this reaction, it was expected that the inadequate separation in GARIS-II between the evaporation residues and the primary beam would lead to breakage of the gas cell and the GARIS-II bulkhead thin mylar windows due to irradiation damage. Therefore, we installed two independent beam stoppers[4)]. We also installed a double-layered plastic scintillator combined with copper energy degraders to suppress the low energy β-rays ($E_\beta \lesssim 4$ MeV) at the GARIS-II focal plane for the β-activity search. The energy and maximum intensity of the ^{36}Ar^{10+} beam were 3.30 MeV/nucleon and 3 particle μA, respectively. The average target thickness of ^{nat}S$_2$Mo on Ti backing was 1.9 mg/cm^2.

Figure 1 shows the intensity distribution of β-activities as a function of magnetic rigidity. Mass measurements were performed with two different GARIS-II settings, $B\rho = 0.86$ Tm and $B\rho = 1.01$ Tm. The settings corresponded, respectively, to the sulfur reaction products and unexpected reaction products on the titanium backing. We found two dozen isotopes in the time-of-flight spectra of the MRTOF with clear peaks. The nuclear masses were determined by the single-reference method; thus, in each isobaric series, we utilized an isotope as a mass reference. The summary of the preliminary results is shown in Fig. 2.

We successfully measured nuclear masses with the required precision under the worse separation condition in GARIS-II. We must now proceed to the more proton-rich side to improve the understanding of the *rp*-process in XRBs.

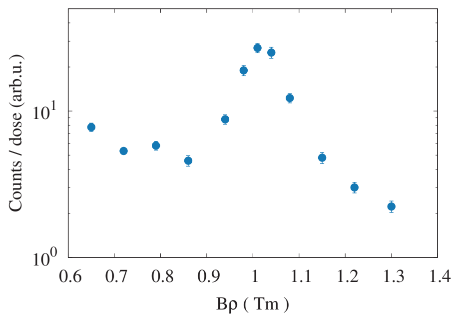

Fig. 1. Intensity distribution of β-activities as a function of magnetic rigidity.

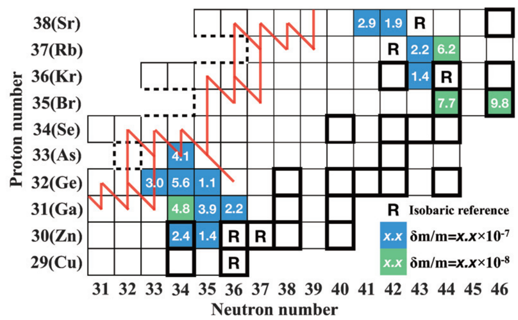

Fig. 2. Summary of the mass measurements. The bold-line boxes indicate the stable isotopes. The dashed lines indicate the proton drip line. The color-coded boxes indicate the mass precision of measurements: a precision of 10^{-7} is indicated by blue and a precision of 10^{-8} is indicated by green. The isotopes labeled "R" are used as isobaric references. The red line represents the *rp*-process pathway, which has a mass fraction greater than 10%[5)].

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