Mass measurements of proton-rich nuclei in the vicinity of ^{84}Mo

S. Kimura,[*1] M. Wada,[*1] C. Fu,[*2,*3] N. Fukuda,[*2] Y. Hirayama,[*1] D. S. Hou,[*1,*3] S. Iimura,[*1,*4] H. Ishiyama,[*2] Y. Ito,[*5] S. Kubono,[*2] K. Kusaka,[*2] S. Michimasa,[*2] H. Miyatake,[*1] S. Nishimura,[*2] T. Niwase,[*6] M. Ohtake,[*2] V. Phong,[*2] M. Rosenbusch,[*2] H. Schatz,[*7] P. Schury,[*1] Y. Shimizu,[*2] H. Suzuki,[*2] A. Takamine,[*6] H. Takeda,[*2] Y. Togano,[*2] Y. X. Watanabe,[*1] W. D. Xian,[*1,*3] Y. Yanagisawa,[*2] T. T. Yeung,[*2,*8] M. Yoshimoto,[*2] and S. Zha[*2,*3]

Nuclear mass data are important physical quantities for revealing the astrophysical nucleosynthesis processes. The rapid-proton capture process (*rp*-process) has been known as the dominant nuclear reaction process driving type I X-ray bursts, one of the candidates for the origin of the p-nuclei. However, the current nuclear mass data are insufficient for performing accurate *rp*-process calculations and are a major source of their non-negligible uncertainties.

Here, we report the mass measurements of the proton-rich nuclei in the vicinity of ^{84}Mo, one of the key nuclides in the *rp*-process. The experiment was performed with the ZD-MRTOF setup.[1] The measured proton-rich unstable nuclei were produced via the fragmentation reaction of a 345 MeV/nucleon ^{124}Xe beam. They were stopped and converted to extremely low-energy ions using the cryogenically cooled helium gas cell (HeGC) behind the ZeroDegree spectrometer. The ions extracted from the HeGC were transported to a planar-geometry radiofrequency quadrupole trap, an injector for the MRTOF-MS. Thereafter, their time-of-flight (TOF) spectra were measured with the MRTOF-MS. A β-TOF detector, which enables the simultaneous measurement of the TOF signals and the β-decay events, was used as an ion detector of the MRTOF-MS.

The measurements were conducted for the doubly charged A = 88, 84, 83, 79, and 78 isobar series, and 14 ion species, including the molecules of the stable isotopes, were identified in the measured TOF spectra. The peak of ^{78}Y, which has an excitation energy unknown, long-lived isomeric state, was found among them. Based on the β-decay information correlated to the TOF events and the efficiency of the measurements, we have concluded that the observed peak of ^{78}Y is that of the isomeric state.

The observed ion masses were determined using the single mass reference method. Figure 1 shows the obtained mass excess values as the difference between the Atomic Mass Evaluation 2020 (AME20) values. In this study, the masses of ^{88}Ru, ^{84}Mo, and ^{78}Y^{m} were determined for the first time. For ^{83}Nb, the uncertainty of its mass excess value was reduced to 9.6 keV from the literature value of 162 keV: the mass precision improved by a factor of 17. A disagreement with the literature value was found for ^{79}Y. The present adopted value was taken from the mass measurement study with the CSRe[2] and is 181 keV heavier than the result of this work. This difference can be accounted for if an unknown, short-lived isomeric state in ^{79}Y exists.

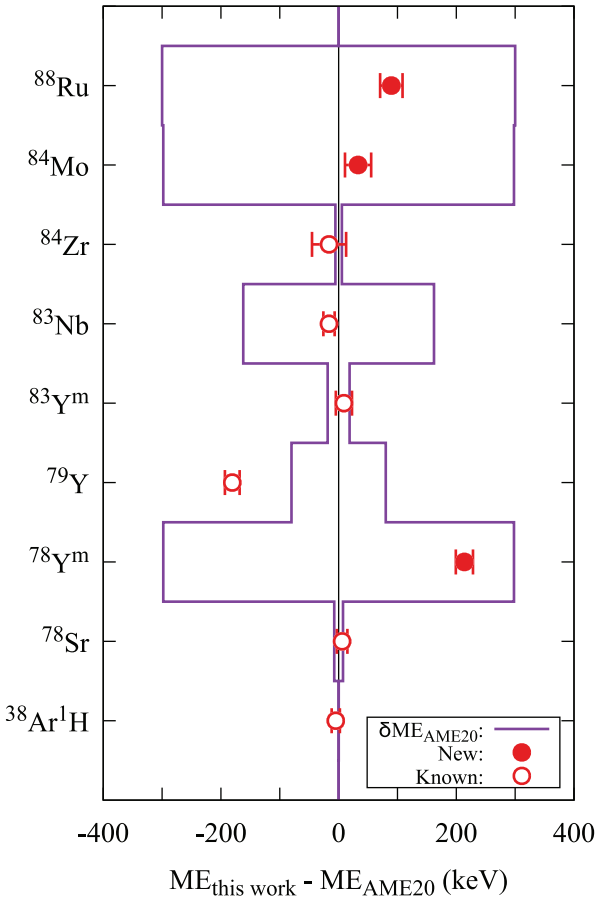

Fig. 1. Comparison between the present measurement results and AME20 values. The purple lines indicate the uncertainties of the evaluations in AME20. The filled cycles represent the masses determined for the first time in this study. Note that ^{78}Y^{m} is plotted as the difference from that in the literature, the extrapolation value of its ground state.

*1 Wako Nuclear Science Center (WNSC), IPNS, KEK
*2 RIKEN Nishina Center
*3 Department of Physics, The University of Hong Kong
*4 Department of Physics, Rikkyo University
*5 Advanced Science Research Center, Japan Atomic Energy Agency
*6 Department of Physics, Kyushu University
*7 Department of Physics and Astronomy and FRIB, MSU
*8 Department of Physics, University of Tokyo

References
1) M. Rosenbusch *et al.*, Nucl. Instrum. Methods Phys. Res. A **1047**, 167824 (2023).
2) Y. Xing *et al.*, Phys. Lett. B **781**, 358 (2018).

DOI:10.34448/RIKEN.APR.58-148