Direct high-precision mass measurements of octupole-deformed nuclei with an MRTOF mass spectrograph

Y. Ito,[*1] M. Wada,[*1,*2] P. Schury,[*2] M. Rosenbusch,[*1] D. Kaji,[*1] K. Morimoto,[*1] H. Haba,[*1] Y. Hirayama,[*2] S. Kimura,[*3] H. Koura,[*1,*4] M. MacCormick,[*5] H. Miyatake,[*2] J.Y. Moon,[*2,*6] K. Morita,[*1,*7] M. Mukai,[*3] I. Murray,[*1,*5] T. Niwase,[*7] K. Okada,[*8] A. Ozawa,[*1,*3] M. Reponen,[*1] A. Takamine,[*1] T. Tanaka,[*1,*7] H. Wollnik,[*9] S. Yamaki,[*1,*10] and Y.X. Watanabe[*2]

Atomic mass is a global property that reflects the net result of all interactions in the atom. Information concerning nuclear structure can be derived by examining the binding energies and is particularly important for nuclear structure studies. The evolution as a function of proton or neutron number, often used the trend of two neutron separation energy (S_{2n}), provides information about even microscopic effects such as nuclear deformation. Theoretically, Möller et al.[1)] showed that octupole contributions to the binding energy and region of octupole deformation in heavy nuclei are distributed around $Z = 85$–94 and $N = 130$–137.

We recently performed direct mass measurements of ^{223,224}Th and ^{224}Pa, which are located in the region. The radioactive ions (RI) were produced via a fusion-evaporation reaction of ^{208}Pb/^{209}Bi(^{18}O, xn) at a bombarding energy of $E_{\rm lab}^{\rm target} = 86$ MeV and transported by the gas-filled recoil ion separator GARIS-II. The RI were then transported to a multi-reflection time-of-flight mass spectrograph (MRTOF) after being thermalized in a cryogenic helium gas cell at 90 K. The MRTOF measurements were performed with a concomitant referencing method[2)] and the reference ions of ^{133}Cs$^+$ were used for both time-of-flight drift compensation and mass reference. By cooling the gas cell at 90 K, contaminant molecular ions were greatly suppressed; therefore, we could obtain quite a clean spectrum with ^{223,224}Th^{16}O^{++} and ^{224}Pa^{16}O^{++} (Fig. 1). Using times-of-flight for the RI and reference ions, we determined the masses using a single-reference analysis method[3)] and computed mass excesses and mass deviations from AME2012.[4)] The mass deviations were computed to be $\Delta m(^{223}\mathrm{Th})$ = -124(24) keV/c^2, $\Delta m(^{224}\mathrm{Th})$ = -130(100) keV/c^2, and $\Delta m(^{224}\mathrm{Pa})$ = -36(35) keV/c^2, respectively. We found a significantly large deviation for ^{223}Th. The mass of ^{223}Th was evaluated by α decay Q-values along the fast multiple α decay to ^{207}Pb. We guess that some α decay goes through an unknown excited state or mis-identification of α peak. Using the measured masses, the S_{2n} for ^{223,224}Th become larger than AME2012 and enhanced a kink at $N = 133$ (Fig. 2). This may indicate an enhancement of octupole deformation in this region.

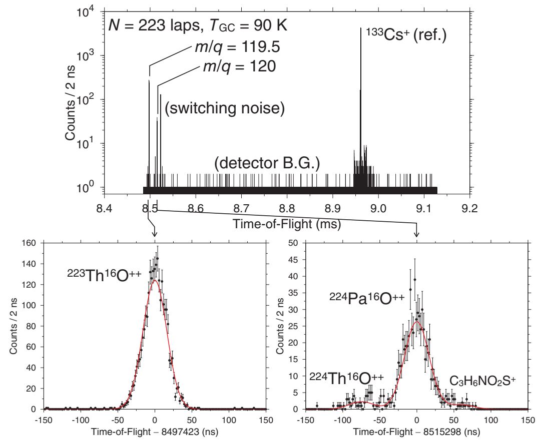

Fig. 1. (top) Full-range time-of-flight spectrum at 223 laps. RI and reference peaks are only seen on a low-rate detector background. (bottom) Enlarged spectra in the $m/q = 119.5$ and 120 regions with a Gaussian fit.

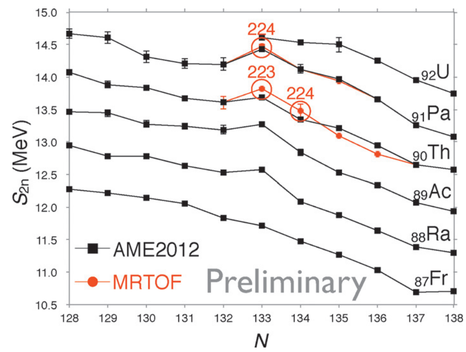

Fig. 2. S_{2n} plot in the region of this work. Black squares show AME2012 and red circles show MRTOF data.

References
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*1 RIKEN Nishina Center
*2 Wako Nuclear Science Center (WNSC), Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK)
*3 Department of Physics, University of Tsukuba
*4 Advanced Science Research Center, Japan Atomic Energy Research Institute (JAEA)
*5 Institut de Physique Nucléaire, Orsay
*6 Institute for Basic Science
*7 Department of Physics, Kyushu University
*8 Department of Physics, Sophia University
*9 Department of Chemistry and Biochemistry, New Mexico State University
*10 Department of Physics, Saitama University