Atomic masses of intermediate-mass neutron-deficient nuclei with sub-ppm precision via multireflection time-of-flight mass spectrograph†

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

Accurate, high-precision nuclear mass data around $N = Z$ line are very important in several fields, *e.g.*, *rp*–process and unitarity of the CKM matrix. The half lives of their key nuclei are of the order of several tens to several hundreds of milliseconds. The multireflection time-of-flight mass spectrograph (MRTOF-MS)[1] has an advantage in the mass measurements of these short-lived nuclei. However there are no actual results of on-line MRTOF-MS measurements with the required precision, $\delta m/m \lesssim 10^{-8}$, so far.

We demonstrated high-precision mass measurements of ^{63}Cu, $^{64-66}$Zn, $^{65-67}$Ga, $^{65-67}$Ge, ^{67}As, ^{78,81}Br, ^{79}Kr, ^{80,81}Rb, and ^{79,80}Sr utilizing MRTOF-MS combined with the gas-filled recoil ion separator GARIS-II.[2] Two different fusion-evaporation reactions—$^{\rm nat}$S(^{36}Ar, X) and $^{\rm nat}$Ti(^{36}Ar, X)—were used for producing these nuclides. The masses of these nuclides were determined by the single reference method using isobaric references of well-known mass.

The results are summarized in Fig. 1. There are some inconsistencies with the 2016 Atomic Mass Evaluation (AME16) values. In order to understand them, two reliability requirements were imposed on the mass values: (i) there must be no contamination with unresolvable isomers, (ii) there are no undue influences of intense neighboring peaks. Among the masses that were inconsistent with AME16, two were found to meet the reliability criteria, and we propose new mass excess values: ME(^{67}Ge) = −62675.2(46) keV and ME(^{81}Br) = −77955.4(53) keV. These mass values were previously deduced through indirect measurements. This result reinforces the need for direct mass measurements of all nuclides, even for stable isotopes, if their masses were previously evaluated by indirect techniques.

The relative mass precision in the present study spans the range from $\delta m/m = 4.1\times10^{-7}$ to 3.5×10^{-8}.

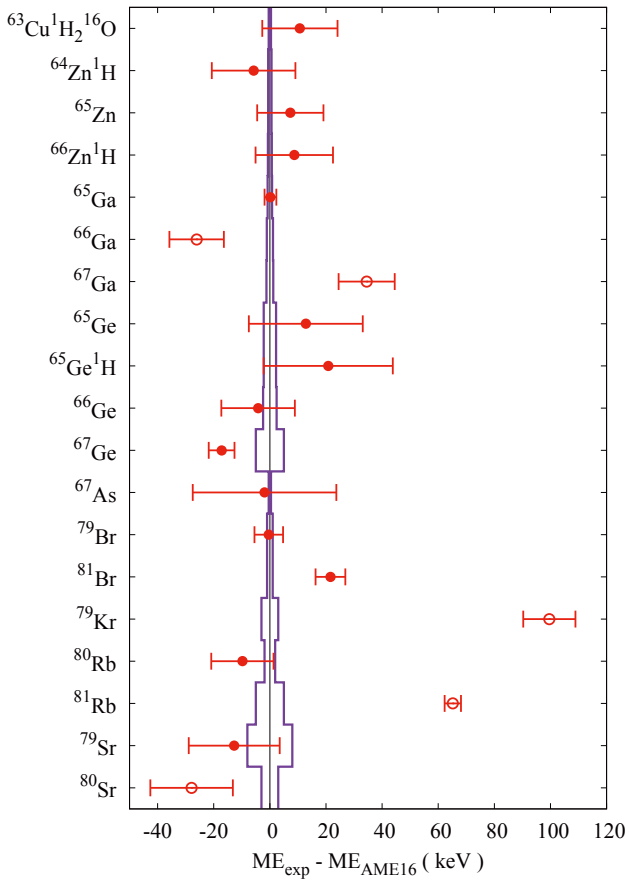

Fig. 1. Differences between the present measurement results and the AME16 values. Purple lines represent the error bands of the AME16 values. The open symbols indicate data derived from spectral peaks insufficiently separated from adjacent spectral peaks.

In the most precise measurement, which was that of ^{65}Ga, a mass uncertainty of 2.1 keV was obtained. This result shows that mass measurements satisfying the requirement of the CKM matrix, $\delta m/m < 5\times10^{-8}$, can be achieved with MRTOF-MS, given sufficient statistics.

References

1) P. Schury *et al.*, Nucl. Instrum. Methods B **335**, 39 (2014).
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*1 Institute of Physics, University of Tsukuba
*2 RIKEN Nishina Center
*3 Department of Physics, McGill University
*4 KEK, IPNS, Wako Nuclear Science Center
*5 Institute for Basic Science
*6 Institut de Physique Nucléaire, Orsay
*7 Department of Physics and Astronomy and National Superconducting Cyclotron Laboratory, Michigan State University
*8 Department of Physics, Kyushu University
*9 Department of Chemistry and Biochemistry, New Mexico State University