【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)

Title of Project： Study of the origin of heavy elements using an innovative mass spectrograph

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Research Area：Nuclear Physics
Keyword：Mass Measurement, r-Process, Superheavy Elements, MRTOF, IonTrap

【Purpose and Background of the Research】

The atomic mass is always slightly less than the sum of the masses of the individual constituents of protons, neutrons and electrons. This mass defect is representative of the total binding energy of the atom, which is the most fundamental property of an atom. Systematic comparisons of the atomic masses can indicate nuclear structure and key information for the origin of heavy elements, such as gold and uranium. The rapid neutron capture process (r-process) in explosive stellar events is considered to be the origin of such heavy elements. Experimental mass values of nuclei contributing the r-process are in high demand. However, such nuclei being very neutron-rich and short-lived hindered such measurements until recently.

Superheavy elements (SHE) can be a terminus of the r-process. Recently, new elements (Nh, Mc, Fl, Ts, Og) were named. However, the experimental data of SHE are extremely limited. Precise masses of SHE can be fingerprints for robust identification of Z as well as A. Furthermore, the mass values are indispensable data toward synthesis of nuclei in the "island of stability".

We will perform comprehensive mass measurements of medium-heavy nuclei and SHE using novel mass spectrographs and universal low-energy RI-beam facilities for studying the origin of heavy elements.

【Research Methods】

RIKEN RIBF has three major devices for RI-beam production: GARIS for SHE, KISS for specific neutron-rich nuclei and BigRIPS+SLOWRI for universal RI-beams. RF ion guide gas catchers thermalize various ion beams from these devices and accumulate RI ions in ion traps, and the bunched ions are injected into a multireflection time-of-flight mass spectrograph (MRTOF-MS).

The MRTOF-MS consists of a pair of electrostatic ion mirrors between which ions go back and forth a few hundred times. The mirror potentials are tuned to be energy isochronous and to provide a mass resolving power of 200,000 within a few milliseond measurement duration. The mass spectrograph can simultaneously measure isobar chains of multiple mass numbers. We developed a novel method to provide isobaric reference ions to guarantees high accuracy and high precision and demonstrated it for mass measurements of rare elements, such as Es, Md and No isotopes and for very short-lived nuclei such as ^{219}Ra ($T_{1/2}$ = 10 ms) with a prototype setup at GARIS.

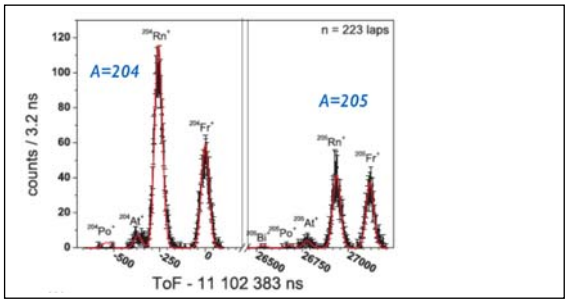

Fig. 1　ToF spectrum of A=204, 205 isobars

【Expected Research Achievements and Scientific Significance】

The combination of the world class RI-beam facility and novel gas catchers and mass spectrographs is a unique setup. Several hundred new masses of medium-heavy nuclei and SHE will be measured in this project, which will advance the study of the origin of heavy elements. Precise masses of SHE will clearly identify the "hot-fusion" SHE and determine a way to the island of stability.

【Publications Relevant to the Project】

・P. Schury et al., Phys. Rev. C95 (2017) 11305(R)
・S. Kimura et al., arXiv:1706.00186 (2017)
・M. Wada, Nucl. Inst. Meth. B317 (2014) 450

【Term of Project】FY2017-2021
【Budget Allocation】427,100 Thousand Yen
【Homepage Address and Other Contact Information】

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