Online extraction efficiency from RF ion guide gas cell at SLOWRI

S. Iimura,[*1,*2,*3] A. Takamine,[*1] D. Hou,[*4,*3,*5] M. Rosenbusch,[*3] M. Wada,[*3] S. Chen,[*3,*6] J. Liu,[*4]
W. Xian,[*3,*6] S. Yan,[*7,*3] P. Schury,[*3] S. Kimura,[*1] T. Niwase,[*8,*1,*3] Y. Ito,[*9] T. Sonoda,[*1] T. M. Kojima,[*1]
Y. X. Watanabe,[*3] S. Naimi,[*1] S. Michimasa,[*10] S. Nishimura,[*1] A. Odahara,[*2] and H. Ishiyama[*1]

We have been developing a radio-frequency carpet (RFC)–type ion guide[1)] gas catcher cell (RFGC) at the SLOWRI. In offline tests, the maximam transport efficiency for the RFGC was more than 80%,[2)] where the efficiency was defined as the ratio of ion current extracted from the cell to that corrected at the first-stage RFC. Here, the efficiency does not include factors such as ion survival probability and ion losses due to molecular formation. In order to obtain the "real" efficiency, an online test was performed using radioactive isotopes (RIs) provided by BigRIPS with an energy of several 100 MeV/nucleon as a symbiotic experiment behind the ZeroDegree spectrometer (ZD), in conjunction with the HiCARI campaign.

A multi-reflection time-of-flight (MRTOF) mass spectrometer[3)] installed at the downstream of the RFGC was used for particle identification (PID) and mass measurements, as shown in Fig. 1. The RIs partly stop in the RFGC, after passing through a rotational energy degrader. Subsequently, the stopped ions are extracted from the RFGC and transported to the MRTOF system through quadrupole ion guides and flat-type ion trap.

Table 1 presents the preliminary result for the efficiencies for several RI species. After identification at ZD, the total efficiency ($\varepsilon_{\mathrm{total}}$) for each RI was determined as the ratio between the observed count rate after the MRTOF and the count rate before the RFGC. The stopping efficiency ($\varepsilon_{\mathrm{stop}}$) is the fraction of RIs stopped in the RFCG, which was evaluated using LISE++ based on the measured energy distribution of each RI. By future application of mono-energetic beam optics,[4)] $\varepsilon_{\mathrm{stop}}$ is expected to improve by a factor of more than 5.

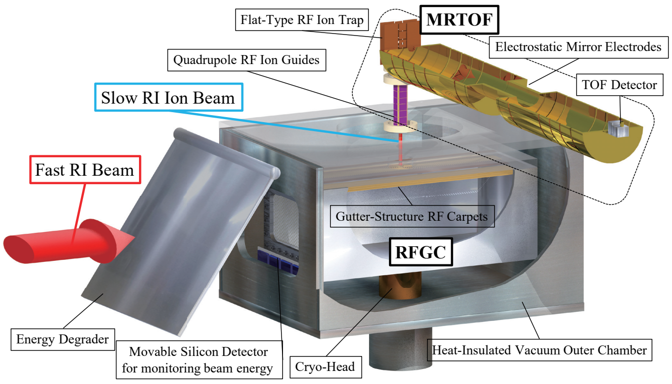

Fig. 1. Schematic view of the experimental setup. The RFGC is 50 cm long. It was operated at a nominal temperature of 180 K and pressurized with helium to 200 mbar room-temperature equivalent.

Table 1. Total efficiencies ($\varepsilon_{\mathrm{total}}$) measured with the detectors on ZD and the MRTOF. Stopping efficiencies ($\varepsilon_{\mathrm{stop}}$) were calculated from LISE++ The transport efficiencies ($\varepsilon_{\mathrm{trans}}$) correspond to ion transmission after stopping in the gas cell.

Nuclide (ions)	$\varepsilon_{\mathrm{total}}$	$\varepsilon_{\mathrm{stop}}$	$\varepsilon_{\mathrm{trans}}$
^{134}Sb$^+$	1.1%	9.1%	12%
^{137}Te$^+$	1.3%	9.2%	14%
^{88}Se$^+$	0.33%	3.4%	10%
^{90}Se$^+$	0.36%	2.0%	18%
^{85}As$^+$	0.16%	3.6%	4%
^{55}ScOH$^+$	0.0007%	2.9%	0.02%
^{48}CaOH$^+$	0.014%	3.2%	0.44%

The transport efficiency ($\varepsilon_{\mathrm{trans}}$) was obtained to subtract $\varepsilon_{\mathrm{total}}$ from $\varepsilon_{\mathrm{stop}}$. It should be noted that $\varepsilon_{\mathrm{trans}}$ includes transmission not only for RFGC but also for the ion guide, ion trap, and MRTOF. As indicated in Table 1, for many RIs, a reasonable $\varepsilon_{\mathrm{trans}}$ higher than 10% could be obtained. In this situation, $\varepsilon_{\mathrm{trans}}$ can depend on several factors such as the incoming beam intensity contributing to space-charge effects,[5)] mass-to-charge ratio sensitive to RF trap stability,[2)] and half-life providing decay loss. Another important dependency originates from the chemical properties of the incoming species when impurities are present in the He gas; *e.g.*, ^{55}ScOH$^+$ was identified. Those molecular formations can be suppressed by further improvement of the cooling performance of the RFGC, based on our experience of the cryogenic gas cell at GARIS II.[6)] Further improvement of the gas cell is ongoing.

We have successfully measured the masses of more than 70 nuclides in this experiment and are in the process of further analysis and simulation.

References

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[*1] RIKEN Nishina Center
[*2] Department of Physics, Osaka University
[*3] Wako Nuclear Science Center (WNSC), IPNS, KEK
[*4] Institute of Modern Physics, Chinese Academy of Sciences
[*5] School of Nuclear Science and Technology, Lanzhou University
[*6] Department of Physics, The University of Hong Kong
[*7] Institute of Mass Spectrometry and Atmospheric Environment, Jinan University
[*8] Department of Physics, Kyushu University
[*9] Advanced Science Research Center, JAEA Ibaraki
[*10] Center for Nuclear Study, the University of Tokyo