Temperature and pressure dependence of ion extraction from RF gas cell

D. Hou,[*1,*2,*3] A. Takamine,[*4] S. Iimura,[*4,*5] S. Chen,[*2,*6] Y. Hirayama,[*2] H. Ishiyama,[*4] Y. Ito,[*7] S. Kimura,[*4] J. Liu,[*1] H. Miyatake,[*2] S. Nishimura,[*4] M. Rosenbusch,[*2] P. Schury,[*2] M. Wada,[*2] Y. X. Watanabe,[*2] H. Wollnik,[*8] W. Xian,[*2,*6] and S. Yan[*2,*9]

The SLOWRI facility relies on gas catcher cells to employ the radio-frequency (RF) ion guide method for thermalizing and transporting radioactive ions.[1)] During an online experiment, we studied the pressure and temperature dependence of ion extraction from the gas cell. Molecular impurities in the gas cell can react and exchange charge[2)] with the ions of interest during their transport, and even after extraction, the ions can be neutralized and combined with molecular impurities. Because of the relatively low mobility of molecular impurities, they decrease the overall extraction efficiency of the gas cell. To reduce the amounts of molecular contaminants, we used high-purity helium and a gas purification system and operated the gas cell at very low temperatures. At temperatures below 50 K, most of these molecular impurities are absorbed at the wall of the gas cell.

In this online test setup, secondary beams passed through the ZeroDegree spectrometer and stopped in the gas cell. Subsequently they were extracted from the gas cell and transported to a multi-reflection time-of-flight (MRTOF) mass spectrograph for mass measurements.

The setup, as implemented in the commissioning runs, allowed for cooling the gas cell to ≈180 K. To avoid convoluting the stopping and extraction efficiencies, a pressure regulation system maintains a constant gas density of ≈33 μg/cm^3 for all temperatures. As shown in Fig. 1,

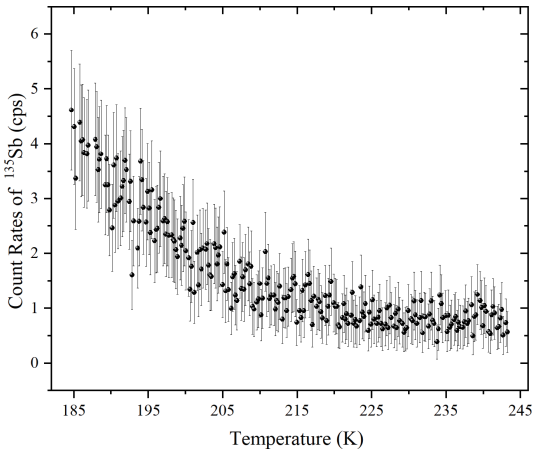

Fig. 1. Rates of ^{135}Sb$^+$ at different temperatures of the gas-cell chamber.

*1 Institute of Modern Physics, Chinese Academy of Sciences
*2 Wako Nuclear Science Center (WNSC), IPNS, KEK
*3 School of Nuclear Science and Technology, Lanzhou University
*4 RIKEN Nishina Center
*5 Department of Physics, Osaka University
*6 Department of Physics, The University of Hongkong
*7 Advanced Science Research Center, JAEA Ibaraki
*8 Dep. of Chem. and Biochem., New Mexico State University
*9 Institute of Mass Spectrometer and Atmospheric Environment, Jinan University

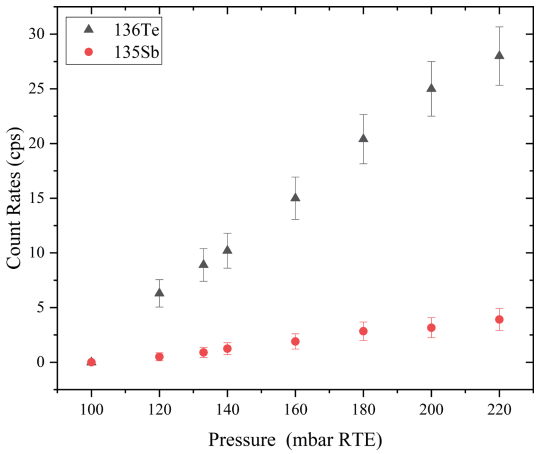

Fig. 2. Rates of ^{135}Sb$^+$ and ^{136}Te$^+$ observed at MRTOF as functions of RTE gas-cell pressure.

the extraction of ^{135}Sb$^+$ increases dramatically as the temperature falls below 210 K, at which some molecular impurities, such as H_2O, SO_2, and Cl_2, start to decrease. As the cryogenic cooling system reaches its lower limit before the extraction efficiency saturates, we intend to implement improvements to allow better cooling prior to the next online campaign.

By varying the gas density, we can probe the stopping efficiency. Figure 2 shows the results of such a measurement, performed with the gas cell at ≈180 K, with the observed rate of ^{136}Te$^+$ and ^{135}Sb$^+$ plotted as functions of room temperature-equivalent (RTE) helium pressure. As one might expect, the stopping fraction increased as the gas density increased. As such, we must consider how to safely operate at the highest possible gas density.

We used LISE^{++} to evaluate the stopping efficiency in the gas cell. With a pressure of 220 mbar RTE, 6.4% of ^{136}Te and 6.5% of ^{135}Sb should be stopped in helium gas, while decreasing the pressure to 133 mbar RTE would result in the reduction of stopping efficiencies to 2.3% and 2.4%, respectively. As shown in Fig. 2, the rates improved by a factor of 3.4 for ^{136}Te and 4.3 for ^{135}Sb, while LISE^{++} indicated that the stopping efficiencies should only increase by a factor of 2.7 from 133 mbar to 220 mbar. The difference likely results from the pressure dependence of the RF ion guide efficiency and ion mobility. Detailed analysis is underway to find an optimum operation condition ahead of the next online experiment.

References

1) M. Wada *et al.*, Nucl. Instrum. Menthods Phys. Res. B **204**, 570 (2003).
2) D. J. Morrissey *et al.*, Nucl. Instrum. Menthods Phys. Res. B **266**, 4822 (2008).