Study of extraction yield of multi-nucleon transfer reaction products by using cooled argon gas cell

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We have developed the KEK Isotope Separation System (KISS) to study the β-decay properties of neutron-rich isotopes with neutron numbers around $N = 126$ for astrophysics research.[1)] KISS uses a laser ion source to produce pure low-energy ion beams of the isotopes, which are produced as target-like-fragments (TLFs) in multi-nucleon transfer reactions by impinging a stable ^{136}Xe beam with an energy of approximately 10 MeV/nucleon on a ^{198}Pt target. The extraction efficiency from the laser ion source, which is based on an argon gas cell, was as low as 0.1%.[2)] We assume that the low extraction efficiency stems from the formation of molecule ions between TLF ions and impurities in the gas cell. The molecule ions would be neutralized in the argon gas cell, and, therefore, we cannot confirm the formation of neutral molecules by detecting and identifying them using usual electromagnetic methods.

To study this assumption, we developed a cooling system for the argon gas cell to freeze out the impurities in the argon gas and gas cell for suppressing the formation probability. Figure 1 shows a schematic view of the gas cell system with a cooling system that consists of a He cryo-module and liquid nitrogen cooling circuit. The gas cell is on the module to be cooled effectively, and liquid nitrogen is flowed along a wall of the gas cell. Two thermometers (Pt100) were installed to monitor the temperatures at the center and the argon gas inlet part of the gas cell. The cooling system enabled the argon gas and the gas cell to be cooled down to approximately 120 K in an off-line cooling test.

To study whether the extraction yield could be increased by suppressing the formation probability of molecules using the cooling system, we performed an on-line experiment using a ^{136}Xe^{20+} beam with 10.75 MeV/nucleon and an intensity of 20 pnA. Figure 2 shows the measured extraction yield of ^{198}Pt^{+} (top) and the temperatures (bottom) as a function of time, respectively. The red and blue lines in the bottom figure show the temperatures at the center and the gas inlet part of the gas cell, respectively. The extraction yield decreased with decrease in the temperature, and became almost saturated at 60 min with temperatures of 170 K and 130 K at the center and the gas inlet part of the gas cell, respectively. The origin of bumps measured at approximately 26 and 36 min in the top figure was unclear. After saturation, we decreased the argon gas pressure down to 15 kPa from 30 kPa to keep the gas density constant according to the change in temperature. After that, we found a recovery of the extraction yield.

However, we did not find any increase in the extraction yield by cooling the gas cell system. This indicates that the formation of molecules is not the dominant cause for the low extraction yield. The extraction yield of unstable ^{199}Pt at 170 K was also the as same as that measured at room temperature.

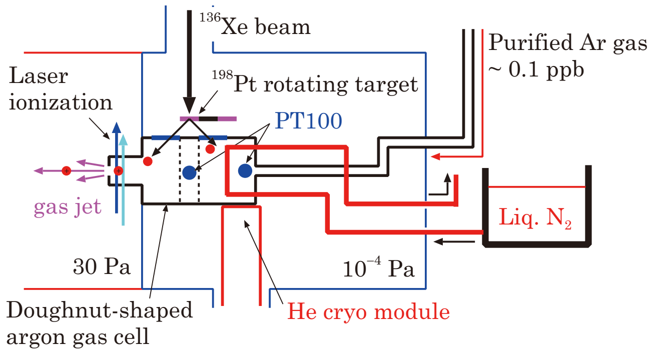

Fig. 1. Schematic view of the gas cell system with a cooling system. The details of the gas cell system were reported in Ref. 2).

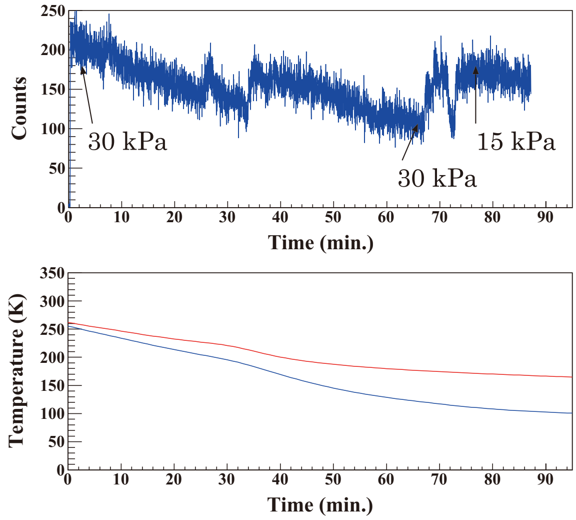

Fig. 2. Measured extraction yield of ^{198}Pt^{+} (top) and the temperatures (bottom) as a function of time.

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