

Development of KEK isotope separation system

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We have been constructing the KEK Isotope Separation System (KISS) to study the β -decay properties of the neutron-rich isotopes with neutron numbers around $N = 126$ for astrophysics research¹⁻³). In the KISS, a gas cell filled with argon gas at a pressure of 50 kPa, which stops and collects unstable nuclei in it, is an essential equipment for selectively extracting the isotope of interest by using a resonant ionization technique. The absolute extraction efficiency of the gas cell and beam purity of the KISS gas cell can be evaluated only from the measurements of the intensities of beams implanted in and extracted from the gas cell in an on-line test.

We performed on-line tests using the ^{56}Fe beam with the energy of 90 MeV/nucleon and the maximum intensity of 4 pps. The energy of ^{56}Fe beam was degraded to 1.5 MeV/nucleon in front of the gas cell by using an aluminum energy degrader in order to implant at the center of the argon gas cell. The thermalized and neutralized ^{56}Fe atoms were re-ionized in the gas cell, and the ions were extracted and detected by using a Channeltron detector for ion counting after mass separation.

We successfully extracted laser-ionized ^{56}Fe atoms by cleaning the gas cell system and by using a “bent type” gas cell, which was designed to reduce the plasma effect. Figure 1 shows the measured efficiency and

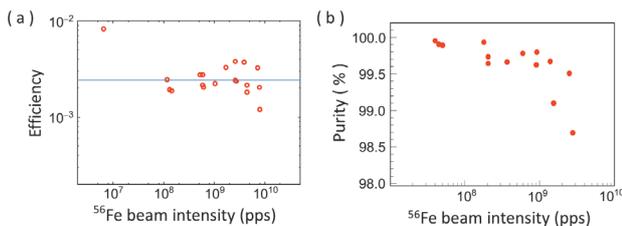


Fig. 1. (a) Extraction efficiency of ^{56}Fe ions and (b) beam purity measured as a function of ^{56}Fe beam intensity.

beam purity as a function of the primary beam intensity. The extraction efficiency was defined as S/I . Here, S and I present the numbers of laser-ionized ^{56}Fe atoms and implanted ^{56}Fe atoms in the gas cell, respectively. The measured efficiency was about 0.25% after the correction of the detector efficiency (16%)

and the laser repetition rate (20%). The efficiency was independent of the primary beam intensity, as shown in Fig. 1-(a), owing to the bend structure of the gas cell. Beam purity was defined as $S/(S + N)$. Here, N is the number of the extracted ions with $A = 56$, which was measured without irradiation with ionization lasers. Figure 1-(b) shows the obtained beam purity of $> 98\%$, and it depended on the primary beam intensity. The beam purity decreased with increasing primary beam intensity. However, the impurities probably consist of molecular ions of argon, which are stable against radioactive decay and do not affect the β -decay lifetime measurements.

In the case of the primary beam intensity of 2.5×10^7 pps, we measured mass distributions without and with ionization lasers, as shown in Figs. 2, in order to investigate how many laser-ionized ^{56}Fe atoms formed impurity molecules with H_2O , Ar_2 , and hydrocarbons. Figure 2-(a) shows background ions extracted from the gas cell, which are ionized by the primary beam injection. Dimers of argon isotopes and their compounds with hydrogen were dominant. In the case of ionization laser irradiation, we clearly observed laser-ionized ^{56}Fe peak and molecular ion peaks of $^{56}\text{Fe}(\text{H}_2\text{O})$ and $^{56}\text{FeAr}_2$. By reducing the amount of water molecules in the gas cell, the number of laser-ionized ^{56}Fe atoms would increase, and as a result, the extraction efficiency of ^{56}Fe would be doubled.

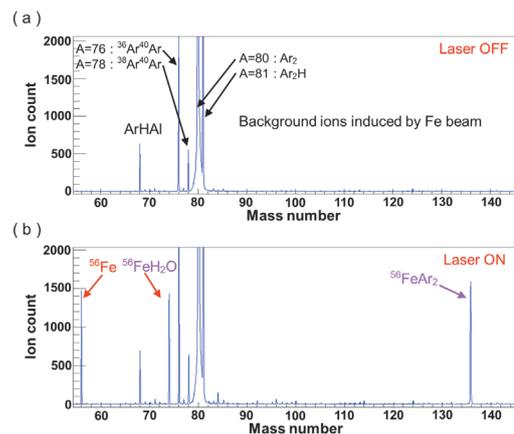


Fig. 2. Measured mass distributions (a) without using ionization lasers and (b) using ionization lasers.

References

- 1) S.C. Jeong et al.: KEK Report 2010-2.
- 2) Y. Hirayama et al.: RIKEN Accel. Prog. Rep. **44** (2011) 25; **45** (2012) 152; **46** (2013) 176.
- 3) H. Ishiyama et al.: RIKEN Accel. Prog. Rep. **45** (2012) 151.

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