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Actinides and 129I Analyses with the 300 kV Multi-Isotope Low-Energy AMS

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The 300 kV Multi-Isotope Low-Energy AMS (MILEA) system was developed by ETH Zurich and Ionplus AG, Switzerland for the ultra-sensitive measurement of long-lived nuclides, such as 14C, 129I, actinides, 10Be, 26Al and 41Ca. The negatively charged ions (such as C-, I-, AnO-) were extracted from the target sample in a Cs-sputtering ion source, and injected into a low-energy analysis system, including a 90° low-energy ESA (r=534 mm) and a 90° magnet (r=450 mm). Then the ion beam was introduced into a vacuum insulated high voltage platform with the maximum acceleration voltages of 300 kV, where He gas as stripping gas was fed. Meanwhile, the incident negative ions were transformed into positive ions and the molecules were break up. After focusing of different charge states and molecular break-up products using the following electrostatic quadrupole triplet lens, the ion beam passed through the high energy side, which consists of twoagnets (90◦ and 110◦ bending angles) with a 120◦ ESA in between. While the ion currents of stable nuclides or high abundance nuclides (e.g. 12C, 127I, 235U, 238U, etc.) were measured by one of seven movable Faraday cup behind the high energy magnet 1. The rare nuclides (14C, 239Pu, 240Pu, 241Pu, 242Pu, 243Am, 241Am, 244Cm, 233U, 236U, etc.) were counted with a low noise two-anode gas ionization detector (GID).
For the determination of long-lived actinides (237Np, 239Pu, 240Pu, 241Pu, 244Pu, 241Am, 244Cm, 233U, 236U, 235/238U), An3+ ions were selected, and transmission from injector to HE cup is more than 36% at the terminal voltage of about 260 kV in accelerator. The AMS target preparation method was optimized by adding 0.4 mg Fe and 0.1 mg Ti to co-precipitate the Am and Cm, Pu and Np. The overall detection efficiencies were 8.8 × 10-4 for Pu, 6.3 × 10-4 for Np, 3.1× 10-4 for Am and 7.2 × 10-4 for Cm after 2 h of sputtering time. The correction factors of Pu/Np and Am/Cm were 1.39-1.41 and 0.39-0.43, respectively. The abundance sensitivity of 239/238 reached an optimal value of (2.1 ± 0.6) ×10-13. For the measurement of 236U/238U ratios at (6.98 ± 0.32) ×10-11, the single sample scatters were between 0.9% and 1.4%. For129I measurement, the127I transmission from injector to HE cup was more than 50.9% using I2+, and the 129I transmission from HE cup to detector was more than 95.6%. The 129I/127I ratio of WWI was (2.0-3.7) × 10-14. For the measurement of standard solution with 129I/127I ratio at 3.98 × 10-14, 9.95 × 10-14, 100.37 × 10-14, the precisions were 0.41%, 0.71%-0.75%, 0.20%-0.22%, respectively. The performance of the AMS system is shown in Table 1.

Table 1 The performance of 300 kV Multi-Isotope Low-Energy AMS (MILEA) system for actinides, 14C and 129I
Nuclide Transmission Blank Precision Detection limit
Actinides > 36% (2.1 ± 0.6)×10-13 (239/238) 236U/238U ≤ 1.4% 237Np: 0.005 fg (1.3 × 10-10 Bq)
239Pu: 0.005 fg (1 × 10-8 Bq)
240Pu: 0.002 fg (2 × 10-8 Bq)
241Pu: 0.003 fg (1.1 × 10-5 Bq)
241Am: 0.03 fg (3.8 × 10-6 Bq)
244Cm: 0.004 fg (1.2 × 10-5 Bq)
C-14 > 46% 14C/12C < 1.34 × 10-15 14C/12C < 0.2% -
I-129 > 50% 129I/127I: (2.0-3.7) × 10-14 129I/127I < 0.4%

For dose assessment in the event of internal exposures at nuclear facilities and nuclear power plants, the analytical methods for actinides (Pu isotopes, 237Np, 241Am, 244Cm) in urine bioassay have been developed using sequential separation and AMS determination, and the detection limits obtained in this work were 10-17-10-18 g/d in 1.0-1.6 L of urine samples. For the environmental tracer and monitoring studies, series of analytical methods for actinides and 129I in seawater, soil, sediment, aerosol have also been developed in China Institute for Radiation Protection.

Student Submission

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