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Highly-sensitive uranium isotopic analysis for nuclear safeguards

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Introduction

This application note describes the analytical performance of the Thermo Scientific™ Neptune XT™ multicollector ICP-MS for measuring uranium isotopes from 2 ng uranium samples.

Instrumentation

Jet Interface for ultimate sensitivity

The Neptune XT MC-ICP-MS is equipped with the Jet Interface for highest sensitivity. The Jet Interface comprises a high performance interface pump with Jet sample and X skimmer cones. Solutions were introduced by an ESI µFlow PFA-100 self-aspirating nebulizer and a CETAC Aridus II desolvating nebulizer system. The sequence was automated using a CETAC ASX-112 FR autosampler.

The Neptune XT MC-ICP-MS was equipped with a multi-ion-counting array configured for nuclear applications. This array uses a combination of compact discrete dynode (CDD) type ion counters and full-sized SEM ion counters. The CDD type ion counters offer similar performance characteristics to the full-sized SEM.

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The beams ^{238}U and ^{235}U were measured on Faraday cups. ^{234}U and ^{236}U were measured simultaneously in SEM ion counters with RPQ ion energy filters for improved abundance sensitivity (dual RPQ option). The abundance sensitivity from ^{238}U on *m/z* 236 (2 a.m.u.) was estimated to be ca. 1×10^{-7}.

Outline of methodology

The NBS standard reference material U-030 was run as a standard, bracketing samples of U-010 (currently available as CRM U-010, New Brunswick Laboratory, Argonne, IL, USA). The uranium concentration of the U-010 'sample' solution was 2.3 ng/g (ppb) in 3 wt. % HNO_3.

A certified 1 µg/L (ppb) uranium concentration solution gave a ^{238}U signal of 1.22 V on a standard 10^{11} Ω amplifier (1220 V/ppm at 87 µL/min). The sample utilization (ions detected/atoms in solution consumed) is estimated to be 2.1%.

Results

Combination of highest sensitivity and stability

The data for each of the standards and isotopes are plotted in Figure 1, and statistics are summarized in Table 1. It can be seen that for each isotope the scatter of measured data is small and within the range of uncertainty of the certified reference materials. More recent and precise reference values from Richter and Goldberg (2003) are plotted for comparison against the certified values. Accuracy of the analytical data was not compromised by using the high-sensitivity Jet Interface option.

These data demonstrate that the analytical performance of the Neptune XT MC-ICP-MS for ^{235}U abundance analysis is well within the International Target Values for Measurement Uncertainties in Safeguarding Nuclear Materials (IAEA 2010).

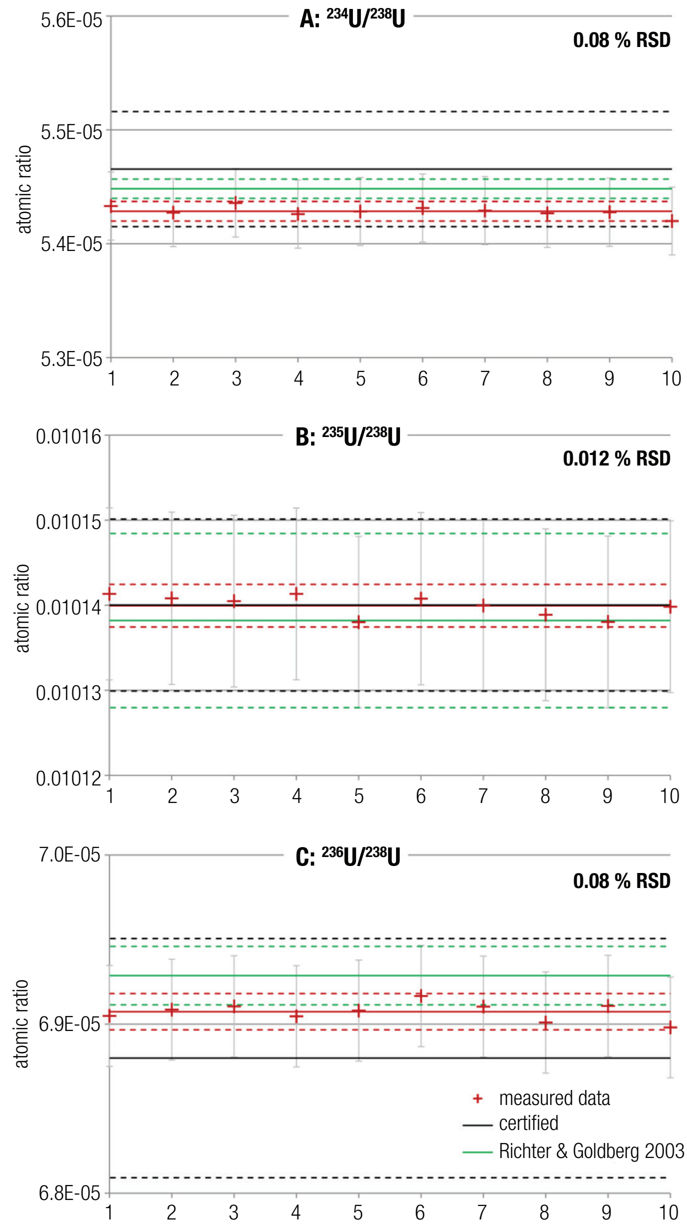

Figure 1. The scatter of data for the measurements is small compared to the uncertainty of the certified reference values (dashed lines show uncertainty at 95%). The 95% C.I. error bars for the measured data include the uncertainty propagated from the NBS U-030 standard's certified reference values.

Table 1. Mean and external reproducibility for 10 repeat analyses of NBS U-010 (externally corrected using NBS U-030).

2 ng NBS U-010, n=10	$^{234}U/^{238}U$	$^{235}U/^{238}U$	$^{236}U/^{238}U$
mean	5.43E-05	0.01014	6.91E-05
1RSD	0.08%	0.012%	0.08%

Figure 2. Thermo Scientific Neptune XT MC-ICP-MS.

Conclusions

The data show that the Neptune XT MC-ICP-MS with Jet Interface option is a MC-ICP-MS that is capable of measuring high-precision $^{235}U/^{238}U$ ratios from small uranium samples.

The Neptune XT MC-ICP-MS is supported by a global network of dedicated service engineers, vital for continuous industry critical operations.

References

1. IAEA. 2010. *International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials. STR-368.* International Atomic Energy Agency.
2. Richter, S. & Goldberg, S.A. 2003. *Int. J. Mass Spectrom.* **229,** 181–197.

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