Precise isotope ratio analysis by MC-ICP-MS without matrix separation – Sr, Pb and U case study

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Many previous studies have demonstrates the potential of MC-ICP-MS for precise isotopic measurements using internal standard normalization for instrumental mass discrimination correction. The methods reported here employ an MC-ICP-MS to produce high precision measurements of Sr, Pb and U isotope ratio in natural waters, carbonates and related materials without matrix separation. The “Nu-Instrument” MC-ICP-MS, a double focusing spectrometer with zoom variable dispersion ion-optics, was used for the measurements.

The intensity of the element beams for the samples with matrix was depressed up to 40 % compared to the beams of pure solutions. The matrix strongly affected uncorrected isotope ratios. However, when the isotope ratios were corrected by internal standards (in the case of Sr by ^{86}Sr/^{88}Sr, Pb by ^{203}Tl/^{205}Tl and U by ^{235}U/^{238}U) the impact of the matrix was also corrected. The precision (2_) obtained for the ^{87}Sr/^{86}Sr, ^{207}Pb/^{206}Pb, ^{208}Pb/^{206}Pb and ^{234}U/^{238}U ratios was 20, 30, 40 and 2000 ppm respectively even in samples with total dissolved solid levels of up to 700 mg L^{-1}. The method was shown to be nearly compatible with high precision TIMS analyses. The accuracy of the results was compared with results obtained by TIMS or by MC-ICP-MS after matrix separation and was more than satisfactory (Table 1).

Table 1: Comparison of results of isotope ratios in SRM, natural waters and carbonates using TIMS and the MC-ICP-MS instrument with and without matrix separation.

Sample, type	Isotope ratio	MC-direct	MC-eparation.	TIMS
SRM-610, glass	^{207}Pb/^{206}Pb	.90944		.90950
Timna, coronadite	^{207}Pb/^{206}Pb	.87101	.87101	
Sea of Galilee	^{87}Sr/^{86}Sr	.70750	.70749	.70747
NASS-4, ocean water	^{87}Sr/^{86}Sr	.70935		.70906
Dead Sea, brine	^{87}Sr/^{86}Sr	.70800		.70803
L-3 rock, aragonite	^{87}Sr/^{86}Sr	.70804		.70804
Timna, coronadite	^{234}U/^{238}U	45x10^{-6}	46x10^{-6}	
Sea of Galilee	^{234}U/^{238}U	89x10^{-6}	88x10^{-6}	90x10^{-6}

Nu 1700: a new large-geometry high-resolution multiple collector ICP-MS

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The Nu 1700 represents a new class of high-resolution multiple collector ICP-MS instruments designed for rejection of isobaric interferences at a superior level of analytical performance. The instrument, specifically developed for research at ETH Zurich, is a large-geometry double-focusing mass spectrometer employing a 943 mm radius, 70° sector electrostatic analyzer (ESA) followed by a 750 mm radius, 70° laminated magnet (weighing approx. 4 tons) with curved entrance and exit poles. The plasma interface is operated at 6 kV. Ion signals can simultaneously be recorded by an array of 10 fixed Faraday collectors complemented by 6 mechanically adjustable ones (three on either side of the fixed array) allowing for 16% mass dispersion. Also, three discrete-dynode electron multipliers, operated in ion counting mode, are interspersed with the fixed collector array. One of these is equipped with a retardation filter for enhancing abundance sensitivity. Two electrostatic quadrupole zoom lenses located between the magnet and the collector array serve for focusing and matching dispersion of the isotope beams to collector positions. An electrostatic quadrupole lens between the ESA and the magnet is available for fine-tuning of double focusing.

All relevant optical beam restrictors are controlled externally, which provides the flexibility necessary for operating the instrument in a multi-element analytical environment. A continuously adjustable, manually operated source defining slit in combination with computer-controlled continuously adjustable collector slits at all 19 detectors permit the resolution of the instrument to be varied from ~400 to ~10,000 (10% valley definition). This maintains flat peak tops for high-precision isotope ratio measurement. Correction of aberration terms (becoming important at higher resolution) is achieved with an electrostatic hexapole lens located in front of the ESA. A manually adjustable alpha slit located in the drift space after the source defining slit provides for three horizontal and two vertical window widths in order to further restrict aberration effects.

The Nu 1700 is ideally suited to the precise and accurate determination of isotopic compositions, affected by interfering molecular or multiply charged species, in a variety of terrestrial and extraterrestrial materials. Apart from classical examples such as analysis of Fe biased by interfering ^{40}Ar^{14}N and ^{40}Ar^{16}O, the instrument will play a particularly crucial role in the suppression of matrix related contributions when using laser ablation techniques for sample introduction.