

Enhancing the Performance of Single Collector Sector Field ICP-MS for Isotope Ratio Determinations

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Introduction

Single collector sector field ICP-MS, in addition to its ability for predictable interference free multi-elemental analysis, offers precise and accurate isotope ratio determinations. While multi-collector sector field ICP-MS offers the ultimate in isotope ratio determinations, single collector ICP-MS offers both high performance multi-elemental and isotope ratio determinations in a single instrument.

A highly sophisticated detection system is used in the standard Thermo Scientific ELEMENT 2 which provides nine orders of magnitude linear dynamic range from a dual mode secondary electron multiplier (SEM). In this design ions are accelerated to - 8 kV before they impact onto a conversion dynode that releases electrons which then enter the SEM. The result is a mass-independent detector response that makes manual cross-calibration redundant as a suitable detection mode is chosen automatically by the SEM electronics.

Detector System

A newly designed detector system incorporated in the Thermo Scientific ELEMENT XR, increases the linear dynamic range of single collector sector field ICP-MS from nine orders to more than twelve orders of magnitude.

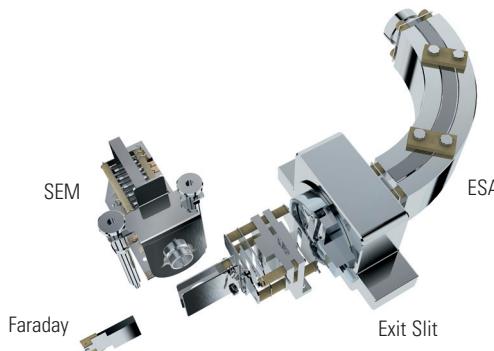


Figure 1: Thermo Scientific ELEMENT XR detection system.

The detection system consists of the same dual mode discrete dynode detector as used in the Thermo Scientific ELEMENT 2 in combination with a single Faraday detector. This enables the ELEMENT XR to cover a linear dynamic range of more than twelve orders of magnitude to allow elemental determinations from ultra-trace to matrix in a single scan of the mass spectrum.

In addition to its unique dynamic range, this modern detection system offers:

- 0.2 cps to $> 1 \times 10^{12}$ cps
 - complete analysis from ultra-trace to matrix
- Minimum integration times:
 - Counting: 0.1 ms
 - Analog: 1 ms
 - Faraday: 1 ms
- No decay time with Faraday detection system
 - Due to an optimized intergration circuit
- Automatic switching between detection modes
 - no preset detector mode required
 - < 1 ms delay between switching from SEM to Faraday detection
- Automatic cross calibration

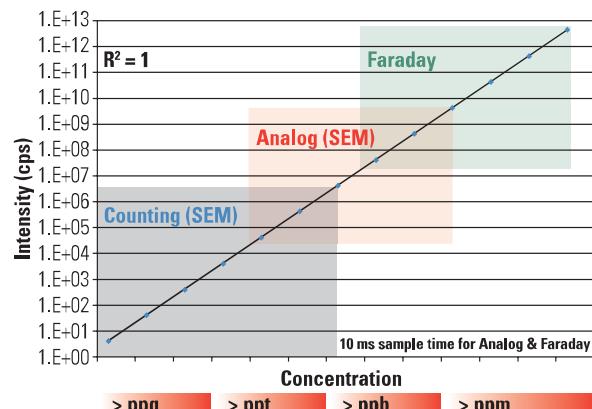


Figure 2: More than twelve orders of linear dynamic range.

It is not necessary to pre-set the detection mode. As with the Dual Mode detector of the ELEMENT 2, the new Triple Mode offered by the ELEMENT XR automatically chooses the appropriate detection mode for the count rate measured. Analog and counting is measured simultaneously if the count rates exceed 10^9 cps. The system switches (in less than 1 ms) to the Faraday detector. The combination of speed and dynamic range makes the ELEMENT XR the ideal multi-element detector for sample introduction systems such as laser ablation. The increased dynamic range also enhances the capabilities of the ELEMENT XR for isotopic analyses, particularly for large ratio systems.

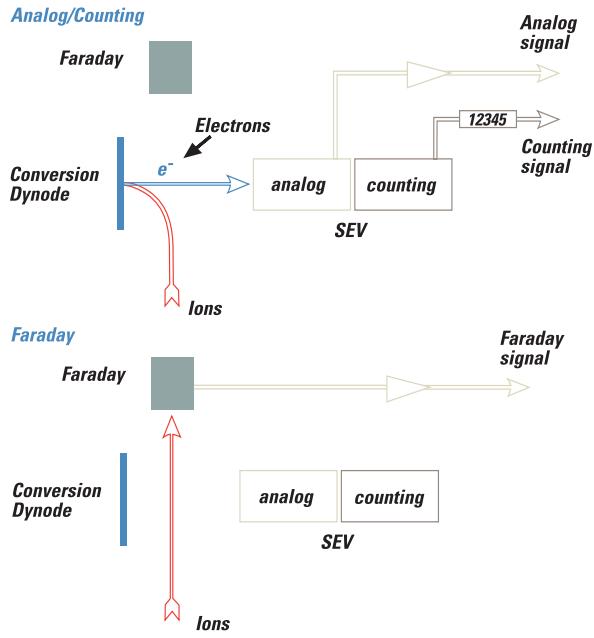


Figure 3: Schematic of the Triple Mode detection system.

With the Thermo Scientific ELEMENT XR it is possible to measure, for example, uranium solutions at significantly higher concentrations. By doing this the major isotope can be measured using the Faraday detector and, by analyzing higher count rates, improve the counting statistics for the minor isotopes that are measured with the SEM. For the uranium example, this means that ^{234}U and ^{236}U are measured using the SEM's counting mode, ^{235}U in the analog mode and ^{238}U with the Faraday Detector.

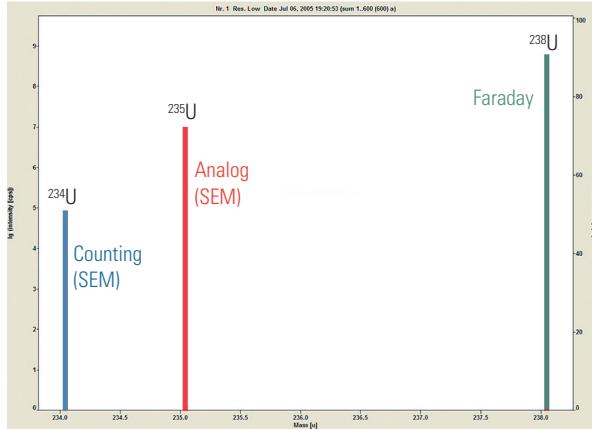


Figure 4: Uranium isotope ratio analysis spectrum showing the use of all three detector modes: Counting (SEM), Analog (SEM) and Faraday.

Using the Triple Mode detector for large isotope ratios results in isotope ratio precisions that were previously only attainable with multicollector ICP-MS instruments.

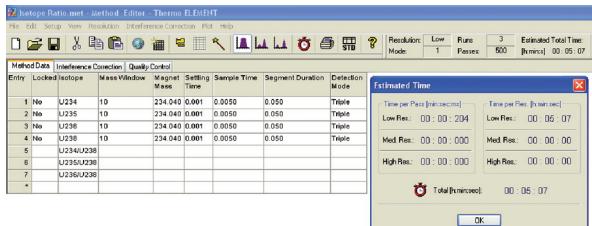


Figure 5: Uranium isotope ratio analysis method.

As with the Dual Mode detector, manual cross-calibration for the Triple Mode detector is redundant: the Faraday detector shows no mass dependence at all!

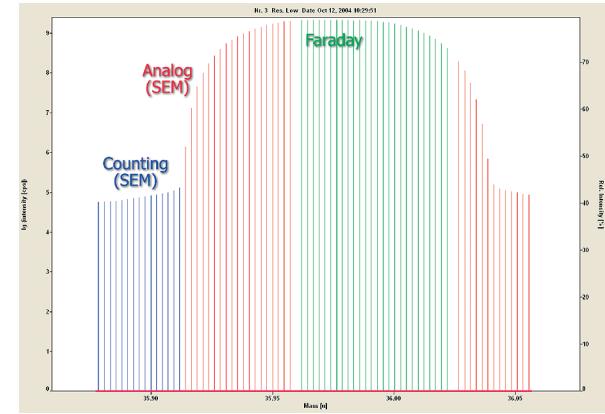


Figure 6: Triple Mode spectrum showing Counting, Analog and Faraday detector modes in a single analysis.

Two important factors that influence the accuracy of Uranium isotope ratio measurements are the formation of UH^+ (i.e. ^{235}UH at ^{236}U) and abundance sensitivity. Using the sample introduction system specified below results in an UH^+ of < 20 ppm (See Figure 7).

- Sample Introduction System:

- Standard Thermo Scientific ELEMENT XR Introduction System
- Glass Expansion 200 $\mu\text{l}/\text{min}$ Micromist quartz glass concentric nebulizer (self-aspirating)
- Glass Expansion Twinnabar quartz glass spraychamber
- Injector
 - Pt tipped quartz sample and skimmer cones
 - CETAC ASX-260 Autosampler

The ELEMENT XR detection system also incorporates an abundance sensitivity 'filter' lens, that discriminates ions of the "wrong" energy, therefore significantly improving the abundance sensitivity.

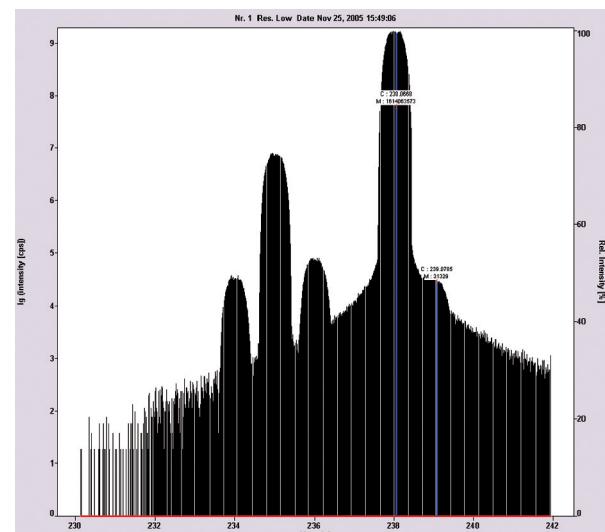


Figure 7: Abundance sensitivity and hydride formation for the analysis of 1ppm of UO10. An abundance sensitivity of 7.4 ppm (m_1/m) and a hydride formation of 14 ppm ($^{238}\text{UH} / ^{238}\text{U}$) were determined.

Results

Figure 8-10 show the results from 5 consecutive measurements of 1 ppm of U010.

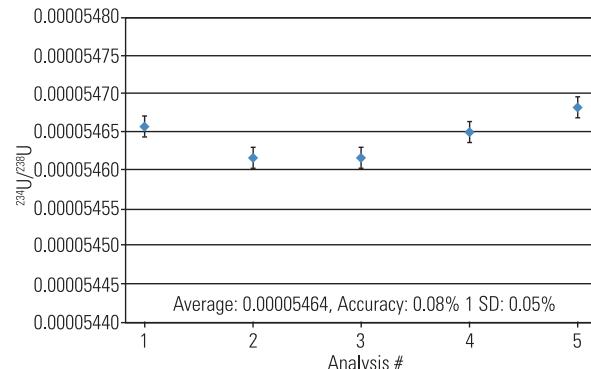


Figure 8: Precision and accuracy U010, 1 ppm, $^{234}\text{U}/^{238}\text{U}$.

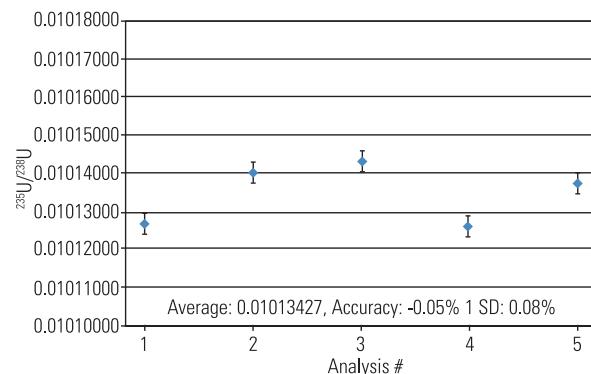


Figure 9: Precision and accuracy U010, 1 ppm, $^{235}\text{U}/^{238}\text{U}$.

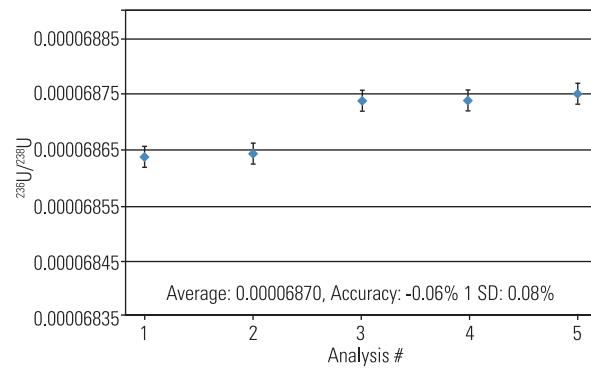


Figure 10: Precision and accuracy U010, 1 ppm, $^{238}\text{U}/^{238}\text{U}$.

Summary

- The Thermo Scientific ELEMENT XR provides all of the advantages of the ELEMENT 2 for isotope ratio measurements:
 - Wide, flat top peaks in low resolution
 - High sensitivity
 - High resolution for reliable interference removal
- In addition the Thermo Scientific ELEMENT XR provides:
 - Increased linear dynamic range ($> 10^{12}$)
 - Fast Scanning
 - No decay time
 - 1 ms integration time
 - Automatic switching
 - Automatic cross calibration
 - Faraday Detector

Related Products for Isotope Ratio Determination

Thermo Scientific TRITON

The TRITON sets a new standard in high precision TIMS isotope ratio measurements. The TRITON's unique capabilities have earned the reputation of the "natural choice" in TIMS instrumentation.



- Guaranteed external precision of Nd and Sr is 5 ppm (1 SD), both in static and multi-dynamic acquisition
- 2 ppm external precision has been shown
- Improved sensitivity
- 21 position sample turret for high throughput
- User friendly software for high throughput, with network capabilities

Thermo Scientific NEPTUNE

The NEPTUNE completes Thermo Fisher Scientific's integrated product family for elemental and isotopic analysis. It shares the field-proven ICP interface of the Thermo Scientific ELEMENT 2, the most advanced single collector high mass resolution ICP-MS with the high precision multicollector platform of the Thermo Scientific TRITON.



The NEPTUNE defines a "third generation" multicollector ICP-MS, combining, for the first time, the features of high mass resolution, variable multicollection, zoom optics and multiple ion counting (MIC).

- High mass resolving power with flat top peak sections
- Excellent short-term and long-term stability of signal intensity and mass bias
- Full sensitivity with standard sample introduction system
- Fully integrated software for unattended operation and high throughput

Thermo Scientific DELTA V

The DELTA V stable isotope ratio mass spectrometer systems deliver the highest precision for the determination of D/H, $^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$, $^{18}\text{O}/^{16}\text{O}$, $^{34}\text{S}/^{32}\text{S}$ (from SO_2 and SF_6) and other isotope ratios. It is unique in its capability to achieve precision measurements from the smallest amounts of sample.

The conversion of any type of organic or inorganic compound into simple gases is the basic principle for isotope ratio mass spectrometry. A wide range of sample preparation devices and interfaces are available as inlets to the DELTA V series.

Thermo Fisher Scientific offers complete analytical solutions with GC, HPLC and elemental analyzers for fully automated isotope ratio analyses on a wide range of samples for practically every application.

- Up to 10 detectors
- Widest range of collector configurations
- Robustness and reliability
- Monolithic analyzer with intrinsic alignment of all ion optical components
- Comprehensive set of automated diagnostics
- Small footprint
- Low noise design



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Thermo Scientific XSERIES 2 ICP-MS

The XSERIES 2 ICP-MS is a robust analytical instrument capable of meeting the most challenging requirements. It is a powerful and precise measurement tool designed to maximize productivity in the laboratory across a wide range of applications.

Analytical scientists benefit from the XSERIES 2 features:

- The world's smallest benchtop ICP-MS
- The highest throughput with protocol compliance
- Unlimited flexibility through complete Plug-and-Play upgradeability
- Rapid start-up through Productivity Packs for routine analyses and comprehensive operator training courses

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