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Potential and Limitations of ICP-QMS Technique for the Measurement of 230Th

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Nuclear forensics is a multidisciplinary science that combines methodologies of radiochemistry, materials science, nuclear physics and engineering, and environmental science, with the ultimate goal of providing evidence for nuclear attribution. The combination of these disciplines for the characterization of intercepted nuclear or radioactive materials supplies valuable information on the possible intended use of the material and on its history, possibly leading to a source attribution.

The parent/daughter 230Th/234U ratio is a valuable signature for a nuclear forensic investigation when uranium bearing materials are involved. The quantification of this chronometer can be applied for the age measurement of uranium, establishing the possible time of manufacture. The determination of this parameter has generally been carried out by mass spectrometric techniques such as thermal ionization mass spectrometry (TIMS) and inductively coupled plasma mass spectrometry (ICP-MS).

During the last decade, the ICP-MS technique has revealed as a relevant tool for nuclear forensics investigations, since it allows the detection and measurement at ultratrace concentration levels of isotopes of uranium (234U), thorium (230Th) and fission products. Its capacity of multielemental analysis (4.5 a.m.u to 242 a.m.u.) enables the study of others elemental signatures (minor and trace elements) of the material that may provide useful information on the history of the material: Er and Gd (burnable reactor fuel poisons), Ga (phase stabilizer for plutonium metal, also help define its origin) Ca, Mg or Cl (residues from a water-based cleaning process), rare-earth and other impurities patterns (uranium starting material, ore).

Recent developments in ICP-MS and more specifically in quadrupole based instruments ICP-QMS (collision/reaction cells technology, improvements in optical transmission ion, more efficient detectors enhanced sensitivity) have led to considerable increase in sensitivity and precision, allowing performing the measurement of 230Th at environmental levels. Based on these premises, this work presents the analytical procedure developed for the detection and measurement of 230Th and 234U with an ICP-MS instrument equipped with a quadrupole analyzer system. This method could be applied to different matrices, including a uranium and thorium certified reference material. The obtained results could be compared with those achieved by high performance α-spectrometry analysis.

The ICP-MS instrument used for this purpose was the iCap Q (Thermo Scientific) equipped with a high transmission interface, 90 degree ion optics and effective interference removal using the QCell working in kinetic energy discrimination (KED) mode with helium as collision gas. Alpha Analyst (CANBERRA Industries) integrated spectrometer was employed for high performance alpha spectrometry determinations, using passivated implanted planar silicon (PIPS) detectors.

Previous treatment of samples, dissolution and separation and/or preconcentration of analites were carried out by microwave acid digestion and ionic plus extraction chromatography (AG1 x 8 and UTEVA resins) respectively.
The Capacity of ICP-MS technique to determine minor and trace elements in complex matrices and its use as signature for nuclear forensic is also reported for the uranium bearing materials.

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