Isotopic ratio study of uranyl ion with Differential mobility Spectrometry-mass spectrometry (DMS-MS)

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Introduction:

The human threat associated with radio-nuclear materials from nuclear fuel feedstock, spent fuel and post detonation debris require a rapid and high throughput analytical approach. Isotope-ratio mass spectrometer (IRMS) – with a magnetic sector analyzer is the conventional instrument employed for IR measurement. The size, weight and power (SWP) requirements of the lab-based instrument makes sampling and analysis laborious and time consuming. Deploying differential mobility spectrometry (DMS) system will reduce the sampling time to order of milliseconds. With the heterogeneous nature of fission products, DMS ion filtration prior to MS analysis will reduce chemical interference while ion of interested is selectively characterized. Herein, we will focus on the DMS filtration of uranyl ion from its salts and further conduct an isotopy-ratio study on selected ion.

Method:

Uranyl nitrate salt, acetyl-acetonate or tributyl phosphate complexed solution were nanosprayed at 1 µL/min. Ions are filtered through 0.5 mm gap between two electrodes (15 mm × 4 mm) of a home-built DMS cell, interfaced to a commercial trap MS (Thermo LTQ-XL). The rf and dc potential were supplied to the DMS electrodes by a commercial Sionex electronic.

Preliminary Data:

A plasma-based ionization technique; Flowing atmospheric pressure after-glow (FAPA) was initially employed. While DMS method was set to scan dispersion voltages (DV) and compensation voltages (CV) within ~ 5 minutes, uranyl acetylacetonate ion [$[UO_2(AcAc)_2+H]^+$] was filtered out at a fixed DV and CV of 1000 V and -1.86 V, respectively. MS/MS of the filtered complexed ion produces uranyl ion (UO_2^+; m/z 270). Hence, isotopy studies were performed on UO_2^+. At DMS off and on, the $^{235}U/^{238}U$ ratio; SD; RSD were 0.00705; 4.25×10^{-4}; 5.9 % and 0.00727; 1.43×10^{-4}; 2.0 %, respectively. This result indicates that DMS is a promising analytical tool for isotopy measurement. For further investigation, we shall explore a continuous ionization source including nanospray for sample in solution; and a laser desorption-atmospheric pressure chemical ionization (LD-APCI) for surface ionization.

Novel Aspect: Nuclear forensic, isotopy ratio measurement, ambient ionization, differential mobility spectrometry for rapid screening of radionuclear debris.