Portfolio of methods and their applications

Analytical Method	Application	Type of material	Range	Typical relative uncertainty (1s) (%)
HRGS	Pu isotopic composition	Pu bearing items (including MOX)	> 0.1 gPu	^{238}Pu: 0.6 – 10 ^{239}Pu: 0.1 – 0.5 ^{240}Pu: 0.8 – 5 ^{241}Pu: 0.2 – 0.8
HRGS	^{241}Am/Pu ratio	Pu bearing items (including MOX)	^{241}Am/Pu <3 % 3<% ^{241}Am/Pu <20 %	0.2 – 10 [f] 5 – 10 [f]
HRGS	U isotopic composition	U bearing items without Pu and Am	>1 gU 0.2 % < ^{235}U <93 %	^{234}U: 1 – 10 ^{235}U: 0.5 – 10 ^{238}U: 0.5 – 10
HRGS	Activity of fission products in liquid waste	Diluted liquid waste	~1 kBq – 1 GBq /aliquot	5 – 50
KED	U content	U solution U solids [a]	50 to 400 g/L	1 to 0.2 [b]
KED	Pu content	Pu solution Pu solids [c]	20 to 300 g/L	1 to 0.2 [b]
HKED	U content	Spent fuel solution U/Pu solution	50 to 300 g/L	1 to 0.2 [b]
HKED	Pu content	Spent fuel solution U/Pu solution	0.2 to 50 g/L	1 to 0.2 [b]
XRF	U content	U solution U solids [d]	0.2 to 50 g/L	5 to 0.2 [b]
XRF	Pu content	Pu solution Pu solids [d]	0.2 to 50 g/L	5 to 0.2 [b]
XRF	U/Pu ratio	U/Pu solution U/Pu solids [d]	4 to 200 g/L	0.2 – 1 [e]
COMPUCEA	U content	Pure UN solutions UOx [d]	120 to 200 g/L	< 0.2
COMPUCEA	^{235}U enrichment	Pure UN solutions UOx [d]	0.2 % < ^{235}U <5 %	0.5 to 0.2
Calorimetry (combined with isotopic data from HRGS or TIMS)	^{241}Am mass Pu mass Pu and ^{241}Am content	Solid and inert Pu and Am bearing material (including MOX) Max. size 1.5cm x 1.5cm x 3cm	^{241}Am: 0.0005 to 0.4g Pu (~90% ^{239}Pu): 0.025 to 20g Pu (~55% ^{239}Pu): 0.003 to 3g ^{238}Pu: 0.0001 to	0.4 – 2

Analytical Method	Application	Type of material	Range	Typical relative uncertainty (1s) (%)
			0.08g	
TIMS - (TE)	U isotopic composition	U and U/Pu solutions U and U/Pu solids[d]	0.1 < ^{235}U < 93 wt% Minor Isotopes	DEU, Unat < 0.15 LEU, HEU < 0.07
TIMS - (TE)	Pu isotopic composition	Pu and U/Pu solutions U and U/Pu solids[d]	< 3 ^{238}Pu: 0.3– 1.5 wt% < 0.1 ^{239}Pu: 50 – 80 wt% < 0.2 ^{240}Pu: 10 – 30 wt% < 0.3 ^{241}Pu: 3 – 15 wt% < 0.3 ^{242}Pu: 1 - 5 wt%	
TIMS - (TE)	^{10}B/^{11}B ratio	Boric Acid B carbid	> 50 mg	0.10
TIMS - (MTE)	U isotopic composition	U solutions U solids[d]	0.1 % < ^{235}U < 20 %	^{233}U: not measured ^{234}U: < 0.5 ^{235}U: < 0.05 ^{236}U: < 5
IDMS	U content	U and U/Pu solutions U and U/Pu solids[d]	50 µg/g	< 0.16
IDMS	U isotopic composition	U and U/Pu solutions U and U/Pu solids[d]	0.1 < ^{235}U < 93 wt% Minor Isotopes	0.5 – 0.05 < 20
IDMS	Pu content	Pu and U/Pu solutions Pu an U/Pu solids[d]	5 µg/g	< 0.16
ICP-MS	Impurities	Solutions of nuclear fuels (UO_2, PuO_2, MOX)[b]	More than 70 elements from Li to Cm with detection limits from 1 ng/l to a few 100 ng/l	Depending on the matrix, the element and the concentration from 1 to over 50
ICP-MS	Radioactive impurities Assay and Isotopic Composition	Radioactive solutions (e.g. waste)	Ac, Th, U, Np, Pu, Am and Cm ng/l level	Assay: depending on the matrix, the element and the concentration from 1 % to over 10 Isotopic composition: > 0.1 – < 1 depending on isotope
ICP-MS	Impurities	Acidic and aqueous solutions	More than 60 elements from Li to U with detection limits from	Depending on the matrix, the element and the concentration from 1 to over 50

Analytical Method	Application	Type of material	Range	Typical relative uncertainty (1s) (%)
		Radioactive solutions	1 ng/l to a few 100 ng/l	
Fusion extraction/ Infrared Detection	C,O,N	C,O,N in U bearing samples	$1x10^{-6}$ to 0.02g of analyte ($1x10^{-6}$g/g < Mass Fraction < 0.4g/g) Minimum sample weight: 3x10mg	1 to 20
Density	density	Any liquid, including U and Pu bearing solutions, devoid of HF and free from precipitates	0.8 to 1.7 g/mL	approx. 0.05
Alpha spectrometry	$^{238}Pu/^{239}Pu$ ratio	Pu bearing material	> 5 µg/g ^{239}Pu	high burnup: 1.8 low burnup: 14

[a] sufficient material required to prepare 10 ml of a solution > 200 g/l, the solids are: UO_2, UO_3, U_3O_8 and U metal
[b] depending on the acquisition time (adjusted for age of source) and the concentration
[c] sufficient material required to prepare 10 ml of a solution > 50 g/l, the solids are: PuO_2 and Pu metal
[d] after dissolution and appropriate dilution
[e] depending on acquisition time, concentration and stability of the photon intensity from the X-ray tube
[f] function of counting statistics and Am abundance
[g] preferably no HF or HCl, because screws up UTEVA and TEVA separation