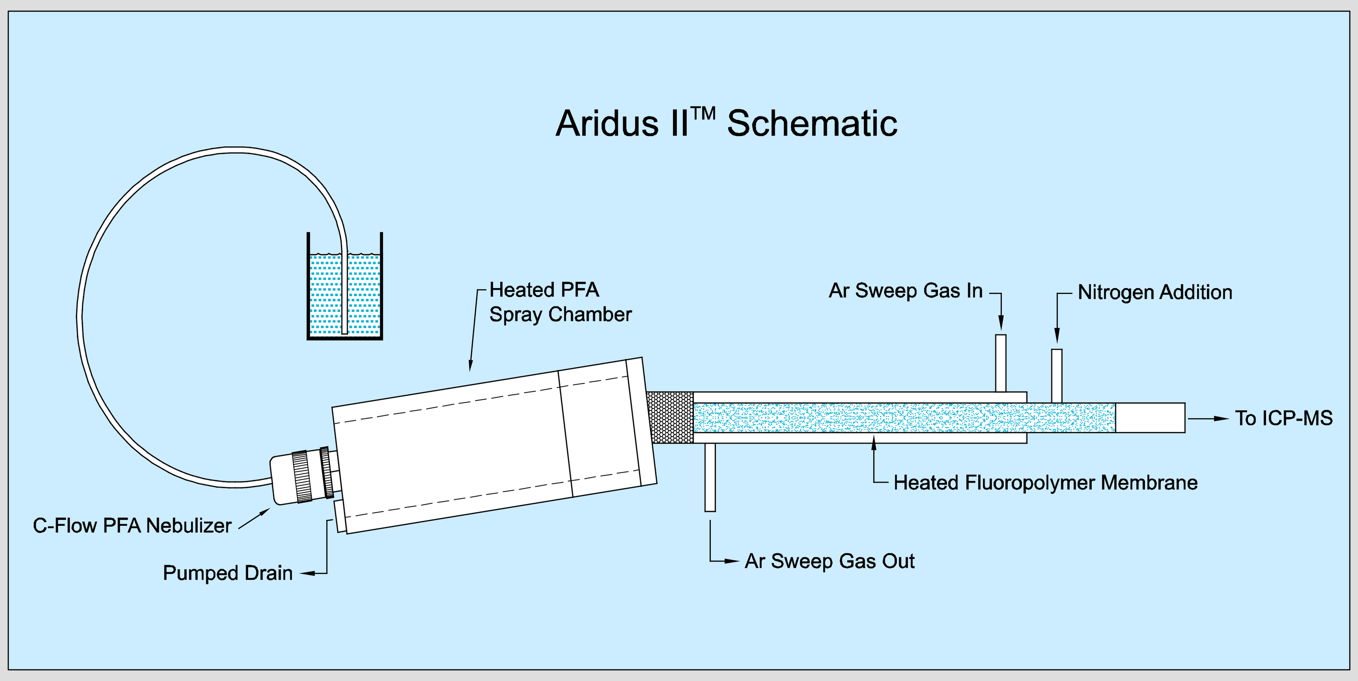
An Inert Desolvating Nebulizer System for Reduction of Matrix-Induced Oxide Interferences on Rare Earth Elements, Iridium, and Platinum Using Quadrupole Inductively Coupled Plasma Mass Spectrometry

Fred G. Smith Teledyne CETAC Technologies, Omaha, Nebraska 68144 USA e-mail: fsmith@cetac.com

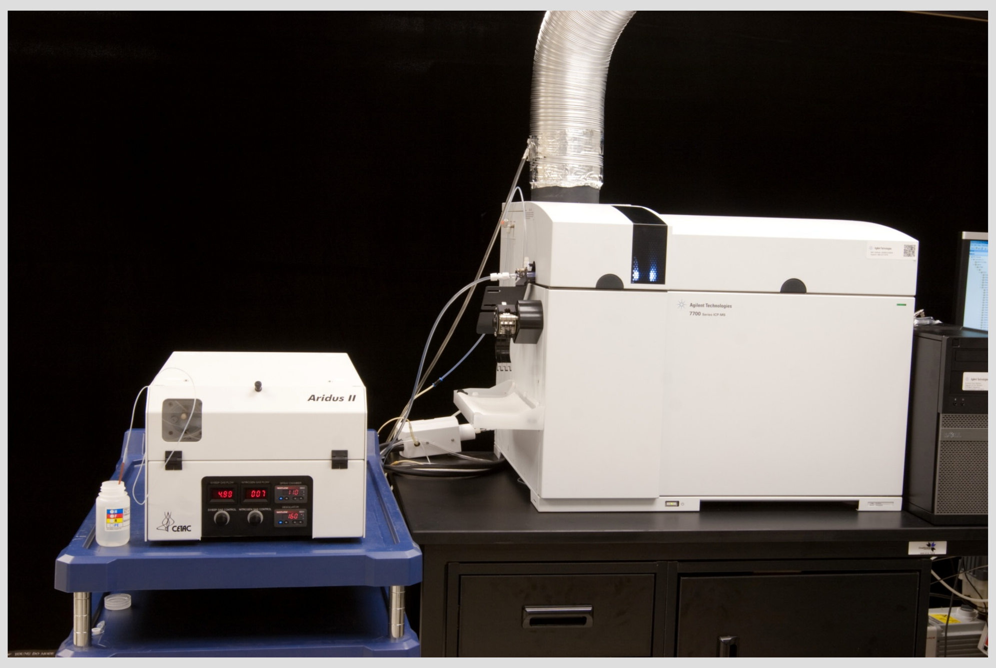
Abstract: This poster will examine the use of an inert low-flow desolvating nebulizer system for reduction of oxide mass spectral interferences that can occur in quadrupole inductively coupled plasma mass spectrometry (Q-ICP-MS). This nebulizer system uses an inert, low-flow nebulizer (100 microliters/min) coupled to an inert, heated membrane desolvator for efficient water vapor removal before sample aerosol injection to the Q-ICP-MS instrument. Water vapor from conventional nebulizer / spray chamber systems used with Q-ICP-MS can cause numerous mass spectral interferences. One general example is metal oxides formed from the combination of oxygen (from injected water) with sample matrix components. Two specific examples of metal oxide interferences will be investigated with and without membrane desolvation: Ba and Ce oxides on several low-mass rare earth elements (Sm, Eu, and Gd) and Hf oxides on iridium and platinum. Rare earth elements are critically important components of modern electronics (ex. magnets, lasers, cellular phones, computers) and iridium and platinum are widely used as chemical catalysts. Figures of merit for a conventional nebulizer / spray chamber and the inert desolvating nebulizer system will include operating conditions, interference intensities and reduction factors, background equivalent concentrations (BECs), instrument detection limits (IDLs), and limits of quantitation (LOQs).

Teledyne CETAC AridusII Desolvating Nebulizer System



Teledyne CETAC AridusII Schematic

AridusII – Front Door Open



Agilent 7700x Q-ICP-MS with AridusII

Selected BaO⁺ & CeO⁺ Interferences

- $^{137}Ba^{16}O^+$ interference on $^{153}Eu^+$ (^{153}Eu, 52.2%)
- $^{138}Ba^{16}O^+$ interference on $^{154}Sm^+$ (^{154}Sm, 22.7%)
- $^{140}Ce^{16}O^+$ interference on $^{156}Gd^+$ (^{156}Gd, 20.5%)
- $^{140}Ce^{16}OH^+$ interference on $^{157}Gd^+$ (^{157}Gd, 15.7%)
- $^{142}Ce^{16}O^+$ interference on $^{158}Gd^+$ (^{158}Gd, 24.8%)

% abundance in ( ).

Selected HfO⁺ Interferences

- $^{176}Hf^{16}O^+$ interference on $^{192}Pt^+$ (^{192}Pt, 0.79%)
- $^{177}Hf^{16}O^+$ interference on $^{193}Ir^+$ (^{193}Ir, 62.7%)
- $^{178}Hf^{16}O^+$ interference on $^{194}Pt^+$ (^{194}Pt, 32.9%)
- $^{179}Hf^{16}O^+$ interference on $^{195}Pt^+$ (^{195}Pt, 33.8%)
- $^{180}Hf^{16}O^+$ interference on $^{196}Pt^+$ (^{196}Pt, 25.3%)

% abundance in ( ).

Quad ICP-MS Operating Parameters

Q-ICP-MS:	Agilent 7700x
ICP RF Power:	1550 W
Sample Depth:	7.0 mm
Carrier Gas:	0.95 L/min
Nebulizer Pump:	0.1 rps, 0.4 mL/min
Makeup Gas:	0.10 L/min
Cell Gases:	Off
Nebulizer:	Glass Concentric (MicroMist)
Spray Chamber:	Scott-type, 2°C
Torch Injector:	Quartz, 2.0 mm i.d.
Resolution:	0.7 amu
Points/Peak:	3
Data Acquisition:	0.99s/mass, 5 replicates

Desolvating Nebulizer Parameters

Nebulizer System:	CETAC AridusII
ICP RF Power:	1550 W
Sample Depth:	4.5 mm
Carrier Gas:	0.80 L/min
PFA Nebulizer:	CFlow 100
Uptake Rate:	110 µL/min
Spray Chamber:	PFA, cylindrical
Cell Gases:	Off
Resolution:	0.7 amu
Spray Chamber Temp:	110°C
Membrane Oven Temp:	160°C
Ar Sweep Gas:	4.57 L/min
N_2 Addition Gas:	2 mL/min

ICP-MS Ion Optic Setting Comparison

Ion Optic	Standard Nebulizer	AridusII
Extract 1	0.0 V	-10.0 V
Extract 2	-200.0 V	-230.0 V
Omega Bias	-90 V	-130 V
Omega Lens	12.0 V	11.0 V
Cell Entrance	-30 V	-30 V
Cell Exit	-50 V	-60 V
Deflect	13.8 V	12.8 V
Plate Bias	-40 V	-60 V
OctP Bias	-8.0 V	-10.0 V
OctP RF	170 V	190 V
Energy Discrim.	5.0 V	5.0 V

Sample Solutions and Experiment Design

1. The ICP-MS (standard configuration) was first tuned for best sensitvity and a % CeO/Ce of 0.86%. Standard solutions containing 1, 2, 5, and 10 µg/L Eu, Gd, and Sm (all in 1% high-purity HNO_3) and 1, 2, 5, and 10 µg/L Ir and Pt (in 0.5% high-purity HCl) were then introduced to the ICP-MS (standard configuration) for calibration.

2. Solutions containing 1 mg/L Ba and Ce (in 1% HNO_3) and 1 mg/L Hf (in 0.5% HCl) were then introduced to the ICP-MS (standard configuration) as normal samples.

3. Background equivalent concentrations (BECs) were measured from the 1 mg/L Ba, Ce, and Hf solutions for ^{153}Eu, ^{154}Sm, ^{156}Gd, ^{157}Gd, ^{158}Gd, ^{192}Pt, ^{193}Ir, ^{194}Pt, ^{195}Pt, and ^{196}Pt.

4. The same measurements were repeated using the AridusII Desolvating Nebulizer System in place of the standard nebulizer and spray chamber. The ICP-MS and AridusII were tuned to provide maximum sensitivity (Li, Co, Y, Ce, Tl) and a % CeO/Ce of 0.025%.

Interference Signal Reduction

Element	m/z	Std Neb (cps)	AridusII (cps)	Reduction Factor
Eu	153	55,379	8,183	6.7
Sm	154	137,631	18,105	7.6
Gd	156	3,403,438	96,823	35.1
Gd	157	723,002	77,999	9.3
Gd	158	437,958	12,591	34.7
Pt	192	140,558	8,410	16.7
Ir	193	545,568	36,007	15.1
Pt	194	889,560	55,024	16.1
Pt	195	591,570	41,882	14.1
Pt	196	1,088,101	63,781	17.0

BECs Without & With AridusII

Element	m/z	Std Neb (µg/L)	AridusII (µg/L)	Reduction Factor
Eu	153	0.18	0.02	9.0
Sm	154	1.14	0.07	16.2
Gd	156	31.74	0.38	83.5
Gd	157	8.72	0.39	22.3
Gd	158	3.31	0.04	82.7
Pt	192	68.55	2.16	31.7
Ir	193	2.35	0.08	29.3
Pt	194	10.44	0.34	30.7
Pt	195	6.71	0.25	26.8
Pt	196	16.37	0.51	32.1

IDLs and LOQs with AridusII

Element	m/z	IDL (µg/L)	LOQ (µg/L)
Eu	153	0.0002	0.0007
Sm	154	0.0005	0.0016
Gd	156	0.004	0.0013
Gd	157	0.008	0.026
Gd	158	0.0007	0.002
Pt	192	0.07	0.23
Ir	193	0.003	0.01
Pt	194	0.02	0.07
Pt	195	0.008	0.026
Pt	196	0.02	0.07

Notes and Observations - I

Sample Uptake Rates: The liquid sample uptake rate of the CFlow PFA nebulizer (110 µg/L, self-aspiration) used with the AridusII was ~ ¼ the rate of the standard glass concentric nebulizer (400 µg/L, pumped) used with the ICP-MS.

Sampling Position: The optimum ICP-MS sample depth position changed from 7.0 mm (standard nebulizer) to 4.5 mm with the AridusII.

Ion Optic Voltages: Four ICP-MS ion optic voltages did optimize at significantly different potentials with the AridusII: Extract 1, Extract 2, Omega Bias, and Plate Bias.

Nitrogen Addition Gas: A nitrogen addition gas flow of 2 mL/min provided a signal enhancement of approximately 2x with the AridusII vs. the standard nebulizer.

Notes and Observations - II

Interference Intensities: Using the AridusII, BaO⁺ signal reductions range from 6.7 to 7.6 (avg. 7.1), CeO⁺ signal reductions range from 9.3 to 35.1 (avg. 26.3) ; HfO⁺ signal reductions range from 14.1 to 17.0 (avg. 15.8).

Background Equivalent Concentrations (BECs): BEC reduction factors using the AridusII range from 9.0 (^{153}Eu) to 83.5 (^{156}Gd), with an overall average reduction factor of 36.4.

Instrument Detection Limits (IDLs) & Limits of Quantitation (LOQs): IDLs and LOQs are based on 3x the std. dev. of the background signal and 10x the std. dev. of the background signal, respectively.

Instrument Detection Limits (IDLs): IDLs with the AridusII range from 0.2 ng/L (^{153}Eu) to 70 ng/L (^{192}Pt), with an overall average IDL of 13.4 ng/L.

Summary:

1. Without extensive method development using cell gases, the coupling of a quad ICP-MS with an AridusII Desolvating Nebulizer is very effective for improvement of LOQs for Eu, Sm, Gd, Ir, and Pt in a 1 mg/L Ba, Ce, or Hf matrix to a range of 0.7 ng/L (^{153}Eu) to 230 ng/L (^{192} Pt). The average LOQ across the five analyte elements is 43.7 ng/L.

2. Other important quad ICP-MS operating parameters do need to be reoptimized when using the AridusII: sample depth (torch) position and selected ion optic voltages.

3. Optimization of the AridusII nebulizer gas (for the CFlow PFA nebulizer), the argon sweep gas (for the membrane desolvator), and the AridusII N_2 addition gas allow for best analyte signal enhancement and oxide interference reduction.