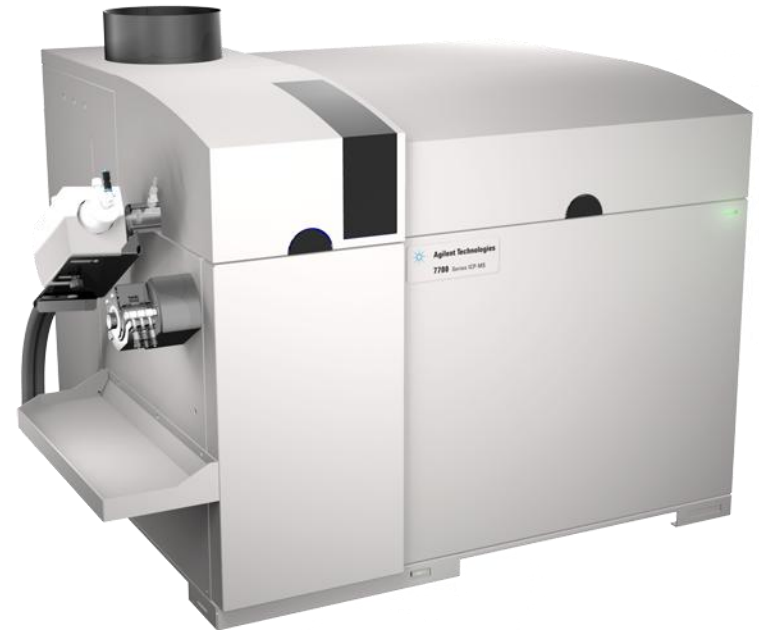


Part 2 Expanding the Applications Envelope of Helium Mode ICP-MS with ORS³

- Simpler
- Faster
- More accurate than ever before



Extending the Applications of He* Mode using ORS³



He mode has been confirmed as the only reliable cell mode for removing unidentified and variable interferences in complex samples

But until now, reaction gases were sometimes needed for special analytes or applications,

- Low level Se, Si and S

With ORS³, improved He mode operation allows:

- Low ppt measurement of Se, including Se isotope ratio analysis (no problems of SeH formation, which occurs with H₂, NH₃, CH₄, etc.)
- Low/sub-ppb DLs for ²⁸Si, ³¹P and ³⁴S.
 - Allows Si, P and S to be measured at low ppb levels in He mode (same cell gas as most other analytes)

***Hydrogen mode option no longer required for routine analysis**

7700x – Largest Analytical Range of any ICP-MS

Calibration ranges

Hg (10 – 200ppt) – no gas Mode

As (10 – 200 ppt) – He Mode

Se (10 – 200 ppt) – He Mode

Na (0.05 – 1000 ppm) – He Mode

Overall calibration range 10ppt (Hg, As)
to 1000 ppm (Na) in a single method
- *without* manual attenuation of
sensitivity to increase working range

Na

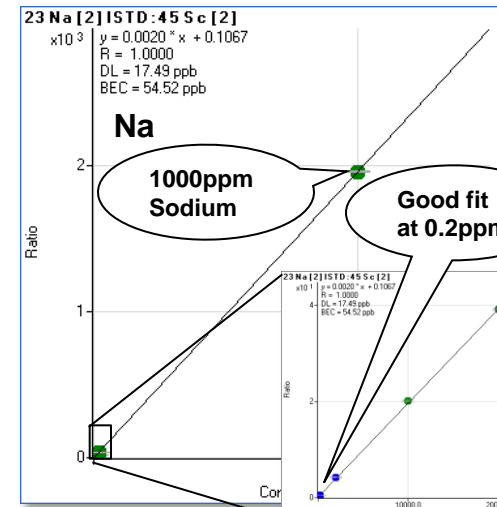
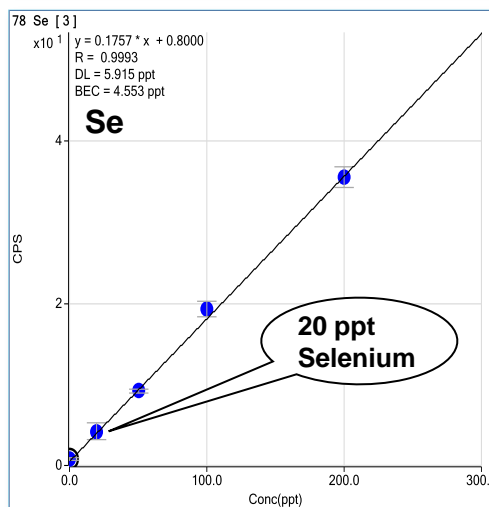
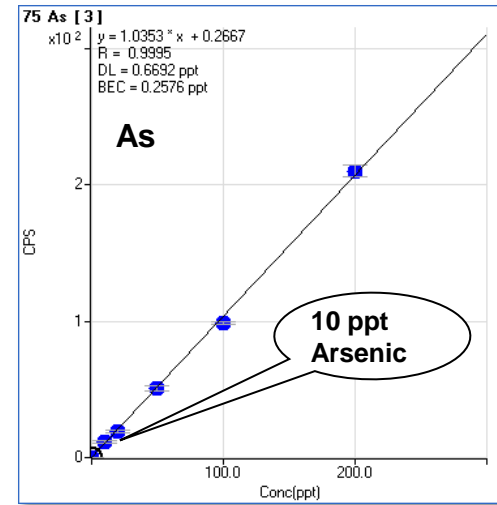
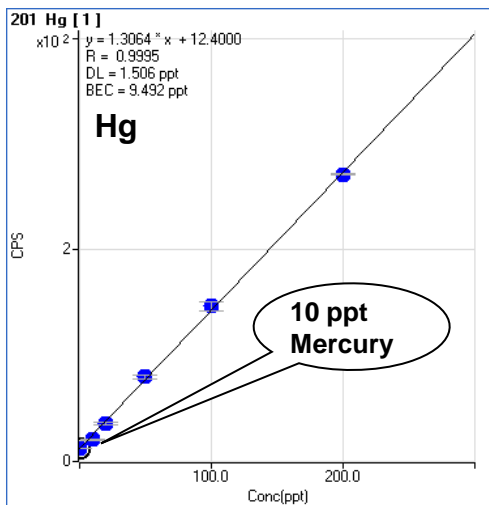
Typically, ICP-MS cannot measure
above 200ppm Na without changing
quad resolution or ion lens settings

Hg

Hg DL on 7700x is about 2ppt – 7700x
can QUANTITATE at 10ppt!

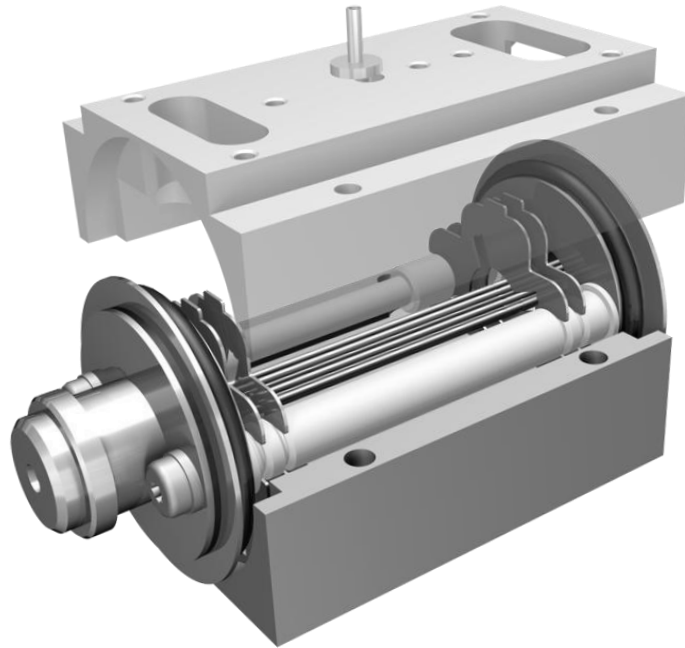
**7700x can do both of the above in the
same run!**

These 4 plots were obtained under the same analytical conditions
on the 7700x – only the gas mode (no gas for Hg) changed

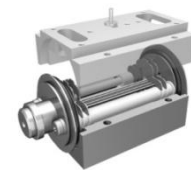


Superior Helium Mode Performance for Difficult Elements

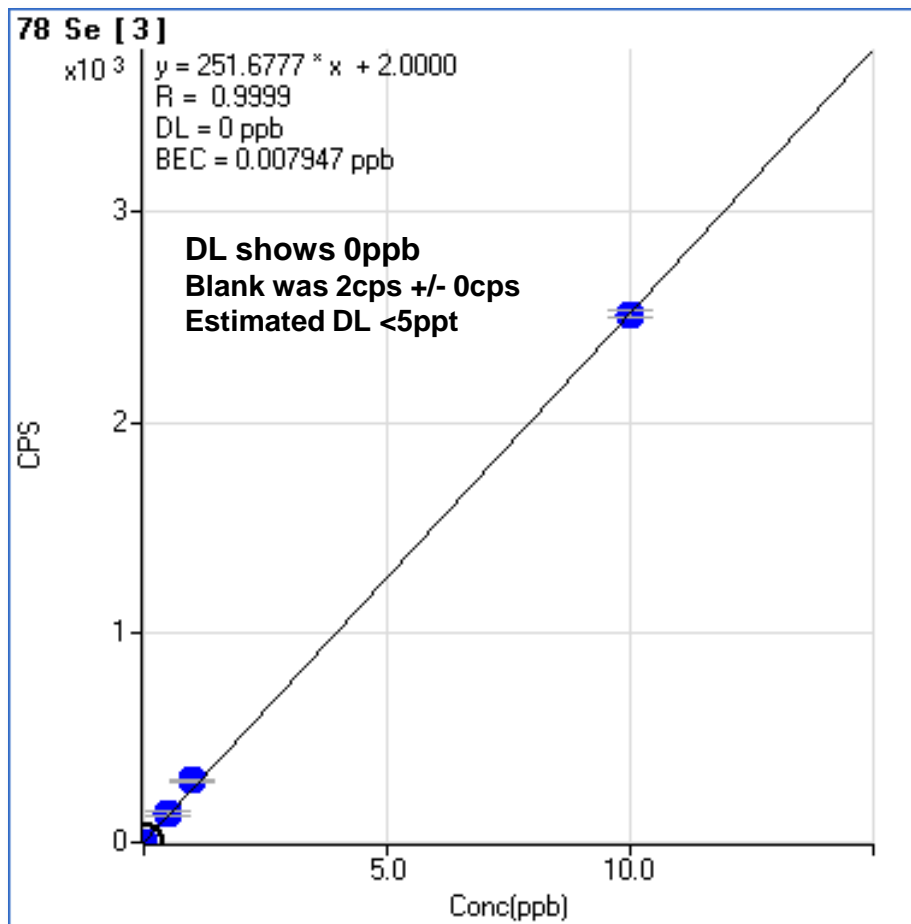
All of the following calibrations, BECs and DLs were performed in Helium mode ONLY using ORS³.



Se Calibration in He Mode with ORS³



Calibration for ⁷⁸Se from 0 to 10ppb in 2% HCl and 100 ppm Ca



Isotope	BEC (ppt)	DL (ppt)
78	<8	N/A

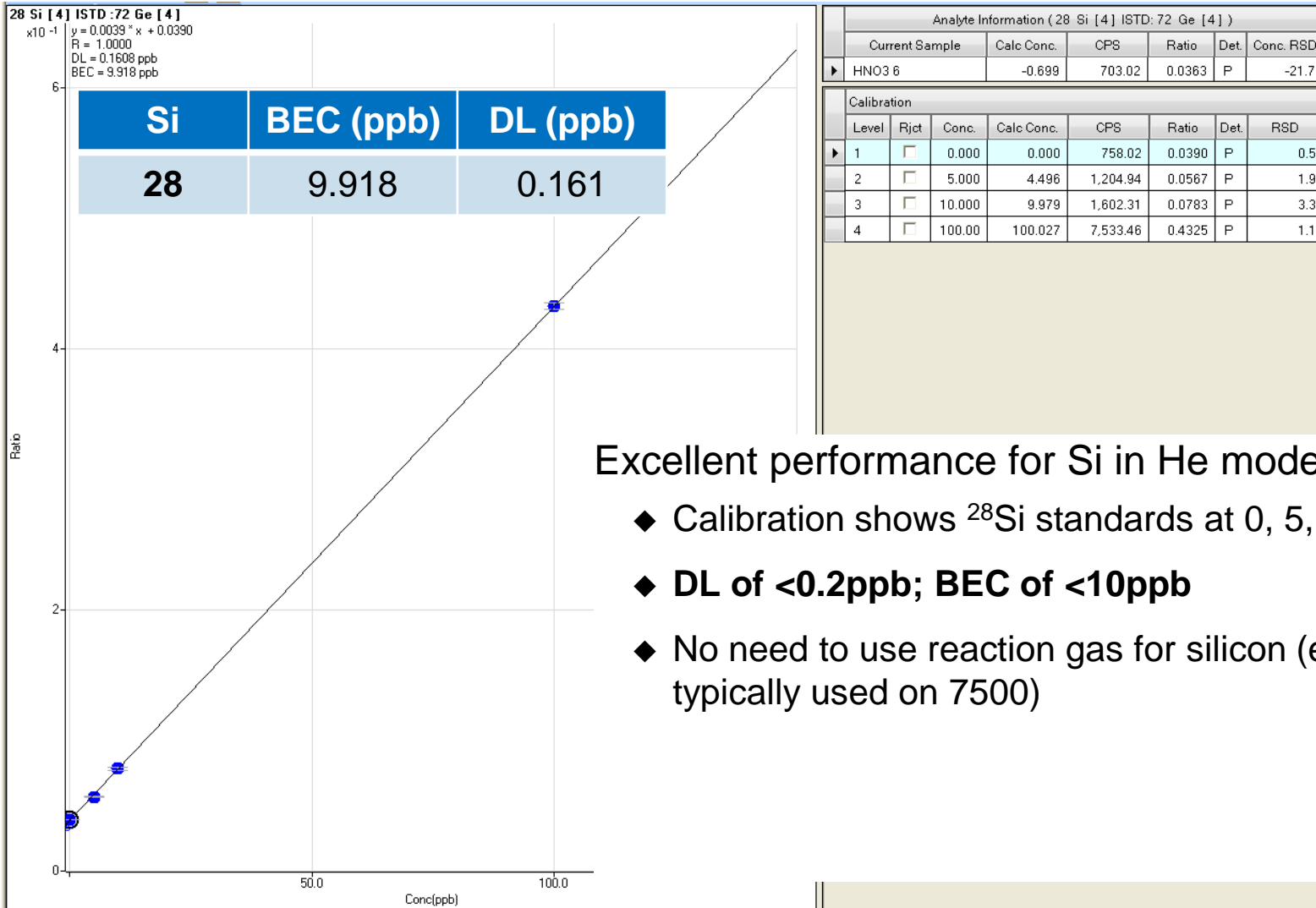
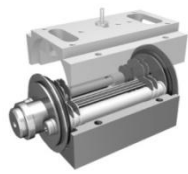
⁴⁰Ar³⁸Ar, ⁴³Ca³⁵Cl and ⁴⁰Ar³⁷ClH are removed simultaneously – only possible using He mode.

No SeH or BrH formation (problem with all reaction gases, when Se 80 and 82 isotopes are measured)

High sensitivity permits single digit ppt DLs for Se in He mode

Silicon in He Mode with ORS³

Calibration for ²⁸Si from 0 to 100ppb in 1% HNO₃ in He Mode

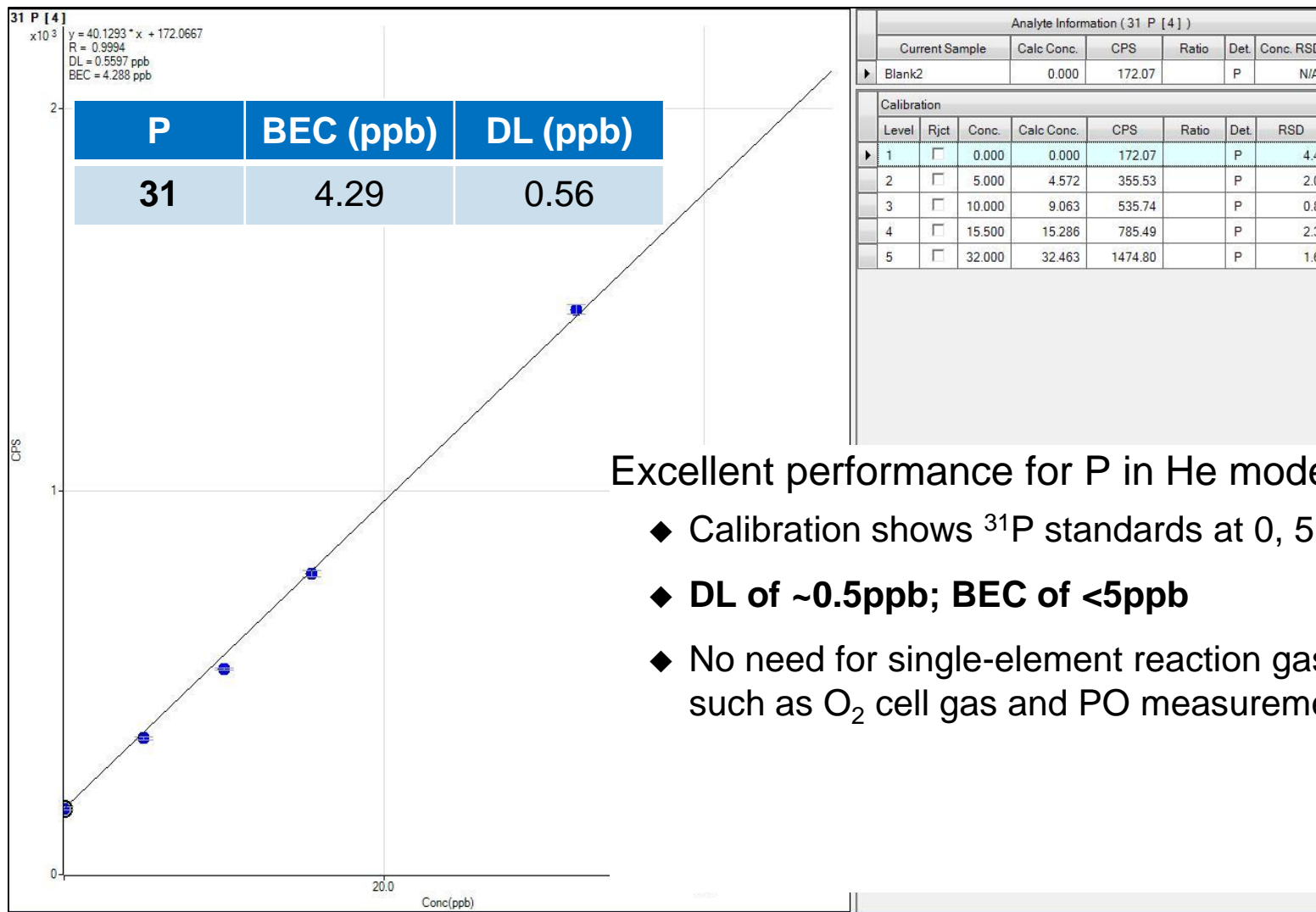
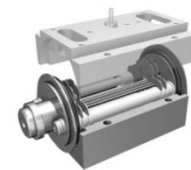


Excellent performance for Si in He mode with ORS³

- ◆ Calibration shows ²⁸Si standards at 0, 5, 10 & 100ppb
- ◆ DL of <0.2ppb; BEC of <10ppb
- ◆ No need to use reaction gas for silicon (e.g. H₂ mode typically used on 7500)

Phosphorus in He Mode with ORS³

Calibration for ³¹P from 0 to 10ppb in 1% HNO₃/0.5% HCl in He Mode

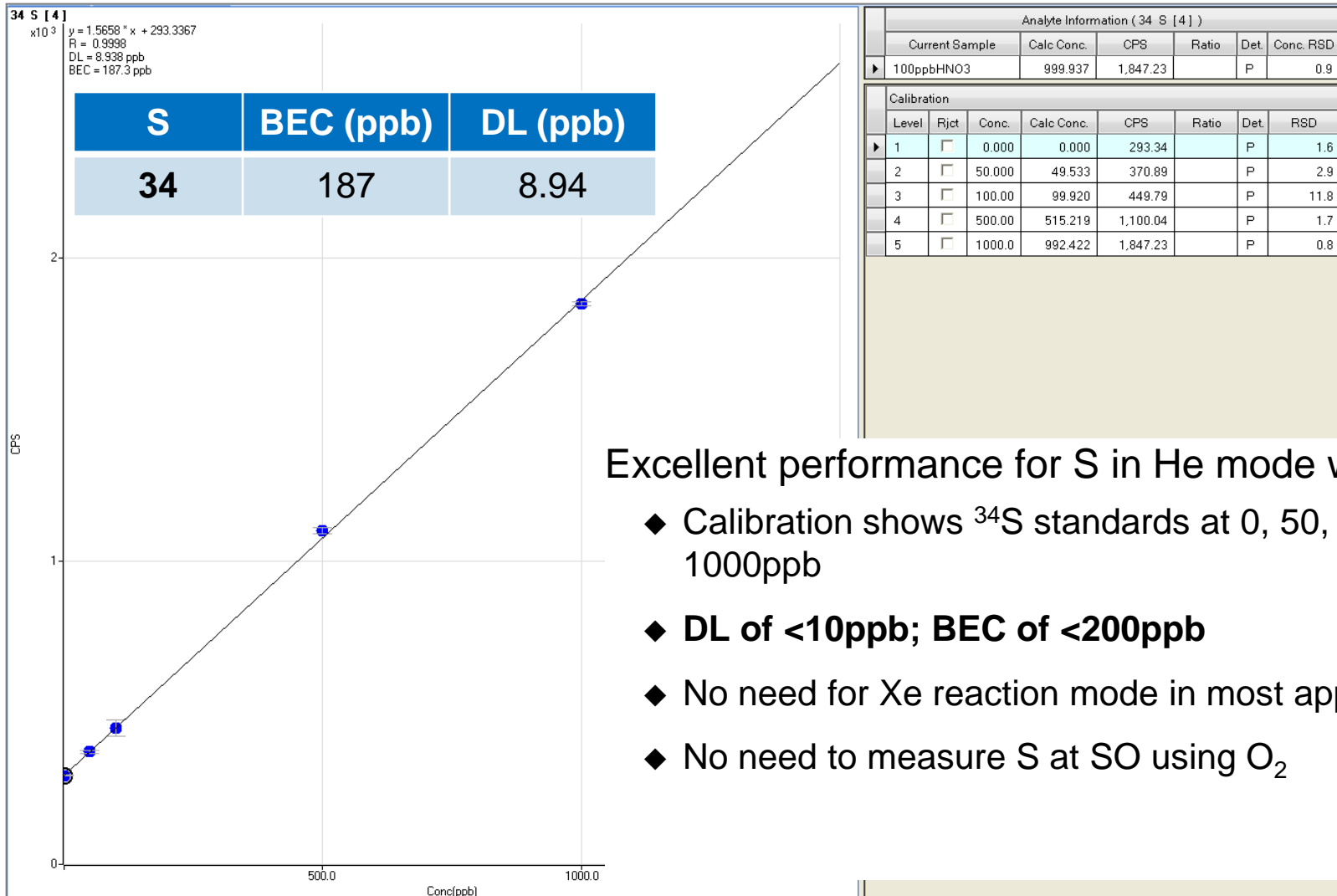
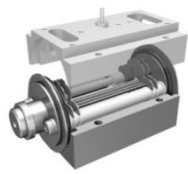


Excellent performance for P in He mode with ORS³

- ◆ Calibration shows ³¹P standards at 0, 5, 10, 15, 30ppb
- ◆ **DL of ~0.5ppb; BEC of <5ppb**
- ◆ No need for single-element reaction gas conditions, such as O₂ cell gas and PO measurement at mass 47

Sulfur in He Mode with ORS³

Calibration for ³⁴S from 0 to 1000ppb in 1% HNO₃ in He Mode



Excellent performance for S in He mode with ORS³

- ◆ Calibration shows ³⁴S standards at 0, 50, 100, 500 & 1000ppb
- ◆ **DL of <10ppb; BEC of <200ppb**
- ◆ No need for Xe reaction mode in most applications
- ◆ No need to measure S at SO using O₂

Putting It All Together

Finally: Simple, one cell gas, interference-free ICP-MS for real world sample analysis

One Configuration
(standard – robust plasma conditions)

One gas mode* (helium collision)

One method for waters, soils, wastes

28 elements in less than 3.5 minutes per run

* Plus no gas mode for non-interfered elements

Test Sequence – 190 Total Analyses in 11.0 hours

Single Initial Calibration

CCV/CCB repeated every 10 samples

Periodic Calibration Check (CCV) and Blank Check (CCB)

MDL Replicates (10)

NIST1643d

Tap Water

Bottled Spring Water

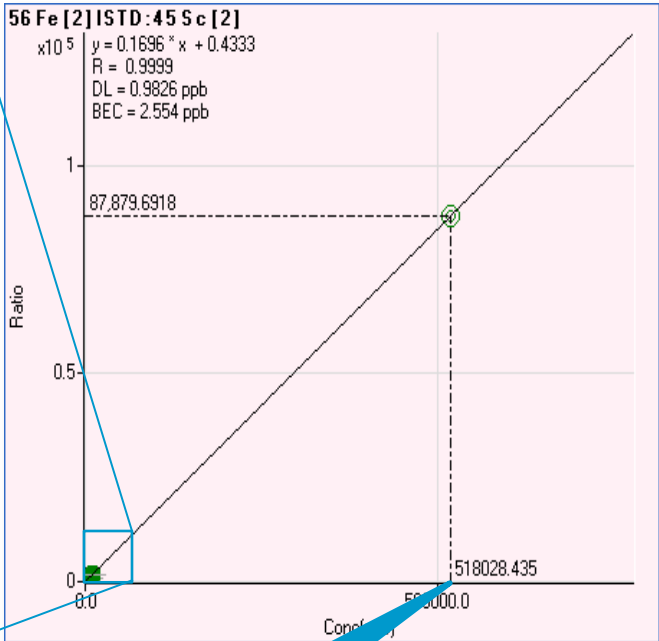
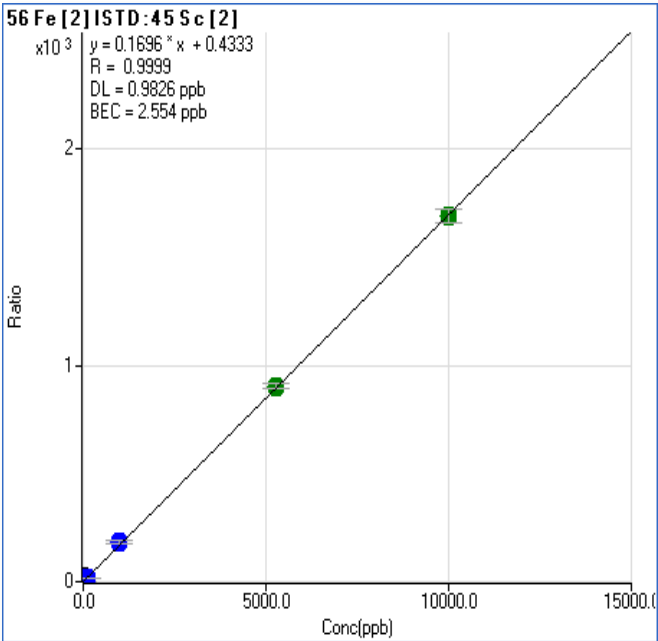
2 High TDS Bottled Mineral Waters

Sample block repeated 28 times

Excellent Linear Range for ^{56}Fe in He Mode at 50x the Upper Calibration Limit – reduced need for reruns due to over range samples

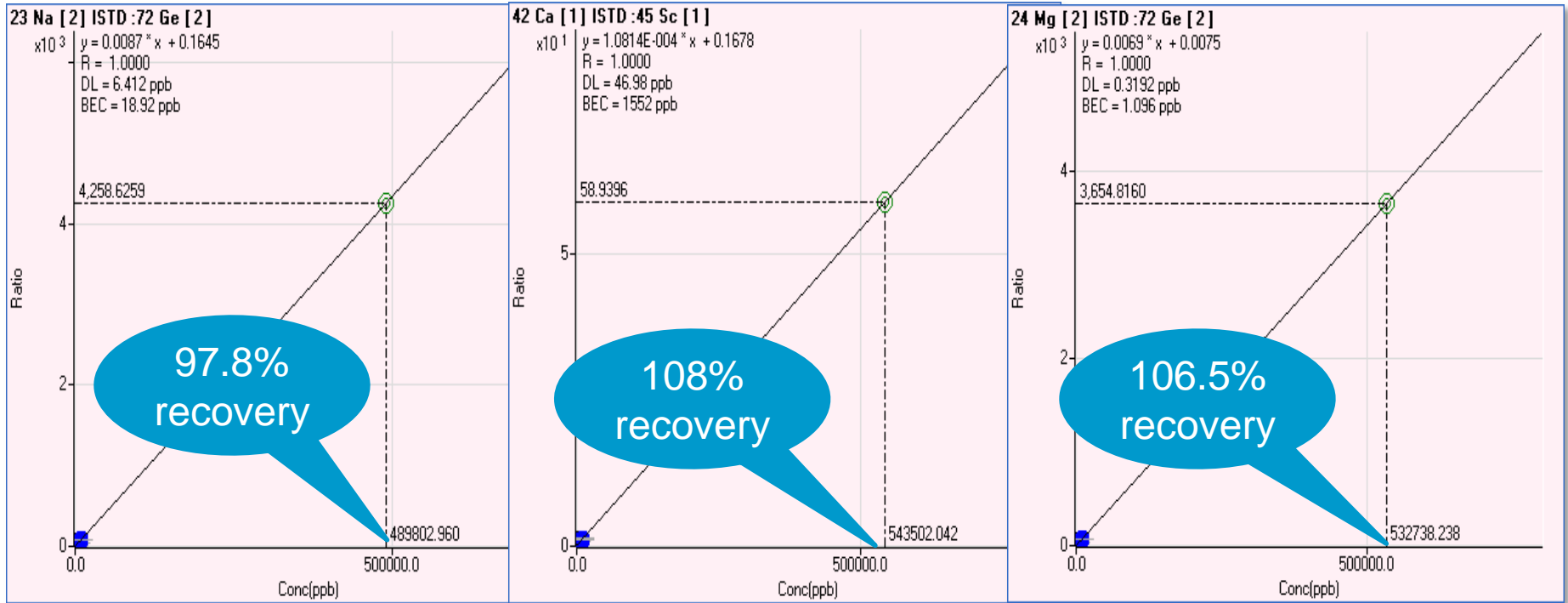
Fe Calibration on left up to 10 ppm

500 ppm linear range sample measured against curve on right resulted in 518 ppm (104% recovery)



104% recovery

Na, Ca, Mg measured at 50x the Upper Calibration Level (500 ppm each)



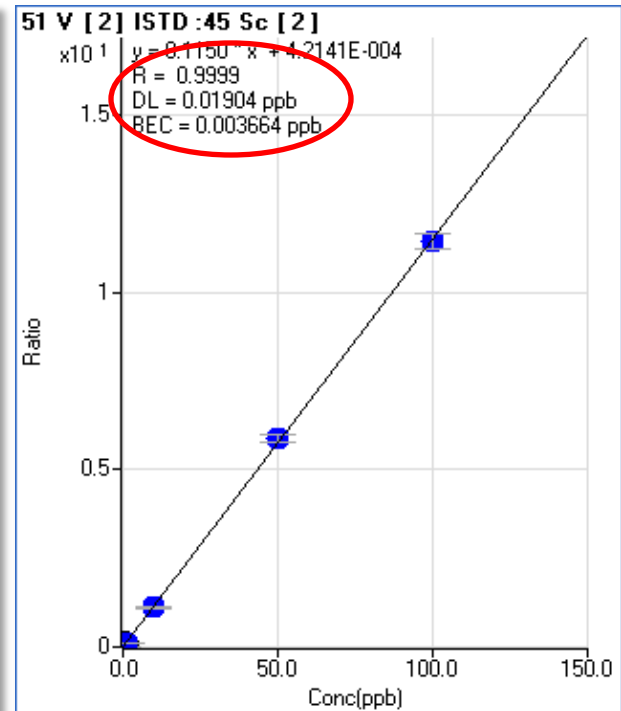
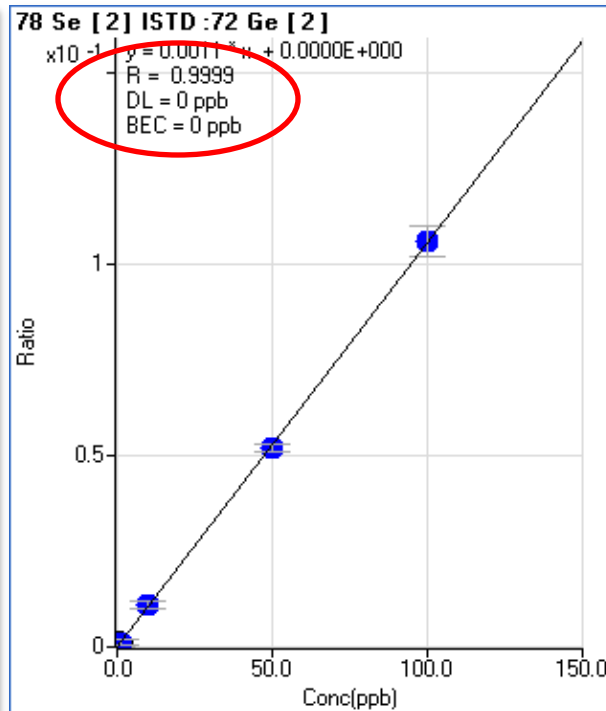
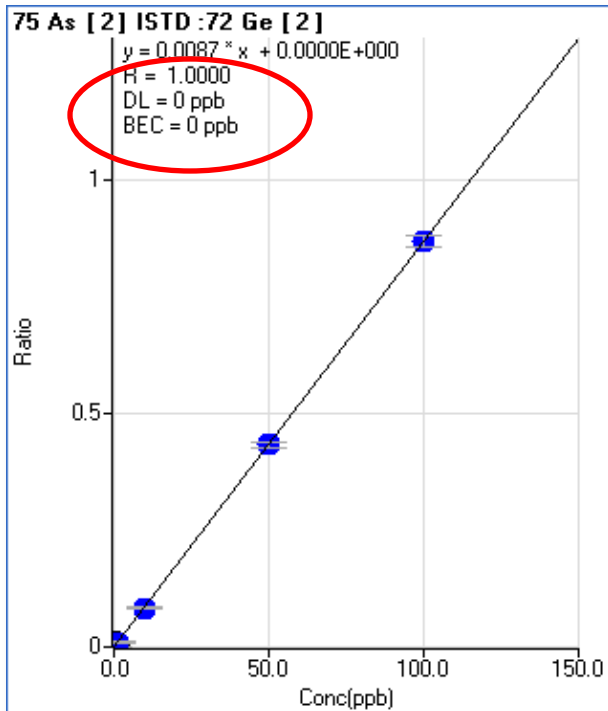
Wide linear dynamic range permits accurate quantification far beyond calibration range

- minimizes need for extremely high calibration levels
- reduces need for dilution and re-analysis of over range samples

Trace Element Sensitivity Under Identical Conditions – calibration 0.1 to 100 ppb (same sequence)

Under identical conditions in the same sequence, the backgrounds for As and Se are “zero” with single digit ppt DLs

Even vanadium in HCl matrix has DL=19 ppt and BEC=3.6ppt in He mode without the requirement for reactive gases i.e NH₃/He

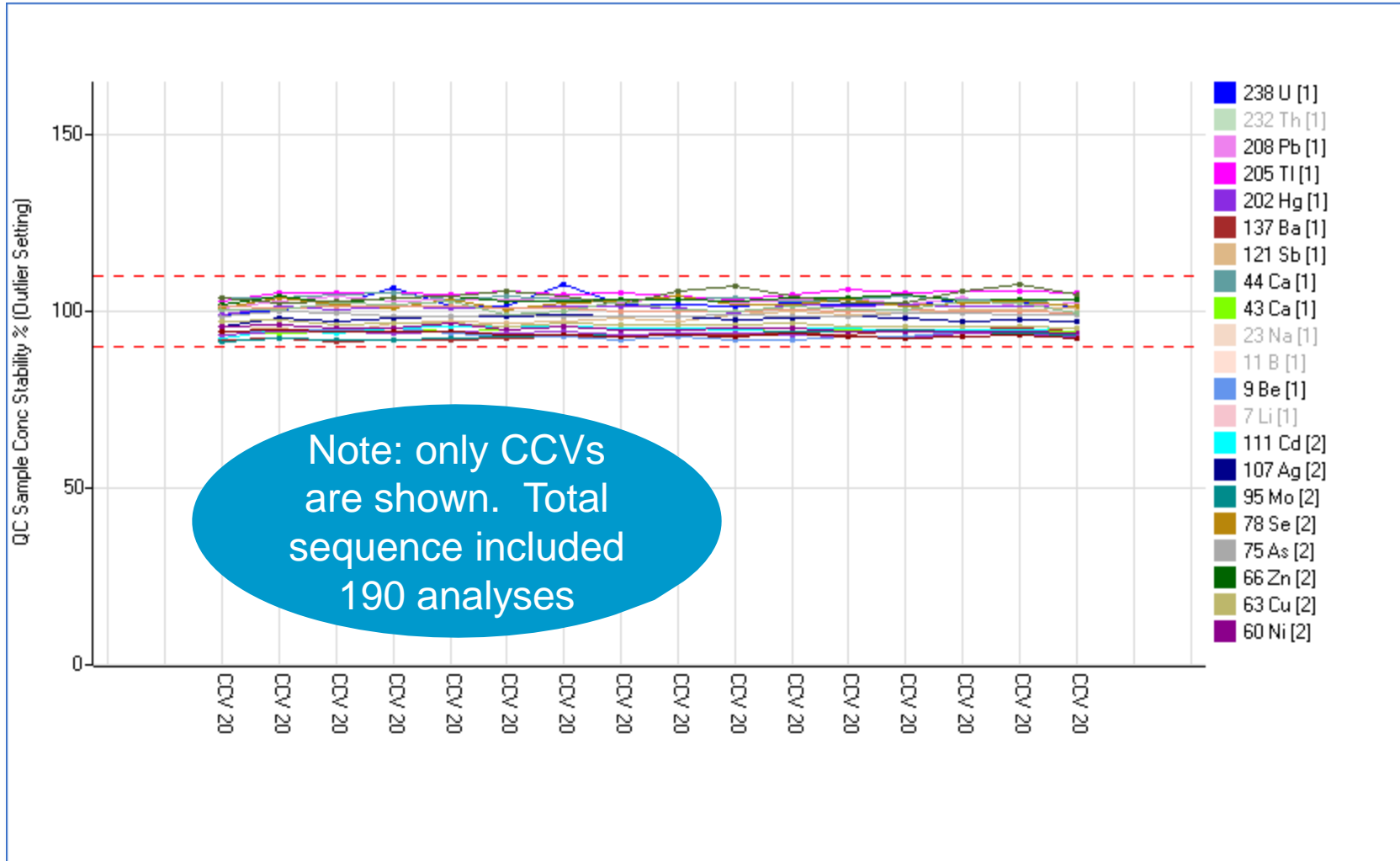


Method Detection Limits - 3σ (n = 10) in Parts Per Billion for Drinking Waters (in 1% HNO₃/0.5% HCl)

Element	Mass	MDL (ppb)	Cell mode	Element	Mass	MDL (ppb)	Cell mode
Be	9	0.005	No gas	Zn	66	0.014	He
B	11	0.005	No gas	As	75	0.011	He
Na	23	0.058	No gas	Se	78	0.017	He
Mg	24	0.002	No gas	Sr	88	0.002	He
Al	27	0.007	No gas	Mo	95	0.006	He
K	39	0.076	He	Ag	107	0.002	He
Ca	44	0.090	No gas	Cd	111	0.002	He
V	51	0.014	He	Sb	121	0.006	He
Cr	52	0.004	He	Ba	137	0.005	He
Mn	55	0.008	He	Hg	202	0.001	He
Fe	56	0.014	He	Tl	205	0.002	He
Co	59	0.004	He	Pb	208	0.001	He
Ni	60	0.014	He	Th	232	0.001	He
Cu	63	0.002	He	U	238	0.001	He

- All elements except low mass non-interfered elements were run in helium mode
- Low mass, non-interfered elements run in no gas mode
- No correction equations used

Continuing Calibration Verification (CCV) Recoveries All Within EPA +/- 10% Limits



NIST 1643e Recoveries - Mean (n = 28)

Run at 1/10 dilution

Excellent accuracy and precision even at concentrations as low as 0.09 ppb (Ag) in diluted sample

%RSDs typically 2% or less over entire 190 sample sequence (n=28)

Note excellent isotopic agreement for elements with different interferences on multiple isotopes such as Cr and Fe

Element / mode	Measured (ppb)	RSD (%)	Recovery (%)
9 Be	14.441	2.0	103.3
11 B	156.309	1.6	99.0
23 Na	19581.645	2.7	94.4
24 Mg	7376.627	2.9	91.8
27 Al	137.544	2.8	97.0
39 K	2043.588	0.9	100.5
44 Ca	34251.973	2.6	106.0
51 V	36.680	0.7	96.9
52 Cr	19.828	1.0	97.2
53 Cr	19.709	0.7	96.6
55 Mn	38.530	0.6	98.9
56 Fe	100.931	1.2	102.9
57 Fe	100.233	1.4	102.2
59 Co	25.843	0.6	95.5
60 Ni	58.263	0.7	93.4
63 Cu	21.133	0.8	92.8
66 Zn	73.241	0.5	93.3
75 As	59.987	2.2	99.2
78 Se	10.913	2.8	91.2
88 Sr	301.510	4.5	93.3
95 Mo	114.912	0.6	94.7
107 Ag	0.936	1.4	88.1
111 Cd	6.320	1.0	96.2
121 Sb	56.160	0.5	96.3
137 Ba	617.007	1.0	113.4
205 Tl	6.005	0.7	99.2
208 Pb	18.870	0.2	96.1

EPA 6020 Analysis of NIST Soil Digests

Combining HMI with Discrete Sampling for Ultimate Performance* in High TDS Samples (up to 1% TDS)

Sample prep (NIST soil CRMs 2710 and 2711 – Montana soils)

EPA 3051⁽¹⁾ Microwave assisted digestion using nitric plus hydrochloric acid

0.5g soil + 9ml HNO₃ + 3ml HCl → 50ml final volume

Sample Analysis

Agilent 7700x ICP-MS with ISIS-DS for discrete sampling

Standard robust plasma conditions

Standard Ni cones

Standard glass concentric nebulizer

Helium + no gas modes

***Total run to run time 1.8 minutes/sample**



(1) 3051a is not intended to provide “total” metals content due to insoluble silicates etc in soils. NIST provides “total” certified concentration which requires complete digestion using HF as well as median leachable recoveries by round robin using nitric/HCl digestion.

Test Sequence – 135 Total Analyses in 4.05 hours*

CCV / CCB repeated every 10 samples

Single initial calibration

Periodic Calibration Check (CCV) and Blank Check (CCB)

NIST1643d

ICS-A

ICS-AB

NIST 2710 Montana Soil Digest

Blank (to monitor carryover)

NIST 2711 Montana Soil Digest

Blank

Soil Prep Blank

Sample block repeated 12 times

*Total run time:
1.8 minutes per sample

In Summary: Agilent 7700 with ORS³

– Advancing ICP-MS Performance

Simpler

- One configuration, one method, all analytes, any matrix – no special gas modes or optimizations
- Widest dynamic range of any quadrupole ICP-MS – less dilution required

Faster

- Only 1 or 2 cell modes required (He and no gas) - reduced stabilization time between modes
- High sensitivity permits short integration times
- With ISIS-DS run times as short as 1 minute are possible

More Accurate

- Absolute confidence in interference removal - even in unknown matrices
- No reactive gases – no new interferences, no loss of analyte due to unwanted reactions

THANK YOU

QUESTIONS?