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ICP | ICPMS | AA

Fully Automated Total Metals and Elemental Speciation Single Platform Introduction System for ICP-MS

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Elemental Scientific, Inc. - Atlanta (ESI HQ are located in Omaha, NE)

Elemental Scientific, Inc. (ESI)

Elemental Scientific, Inc.
Omaha, NE, USA

Elemental Scientific

Elemental Scientific LASERS

MEINHARD®
An Elemental Scientific Glassblowing Company

Setting the Pace in Automation

1999 — ESI
PFA microflow nebulizers & sample intro

2002 — apex
10x improvement in sensitivity

2003 — Scout
Online remote sampling technology

2005 — Autosampler
Ultraclean, intelligent autosampler

2006 — *FAST*
High throughput doubles productivity

2008 — seaFAST
Inline chemistry

2009 — MP²
Accurate flow from low mL/min to 10mL/min

2012 — prepFAST
Inline, automated dilution system

2013 — scoutDX
Remote real time trace metals monitoring

2014 — prepFAST S
Automated introduction of pure semiconductor chemicals

2015 — PLASMATRAX
Automated sample identification and tracking system

2016 — apex Ω
High sensitivity sample introduction system

2017 — prepFAST IC
Automated Speciation and Total Metals Analysis

2017 — scoutISA
Inline silicon analyzer

2017 — ESL
Newly acquired Laser Ablation Division

2018 — scoutHSN
High selectivity nitride analyzer

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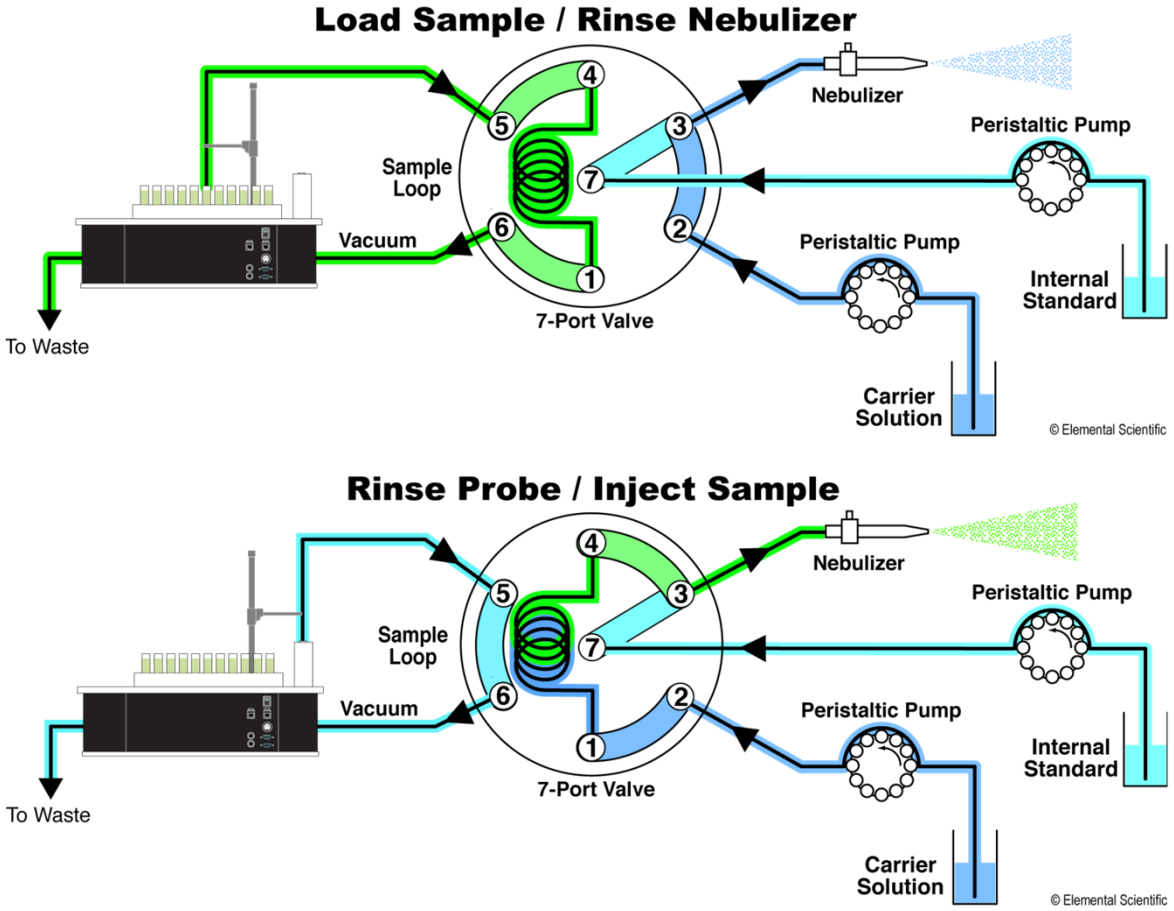
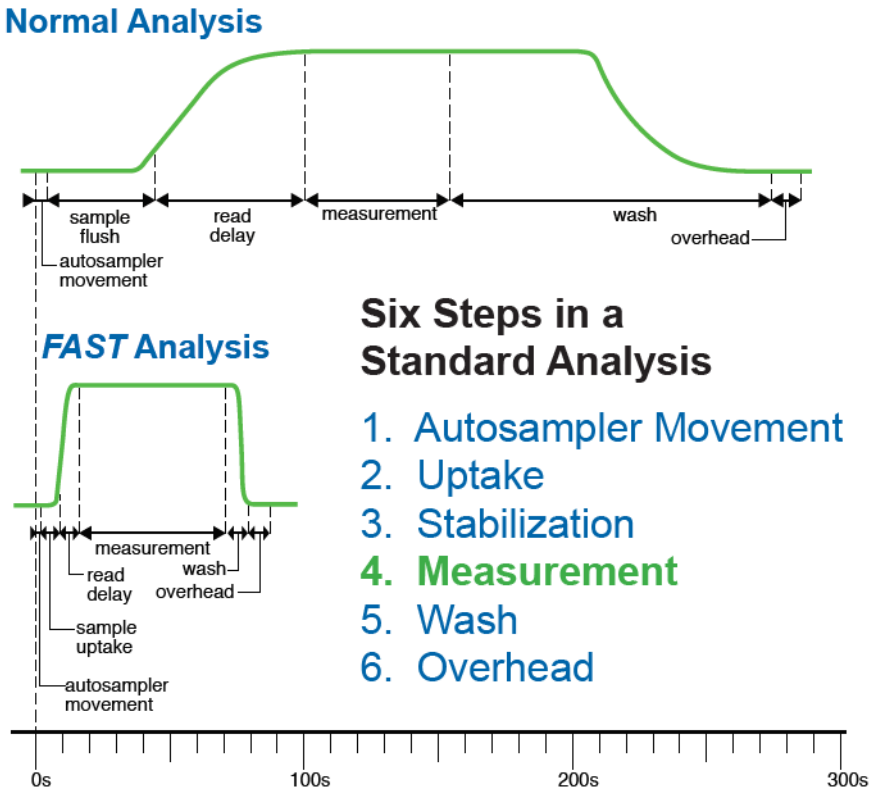
FAST - “Automated Sample Introduction”

What is *FAST*?



Faster Analysis = More Productive



Six Steps in a Standard Analysis

1. Autosampler Movement
2. Uptake
3. Stabilization
4. **Measurement**
5. Wash
6. Overhead

Traditional Autosampler = 5 min per sample
ICP-MS Method = 50 s
4 min 10 s = sample flush, read delay, wash

Traditional Autosampler = 288 samples in 24 h

FAST Autosampler = 1 min 30 sec per sample
ICP-MS Method = 50 s
40 s = sample flush, read delay, wash

Reduction of 200 s per sample

FAST Autosampler = 1200 samples in 24 h

Assuming you run samples 24 h straight
1200 vs 288 = 417% More Productive with FAST

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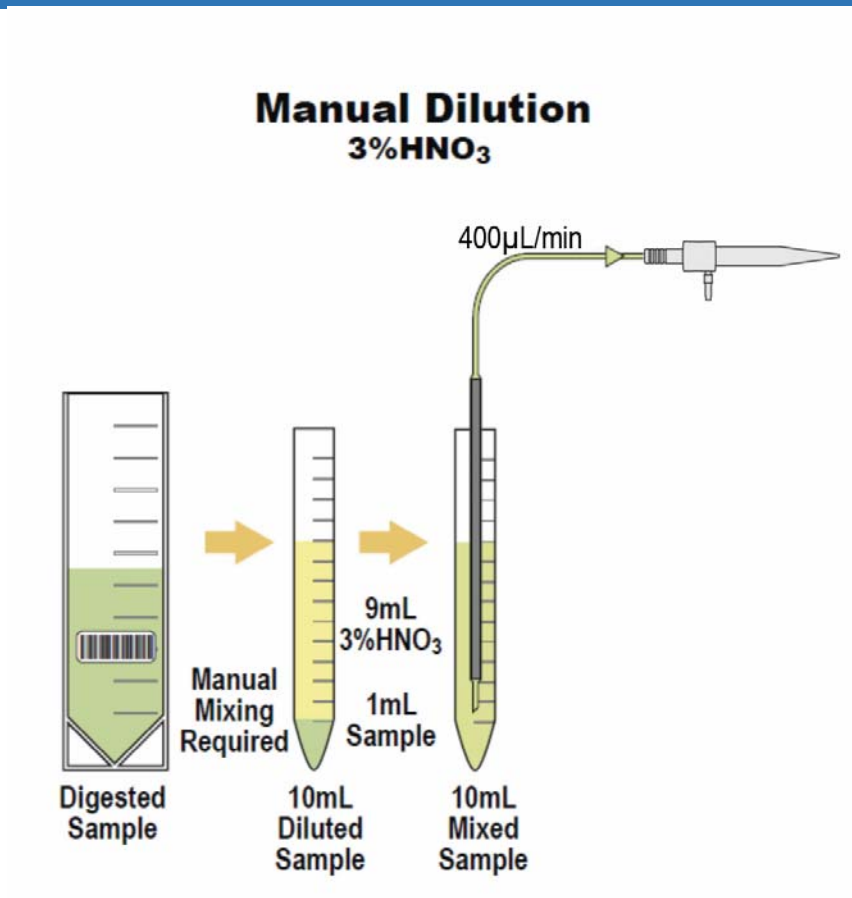
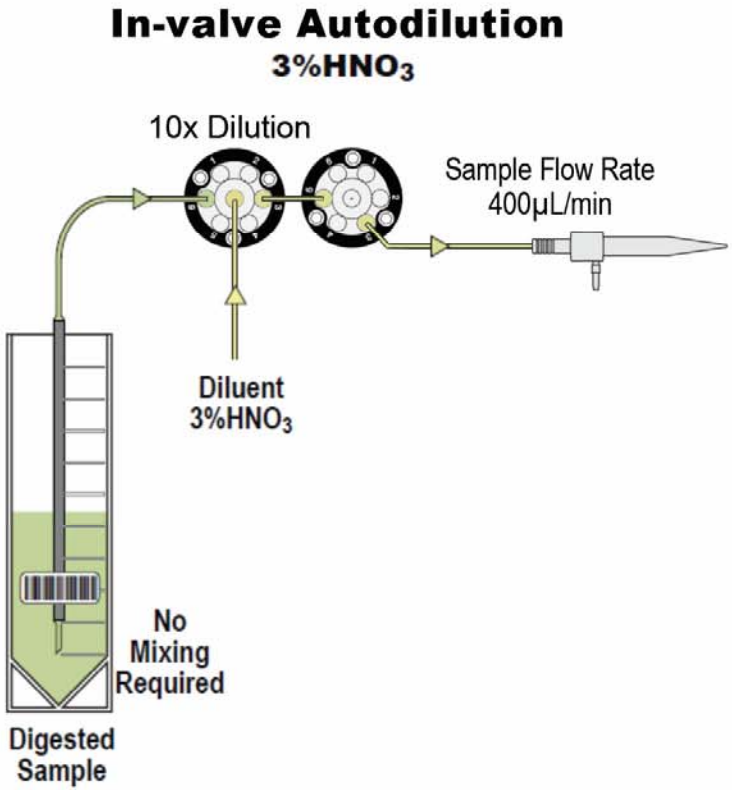
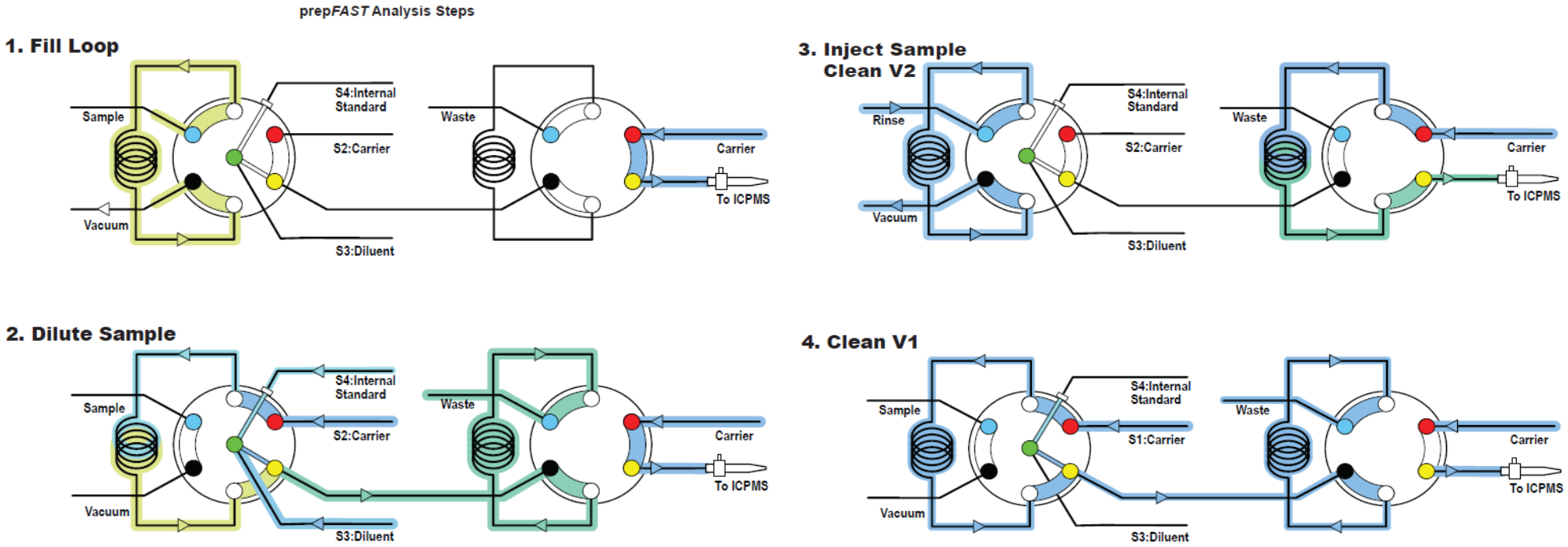
prep*FAST* - “Automated Inline Autodilution System”

prep*FAST* – Inline Dilution





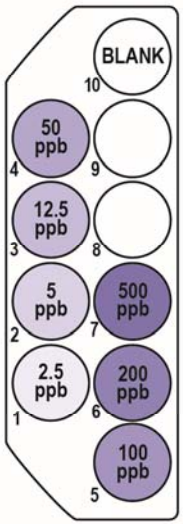
prep*FAST* – Inline Dilution



Conventional Calibration vs prep*FAST* Autocalibration

Conventional Calibration
(seven points)

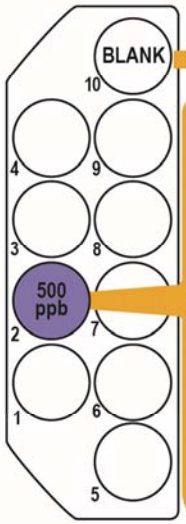
Offline Prep: 1 Blank + 7 Standards



STD Position	Concentration
10	0
1	2.5
2	5
3	12.5
4	50
5	100
6	200
7	500

prepFAST Autocalibration
(seven points)

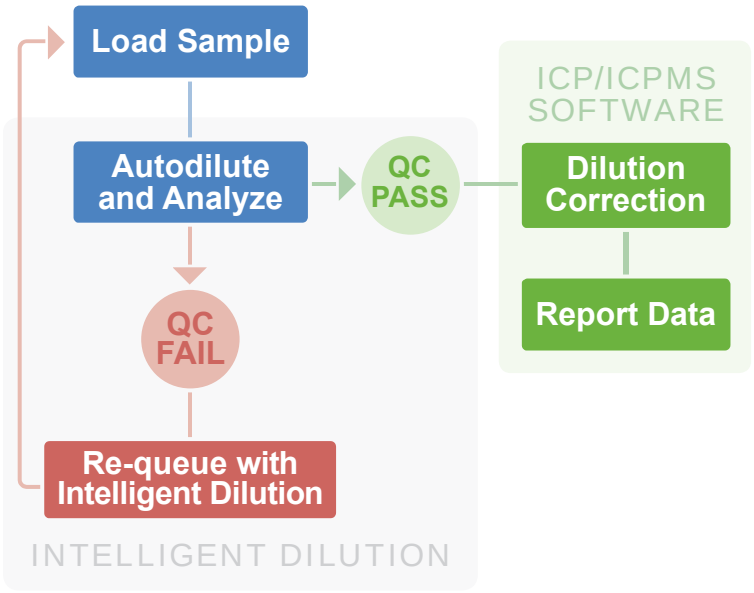
Inline Prep: 1 Blank + 1 Standard

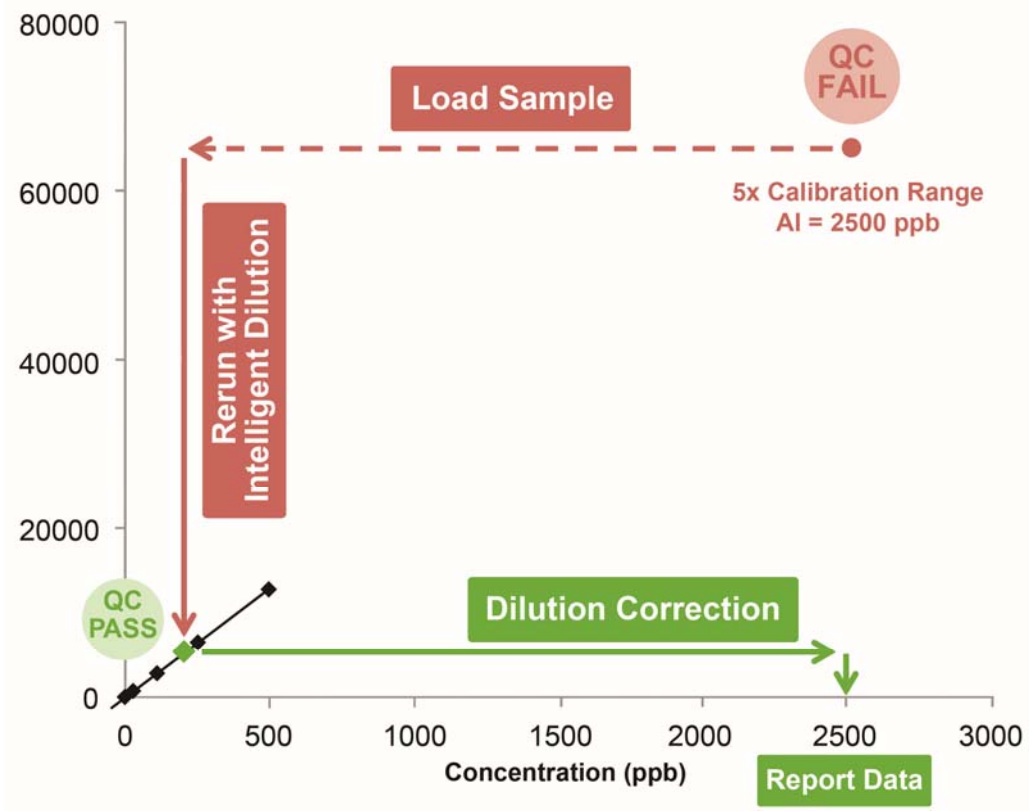


STD Position	Inline Dilution Factor	Dilution Rate			Concentration
		Std	Diluent	Total	
10	200x	50	9950	10000	0
2	200x	50	9950	10000	2.5
2	100x	100	9900	10000	5
2	40x	250	9750	10000	12.5
2	10x	1000	9000	10000	50
2	5x	2000	8000	10000	100
2	2.5x	4000	6000	10000	200
2	1x	10000	0	10000	500

prep*FAST* Calibration: Blank can be analyzed diluted or undiluted.

Sample Outside of Calibration Curve





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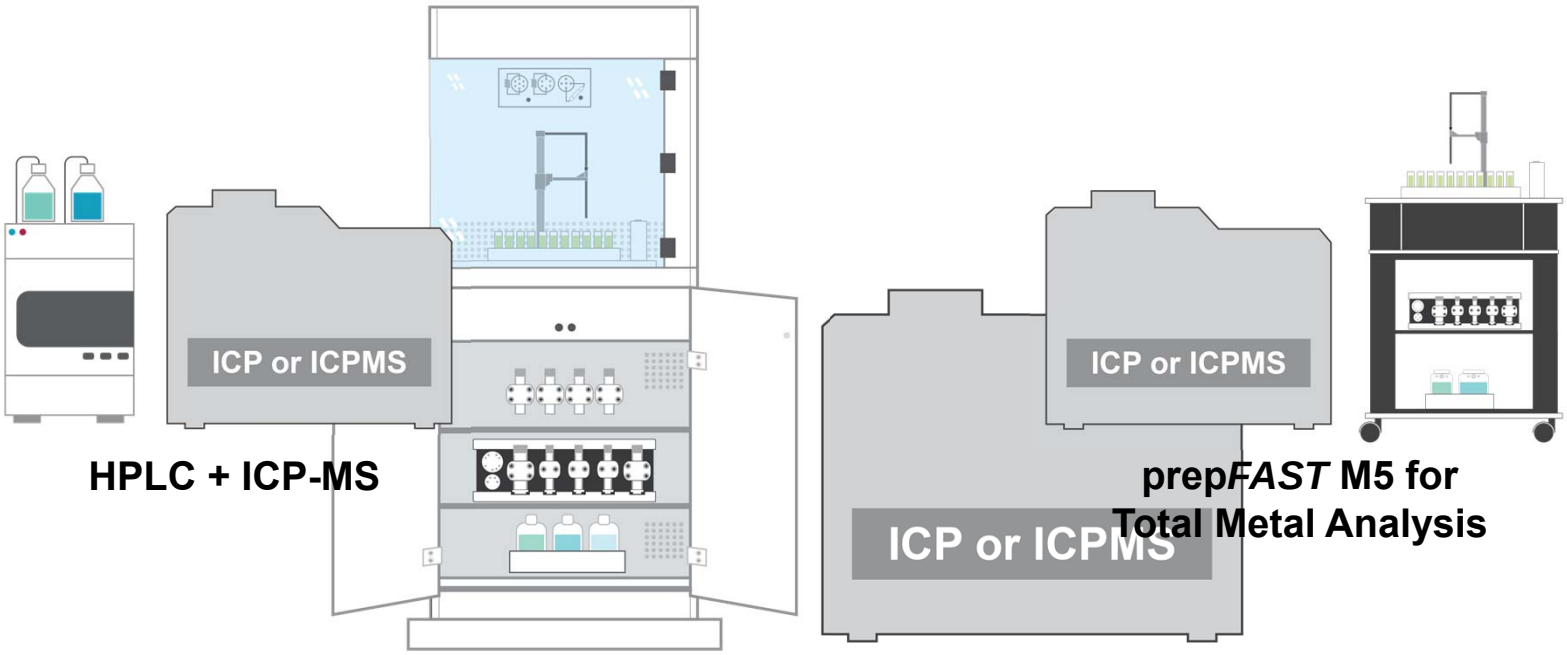
prep*FAST* IC - “Automated Elemental Speciation and Total Metals”

Instrumentation



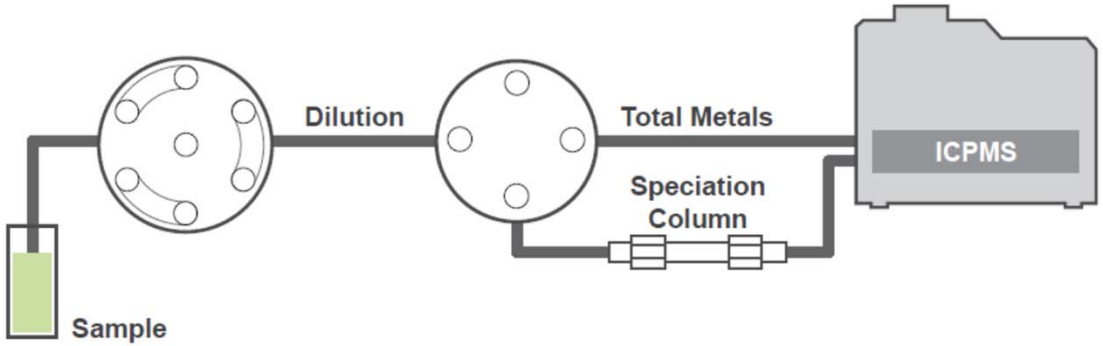
HPLC + ICP-MS

prep*FAST* M5 for
Total Metal Analysis

prep*FAST* IC for Speciation
and Total Metal Analysis

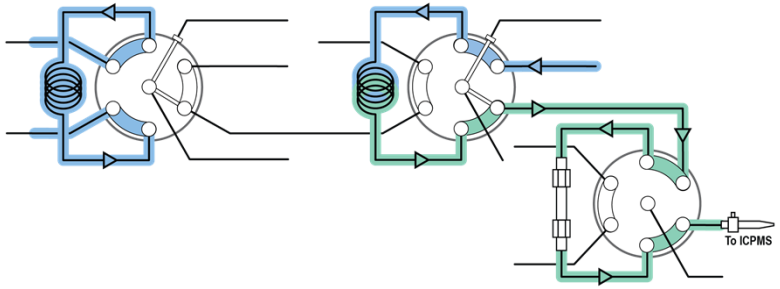
prep*FAST* IC Features

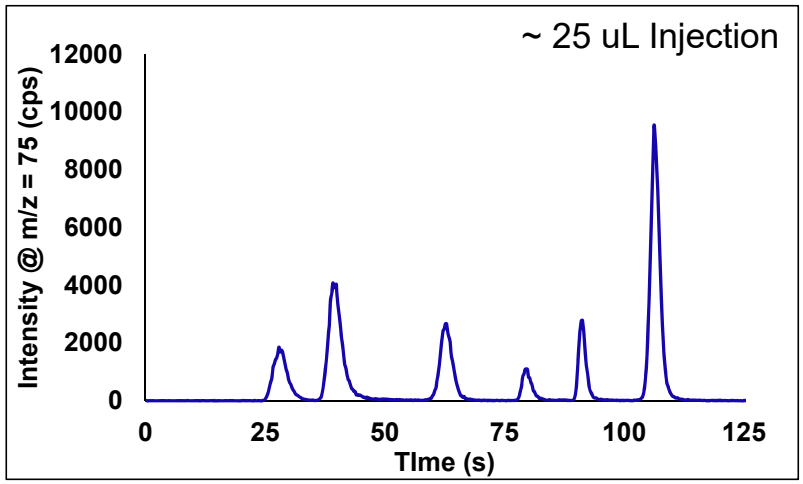
- Completely metal-free liquid and sample flow path from pump to nebulizer.
- Compatible with acids and organic solvents.
- Contamination free.
- Inline autodilution and autocalibration functions.
- Ability to operate in total metals or chromatography mode with a single instrument.
- No instrument modifications required to switch from total metals to speciation.
- Syringe-driven, post-column standard addition, dilution, or derivatization.



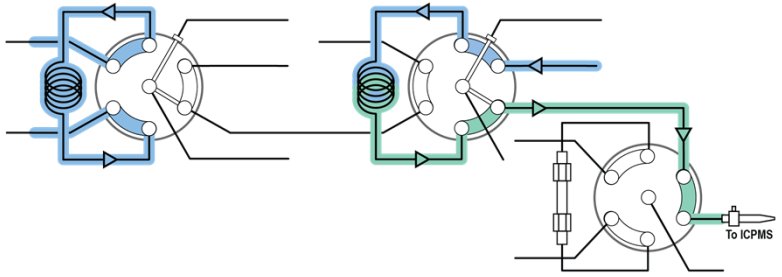
prep*FAST* IC – Total Metals and Speciation

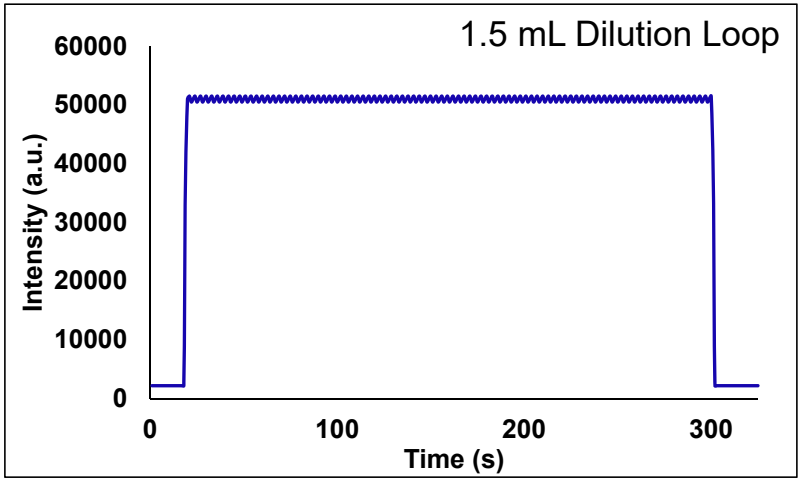
Speciation Mode



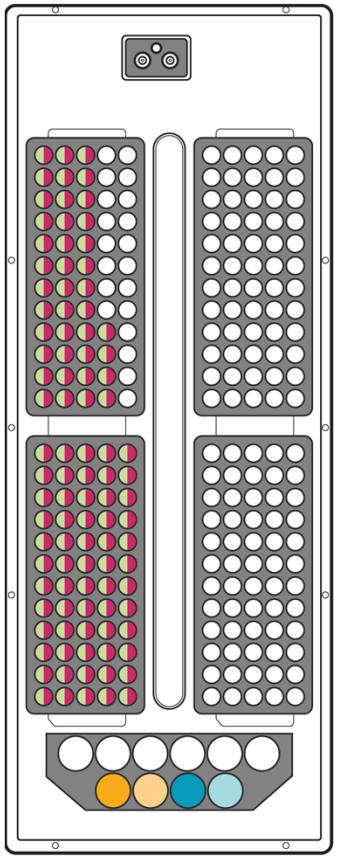


Total Metals Mode





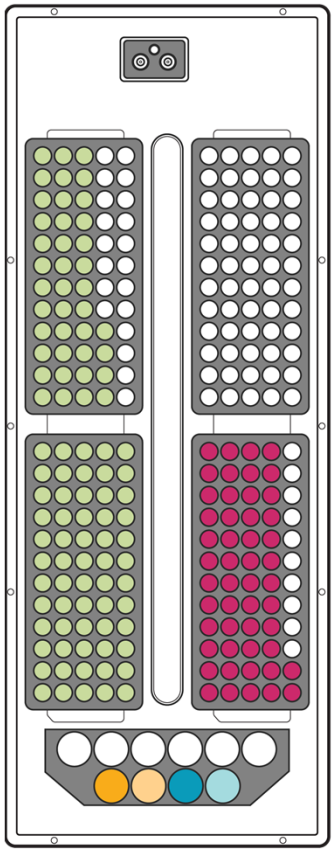
prep*FAST* IC – Total Metals and Speciation



- Samples of Total Metals
- Samples of Speciation
- Speciation Stock Standard
- Speciation Blank
- Total Metals Stock Standard
- Total Metals Blank

Autosampler Location	Dilution Factor	Sample	Action
1	1	Blank - Total Metals	Total Metals
2	50	Standard 1	Total Metals
2	25	Standard 2	Total Metals
2	10	Standard 3	Total Metals
2	5	Standard 4	Total Metals
2	1	Standard 5	Total Metals
101	10	Sample 1	Total Metals
↓	↓	↓	Total Metals
240	10	Sample 100	Total Metals
10	1	Dummy Sample	Prime for Speciation Method
3	1	Blank - Speciation	Speciation
4	100	Standard 1	Speciation
4	20	Standard 2	Speciation
4	10	Standard 3	Speciation
4	5	Standard 4	Speciation
4	2	Standard 5	Speciation
101	10	Sample 1	Speciation
↓	↓	↓	Speciation
240	10	Sample 100	Speciation
9	1	Dummy Sample	Prime for Total Metals

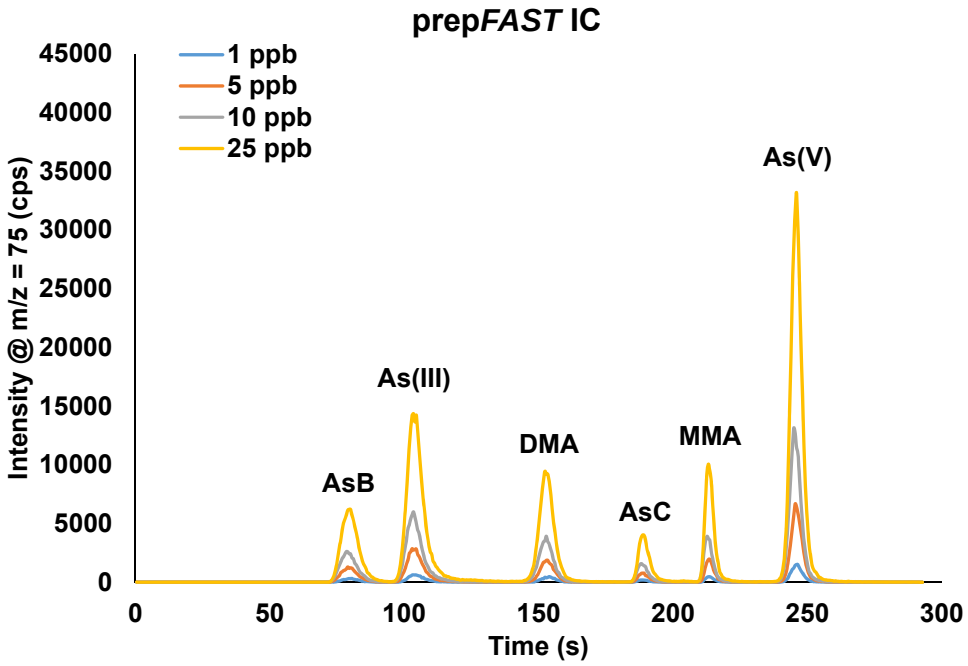
prep*FAST* IC – Total Metals and Speciation

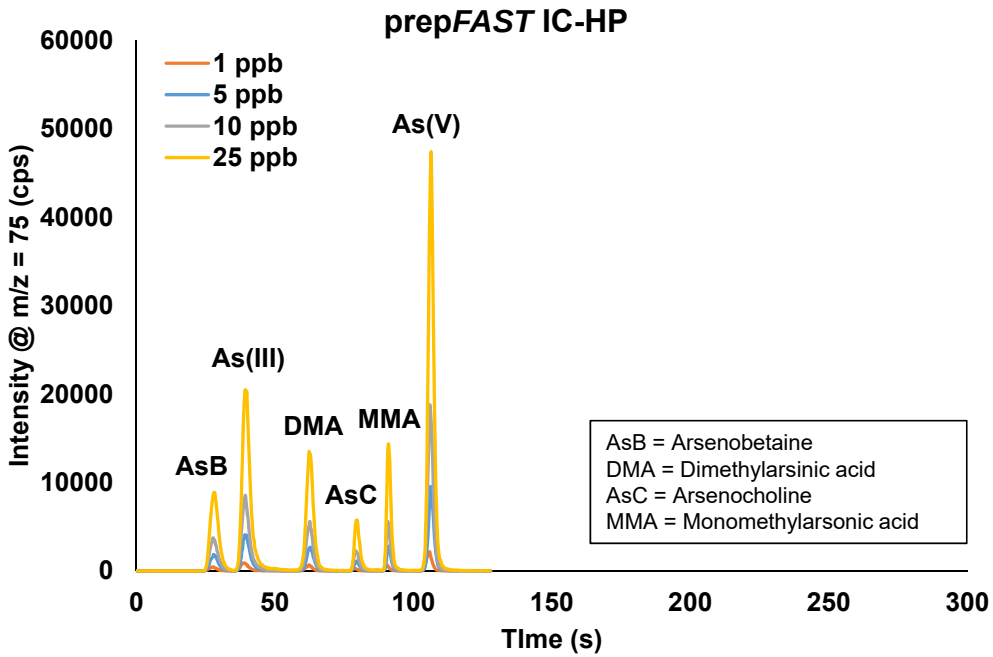


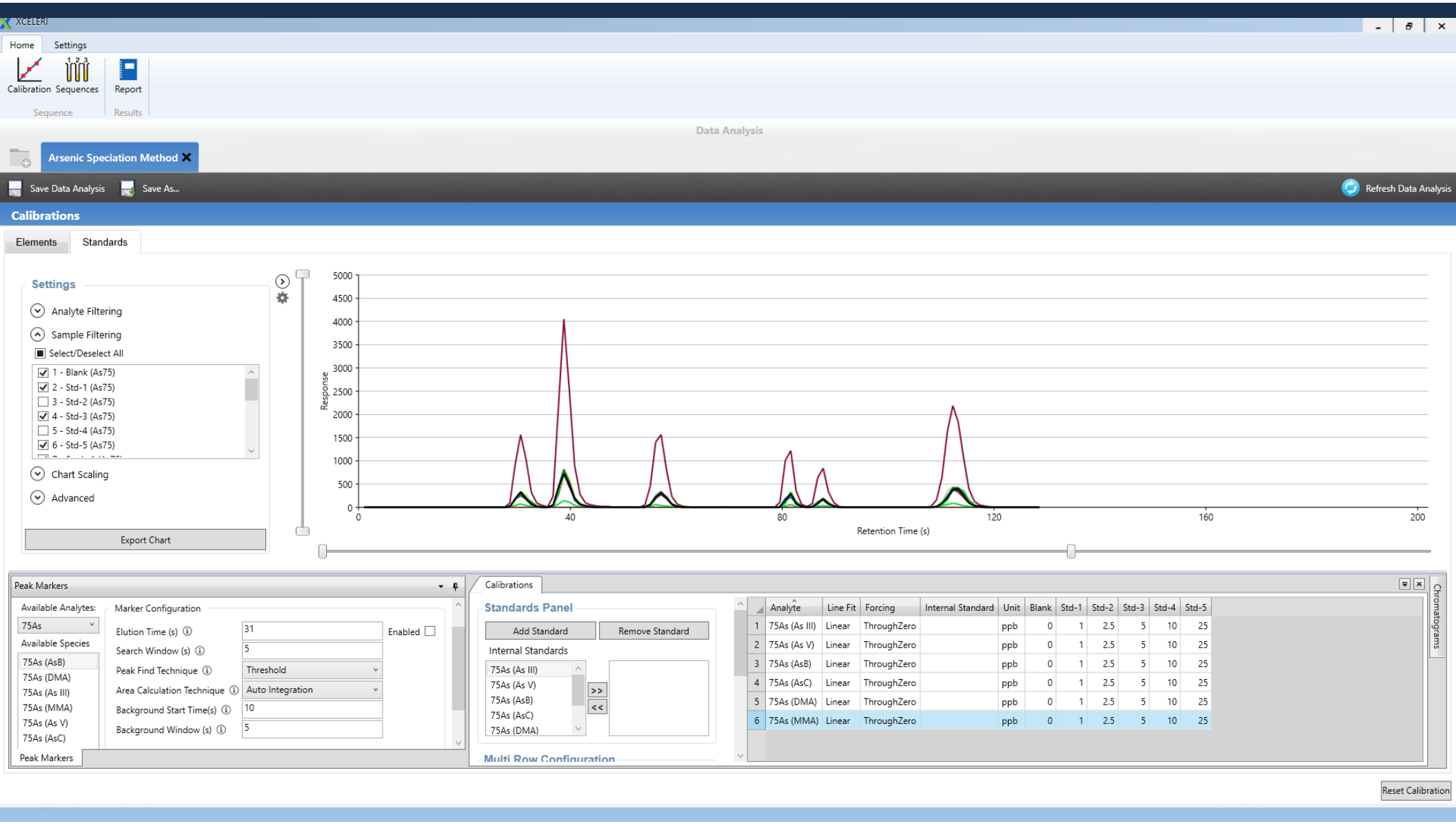
- Samples of Total Metals
- Samples of Speciation
- Speciation Stock Standard
- Speciation Blank
- Total Metals Stock Standard
- Total Metals Blank

Autosampler Location	Dilution Factor	Sample	Action
1	1	Blank - Total Metals	Total Metals
2	50	Standard 1	Total Metals
2	25	Standard 2	Total Metals
2	10	Standard 3	Total Metals
2	5	Standard 4	Total Metals
2	1	Standard 5	Total Metals
101	10	Sample 1	Total Metals
↓	↓	↓	Total Metals
240	10	Sample 100	Total Metals
10	1	Dummy Sample	Prime for Speciation Method
3	1	Blank - Speciation	Speciation
4	100	Standard 1	Speciation
4	20	Standard 2	Speciation
4	10	Standard 3	Speciation
4	5	Standard 4	Speciation
4	2	Standard 5	Speciation
301	10	Sample 1	Speciation
↓	↓	↓	Speciation
350	10	Sample 50	Speciation
9	1	Dummy Sample	Prime for Total Metals

prepFAST IC-HP







	Analyte	Line Fit	Forcing	Internal Standard	Unit	Blank	Std-1	Std-2	Std-3	Std-4	Std-5
1	75As (As III)	Linear	ThroughZero		ppb	0	1	2.5	5	10	25
2	75As (As V)	Linear	ThroughZero		ppb	0	1	2.5	5	10	25
3	75As (AsB)	Linear	ThroughZero		ppb	0	1	2.5	5	10	25
4	75As (AsC)	Linear	ThroughZero		ppb	0	1	2.5	5	10	25
5	75As (DMA)	Linear	ThroughZero		ppb	0	1	2.5	5	10	25
6	75As (MMA)	Linear	ThroughZero		ppb	0	1	2.5	5	10	25

XCELERI

Home | Settings

Calibration | Sequences | Report

Sequence | Results

Data Analysis

Arsenic Speciation Method

Save Data Analysis | Save As... | Refresh Data Analysis

Data Report

Report Settings

- Analyte Column Ordering ☐
- Analyte Column Filtering ☐
- Decimal Point Accuracy: 1
- Minimum Report Value: Actual
- Automatic Scrolling ☐
- Automatic Details ☐
- Synchronize Reports ☑

Export Options

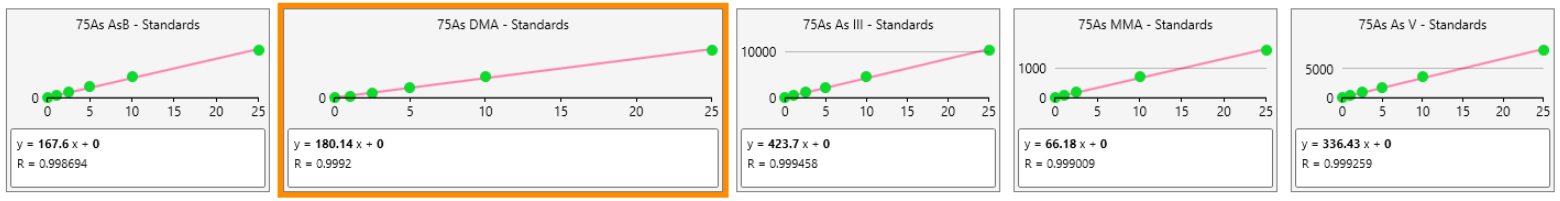
Chromatograms | Intensities | Concentrations

Index	Arrived	Time	Description	75As (AsB)	75As (DMA)	75As (As III)	75As (MMA)	75As (As V)	75As (AsC)
2	■	2/15/2019 10:29:30 PM	Std-1	1.1	0.8	0.9	1.1	1.0	1.0
3	■	2/15/2019 10:33:48 PM	Std-2	2.6	2.6	2.6	2.8	2.6	2.9
4	■	2/15/2019 10:38:06 PM	Std-3	5.5	5.3	5.3	6.2	5.3	5.4
5	■	2/15/2019 10:42:24 PM	Std-4	11.0	10.7	10.6	10.9	10.7	11.9
6	■	2/15/2019 10:46:44 PM	Std-5	24.5	24.7	24.7	24.6	24.6	24.1
7	■	2/15/2019 11:51:12 PM	5ppb-5	5.0	4.8	4.9	5.5	4.9	4.9
8	■	2/16/2019 12:12:40 AM	5ppb-10	5.1	5.1	4.9	5.2	4.9	5.2
9	■	2/16/2019 12:16:58 AM	5ppb-11	5.2	5.2	5.1	5.8	4.9	5.4
10	■	2/16/2019 12:42:42 AM	5ppb-16	5.2	5.3	4.9	5.1	5.1	4.8
11	■	2/16/2019 12:46:58 AM	5ppb-17	5.0	4.9	4.9	5.2	4.7	4.9
12	■	2/16/2019 1:12:44 AM	5ppb-23	5.2	5.1	5.1	5.4	4.8	5.0

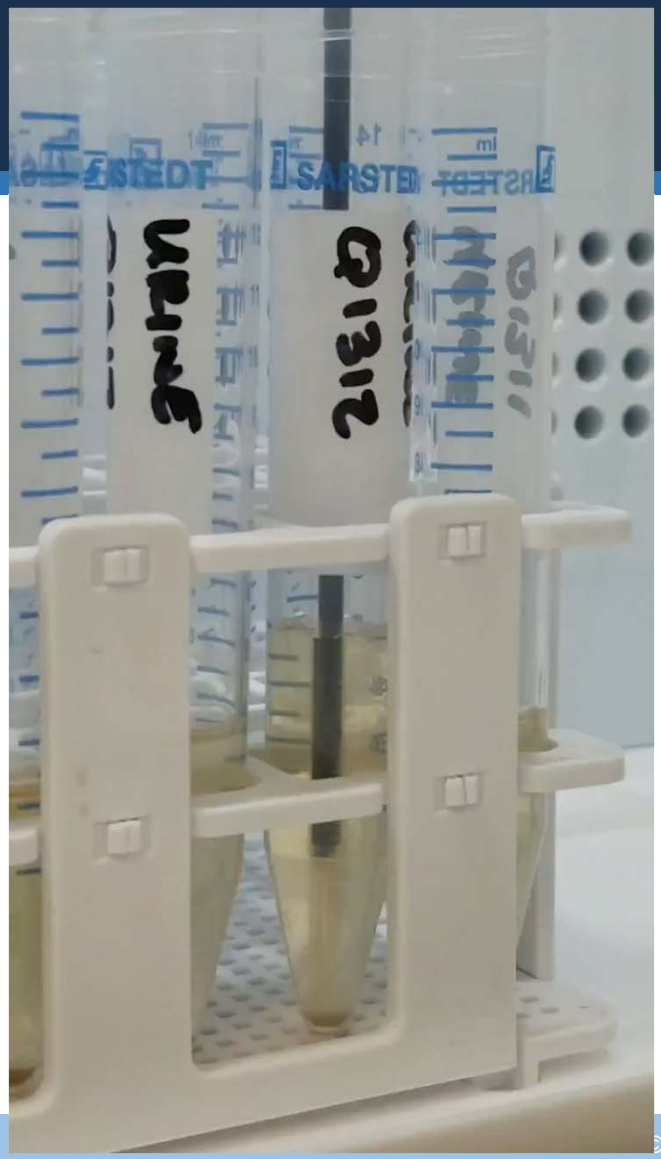
Sample Concentration Details

Index	Arrived	Time	Description	75As (AsB)	75As (DMA)	75As (As III)	75As (MMA)	75As (As V)	75As (AsC)
8	■	2/16/2019 12:12:40 AM	5ppb-10	5.1318	5.1182	4.9160	5.2476	4.8949	5.2131
			Slope	167.5958	180.1394	423.6964	66.1849	336.4323	116.1262
			Intercept	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			Coefficient R	0.9987	0.9992	0.9995	0.9990	0.9993	0.9955
			BEC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

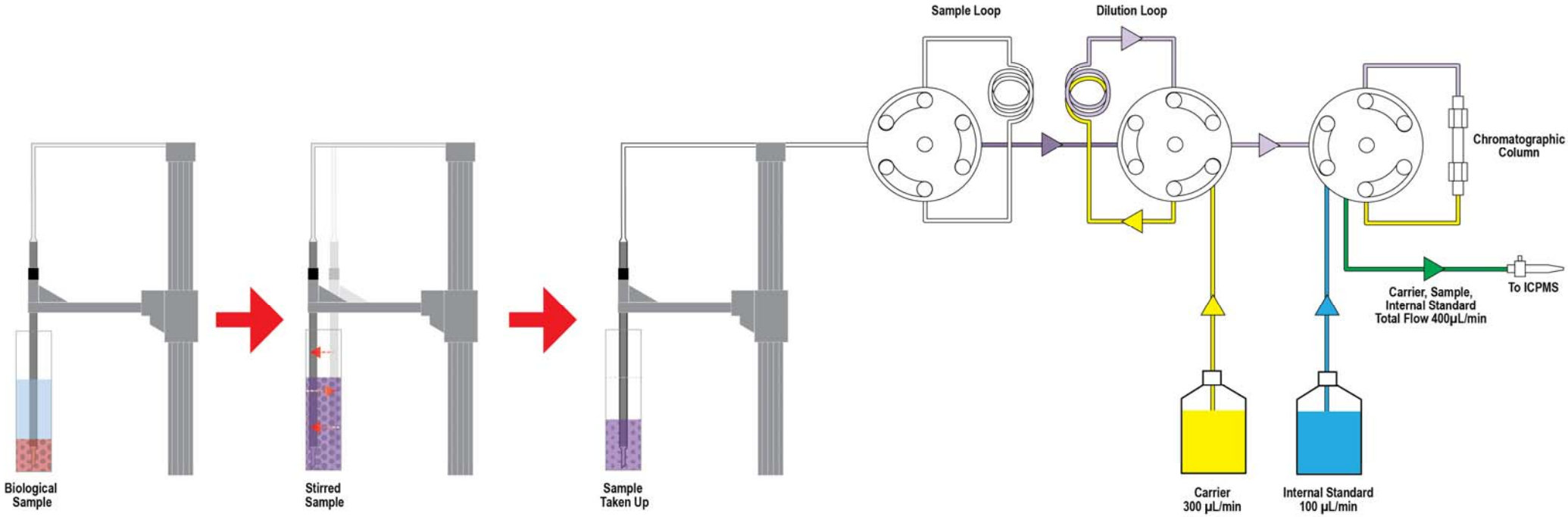
Calibration Curves



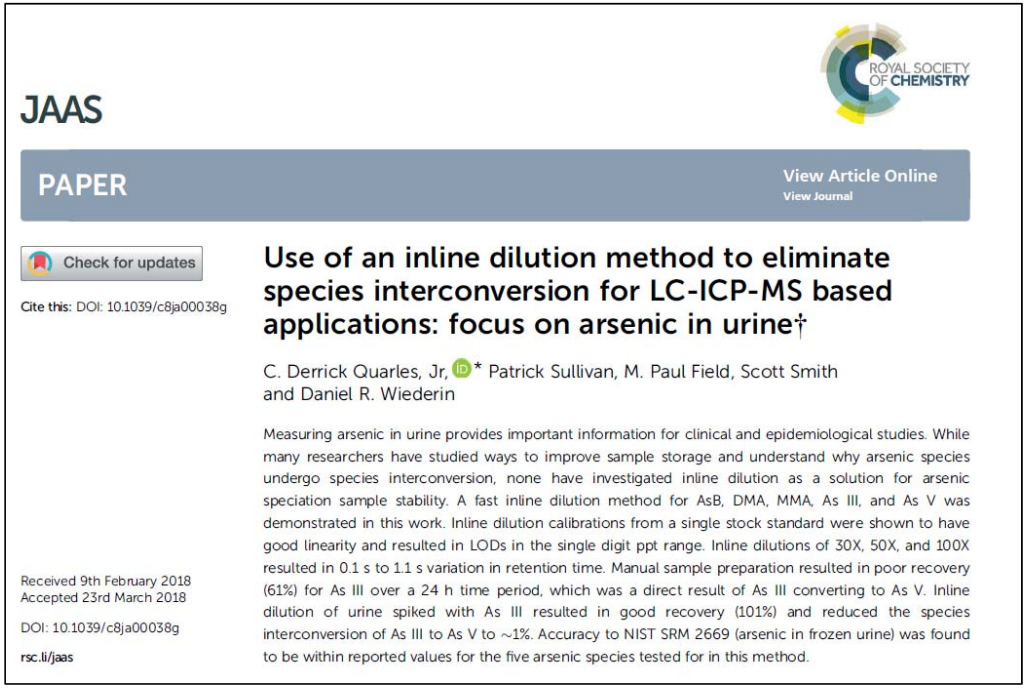
Sample Uptake



Sample Uptake - Speciation Mode



Arsenic Speciation



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Cite this: DOI: 10.1039/c8ja00038g

Use of an inline dilution method to eliminate species interconversion for LC-ICP-MS based applications: focus on arsenic in urine†

C. Derrick Quarles, Jr,* Patrick Sullivan, M. Paul Field, Scott Smith and Daniel R. Wiederin

Measuring arsenic in urine provides important information for clinical and epidemiological studies. While many researchers have studied ways to improve sample storage and understand why arsenic species undergo species interconversion, none have investigated inline dilution as a solution for arsenic speciation sample stability. A fast inline dilution method for AsB, DMA, MMA, As III, and As V was demonstrated in this work. Inline dilution calibrations from a single stock standard were shown to have good linearity and resulted in LODs in the single digit ppt range. Inline dilutions of 30X, 50X, and 100X resulted in 0.1 s to 1.1 s variation in retention time. Manual sample preparation resulted in poor recovery (61%) for As III over a 24 h time period, which was a direct result of As III converting to As V. Inline dilution of urine spiked with As III resulted in good recovery (101%) and reduced the species interconversion of As III to As V to ~1%. Accuracy to NIST SRM 2669 (arsenic in frozen urine) was found to be within reported values for the five arsenic species tested for in this method.

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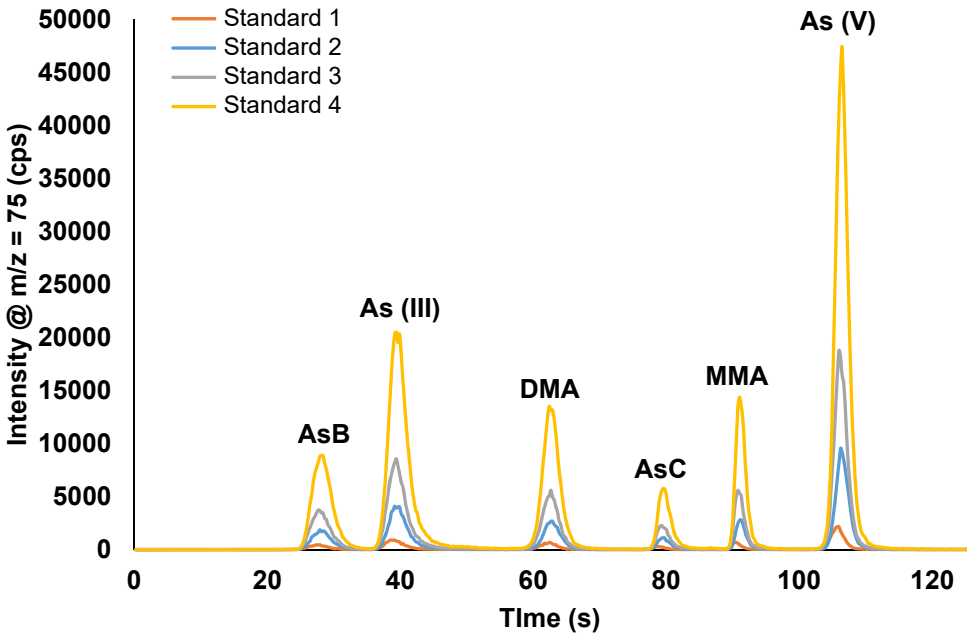
rsc.li/jaas

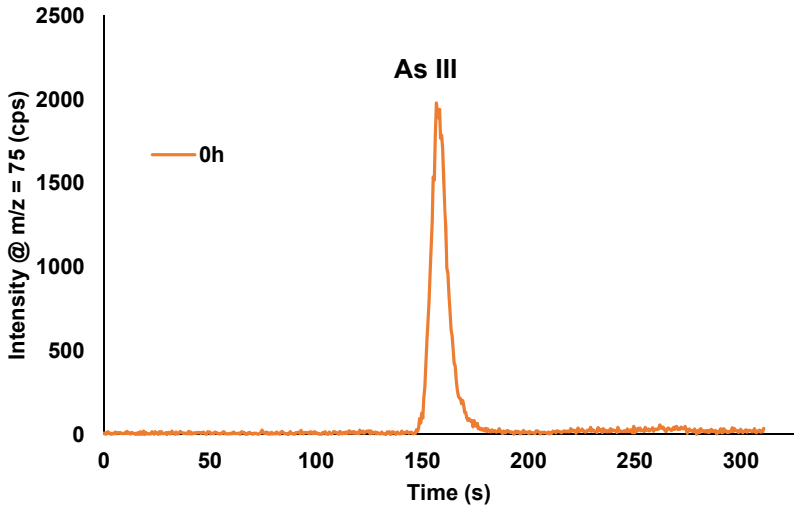


	AsB	As III	DMA	AsC	MMA	As V
LOD (ppt)	1.7	0.6	0.7	0.8	1.0	0.3

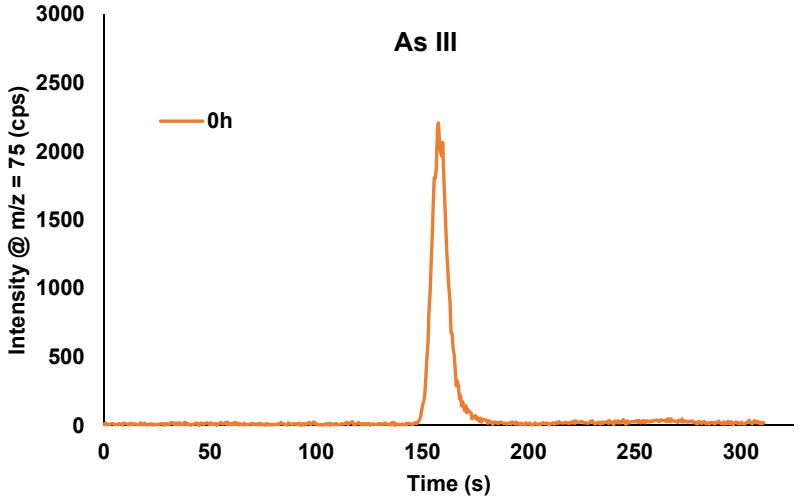
AsB = Arsenobetaine
DMA = Dimethylarsinic acid
AsC = Arsenocholine
MMA = Monomethylarsonic acid

Inline Dilution Eliminates Species Interconversion

Manual Dilution
30X Manual DF
1 (Urine Spiked with 10 ppb As III): 29 (DI H_2O)



Inline Dilution
30X Inline DF
Urine Spiked with 10 ppb As III



C D Quarles Jr., P Sullivan, M P Field, S Smith, D R Wiederin, JAAS, 2018, 33, 745-751.

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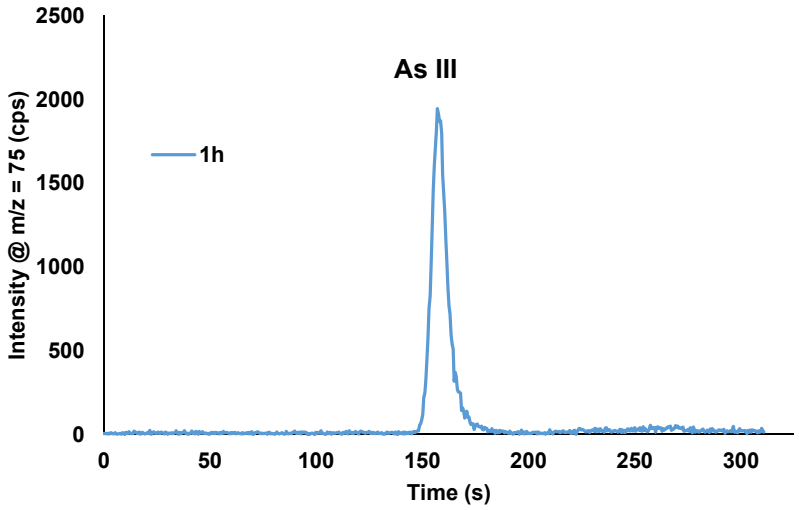

Inline Dilution
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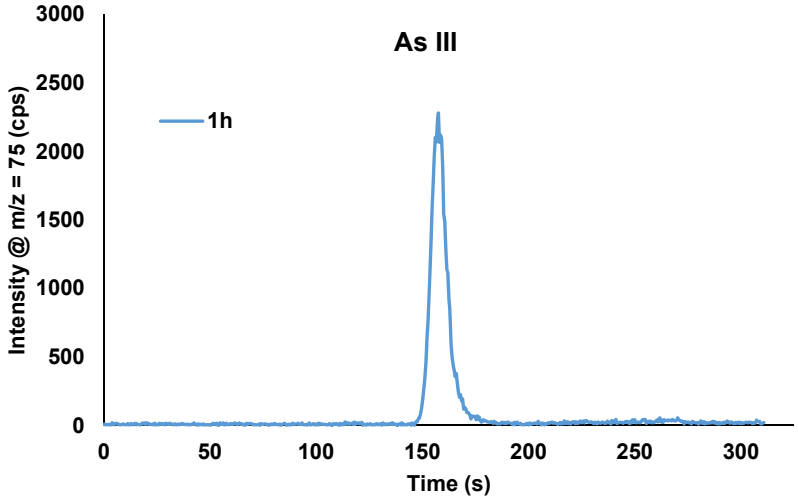
Urine Spiked with 10 ppb As III



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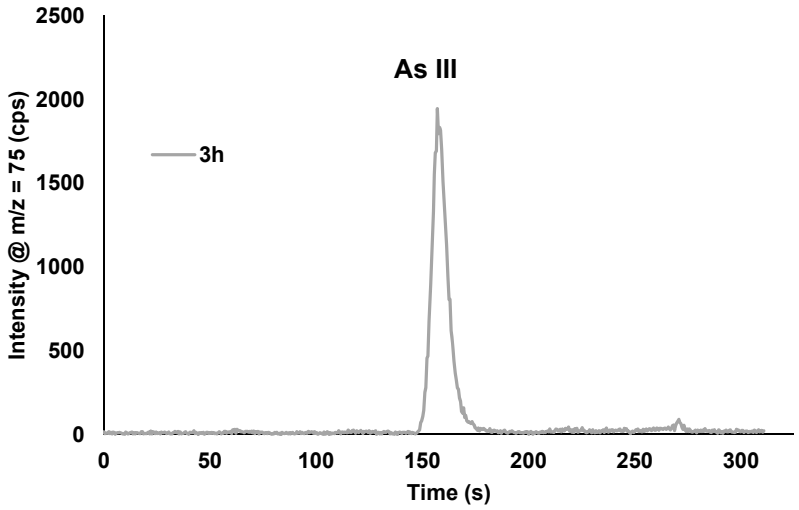
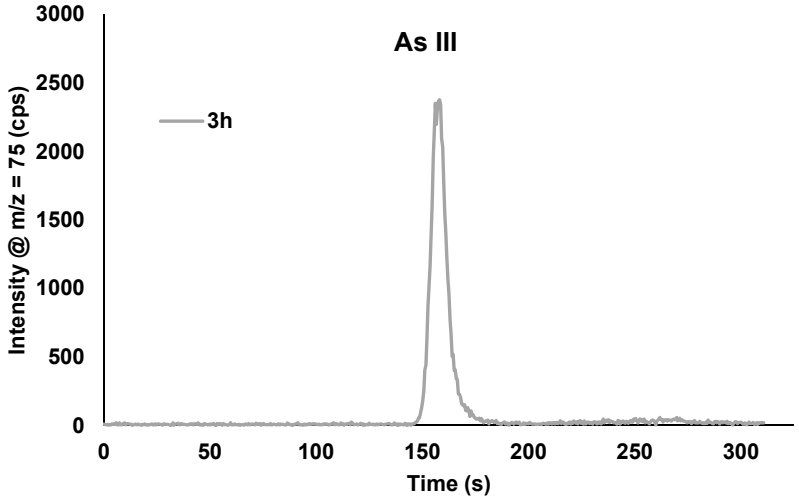


Inline Dilution
30X Inline DF
Urine Spiked with 10 ppb As III



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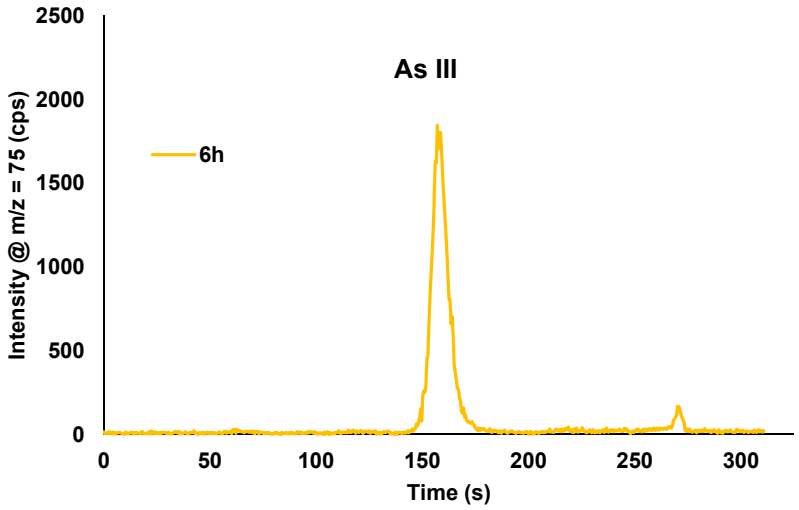
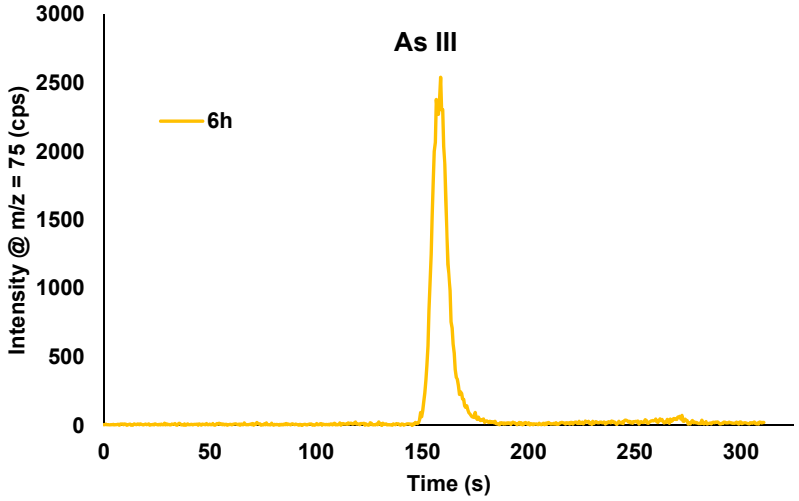


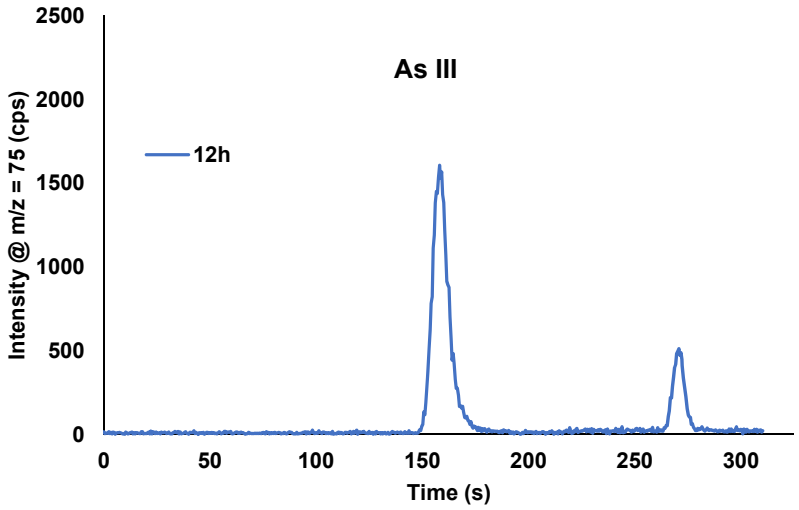
Inline Dilution
30X Inline DF
Urine Spiked with 10 ppb As III



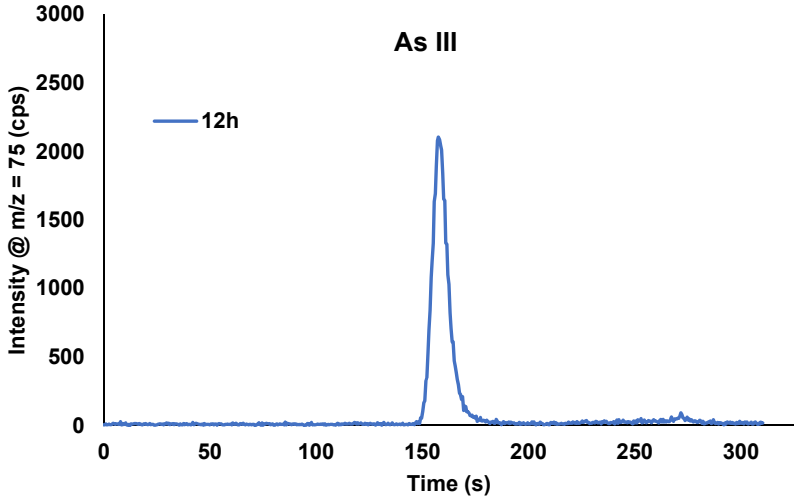
C D Quarles Jr., P Sullivan, M P Field, S Smith, D R Wiederin, JAAS, 2018, 33, 745-751.

Inline Dilution Eliminates Species Interconversion

Manual Dilution
30X Manual DF
1 (Urine Spiked with 10 ppb As III): 29 (DI H_2O)



Inline Dilution
30X Inline DF
Urine Spiked with 10 ppb As III



C D Quarles Jr., P Sullivan, M P Field, S Smith, D R Wiederin, JAAS, 2018, 33, 745-751.

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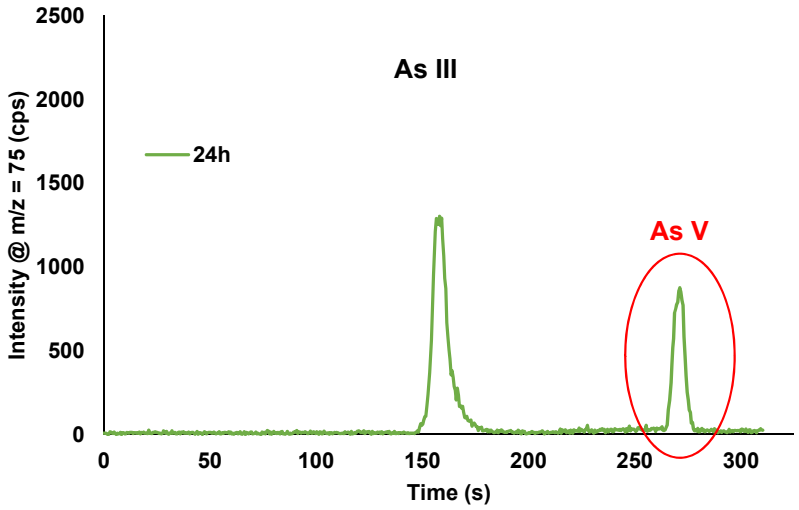
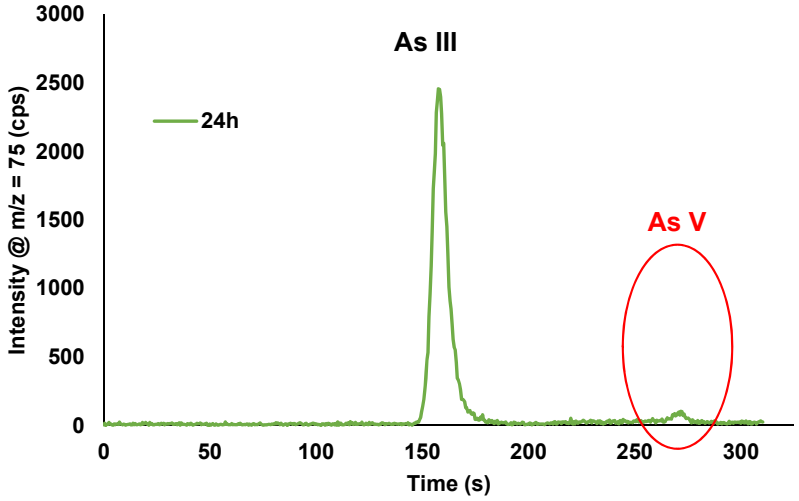


Inline Dilution
30X Inline DF
Urine Spiked with 10 ppb As III



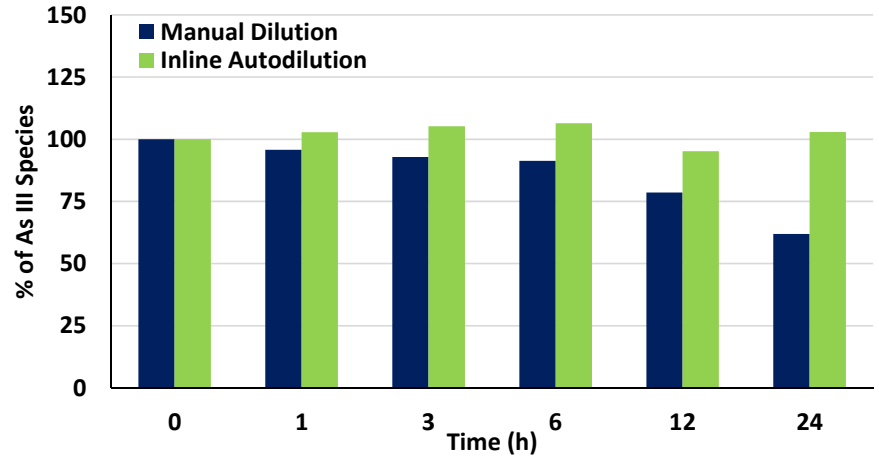
C D Quarles Jr., P Sullivan, M P Field, S Smith, D R Wiederin, JAAS, 2018, 33, 745-751.

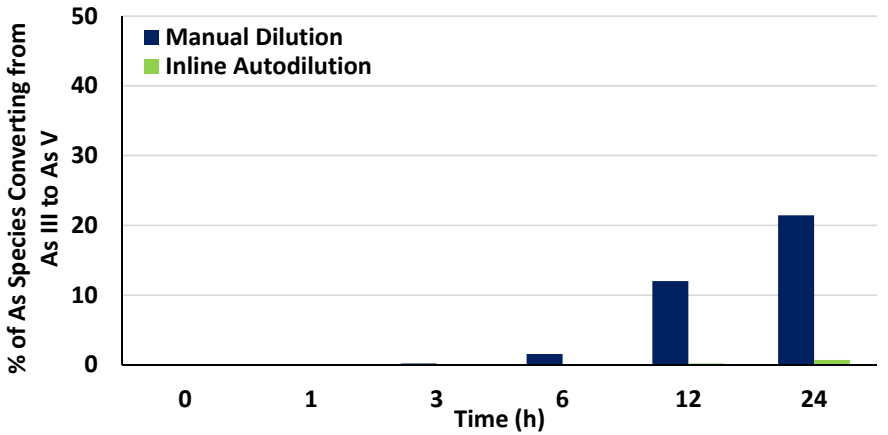
Manual Dilution vs Inline Dilution - Summary

Manual Dilution		10 ppb As III Spiked Urine Samples		
	Time (h)	As III %	As V %	As III + As V
	0	**100.0**	0.0	100.0
	1	**95.7**	0.0	95.7
	3	**92.8**	0.2	93.0
	6	**91.3**	1.6	92.9
	12	**78.5**	12.0	90.6
	24	**61.9**	21.4	83.4

Inline Autodilution		10 ppb As III Spiked Urine Samples		
	Time (h)	As III %	As V %	As III + As V
	0	**100.0**	0.0	100.0
	1	**102.8**	0.0	102.8
	3	**105.2**	0.0	105.2
	6	**106.4**	0.0	106.4
	12	**95.1**	0.5	95.6
	24	**102.9**	1.3	104.2

As III % = (x h As III / 0 h As III) * 100
As V % = (x h As V / 0 h As III) * 100
As III + As V = As III % + As V %





Chromium Speciation and Total Metals Environment Application & Validation Study

prep*FAST* IC *+* ICP-MS

ESI & Eurofins Publication: Chromium Speciation

JAAS

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Cite this: *J. Anal. At. Spectrom.*, 2019, 34, 284

A fully automated total metals and chromium speciation single platform introduction system for ICP-MS†

C. Derrick Quarles, Jr,[a]* Michael Szoltysik,[b] Patrick Sullivan[a] and Maurice Reijnen[c]

Measuring chromium species in drinking water has become of particular interest due to daily environmental contamination that is caused by industrial processes. Agencies such as the US Environmental Protection Agency and the European Union continue to investigate the maximum to which Cr(VI) contaminant levels should be set; thus laboratories must seek more efficient ways of performing routine analyses. In this work a single platform, automated speciation and total metals method is presented for chromium speciation in drinking water, waste water, industrial waters, and recipient waters, and for total metals in sludges, soils, organic waste, ashes, biological samples, or paint. Samples were measured using a prepFAST IC system for Cr(III) and Cr(VI) and the results were compared to the HPLC results. In addition, samples from the aqua regia total method were compared to those of the total metals method performed using the prepFAST IC. Sample comparisons resulted in linear regression plots with very good correlations, greater than 0.97 for total metals over a dynamic range of 0.010–100 000 μg L^{-1} for 63 elements and greater than 0.98 for Cr(VI) speciation. The limits of detection for Cr(VI) and Cr(III) using the prepFAST IC and ICP-MS combination are 7 ng L^{-1} and 12 ng L^{-1}, respectively. The new method resulted in an ~43× improvement in detection limits as compared to the previous method employed in our laboratory. The accurate results for quality control samples of Cr(VI) were in good agreement with the historical values collected using the old method.

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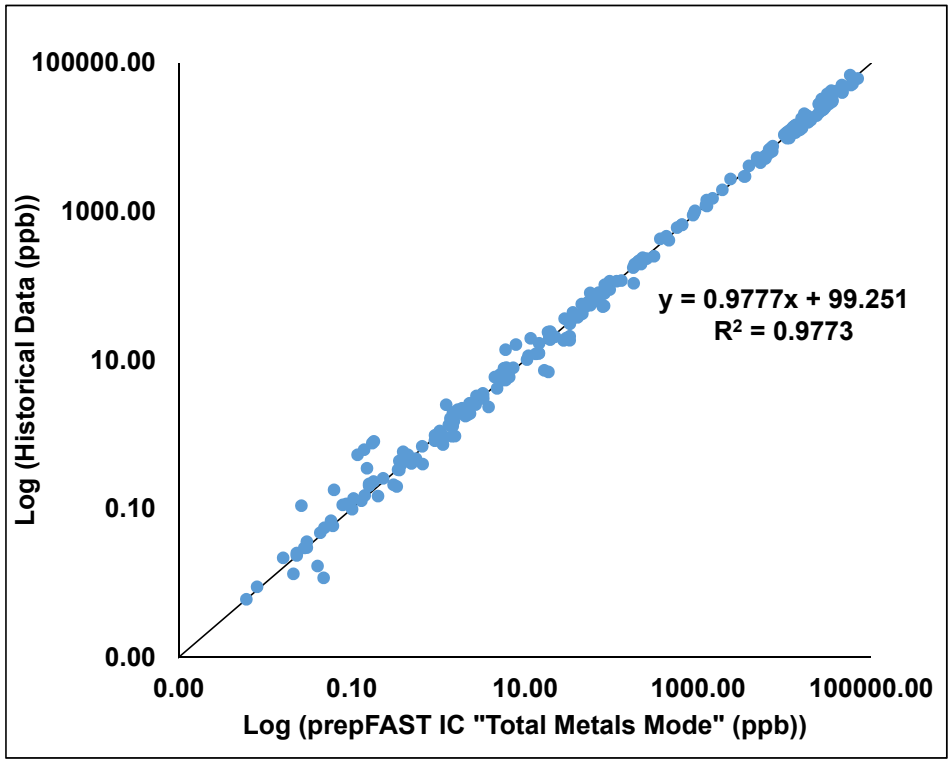
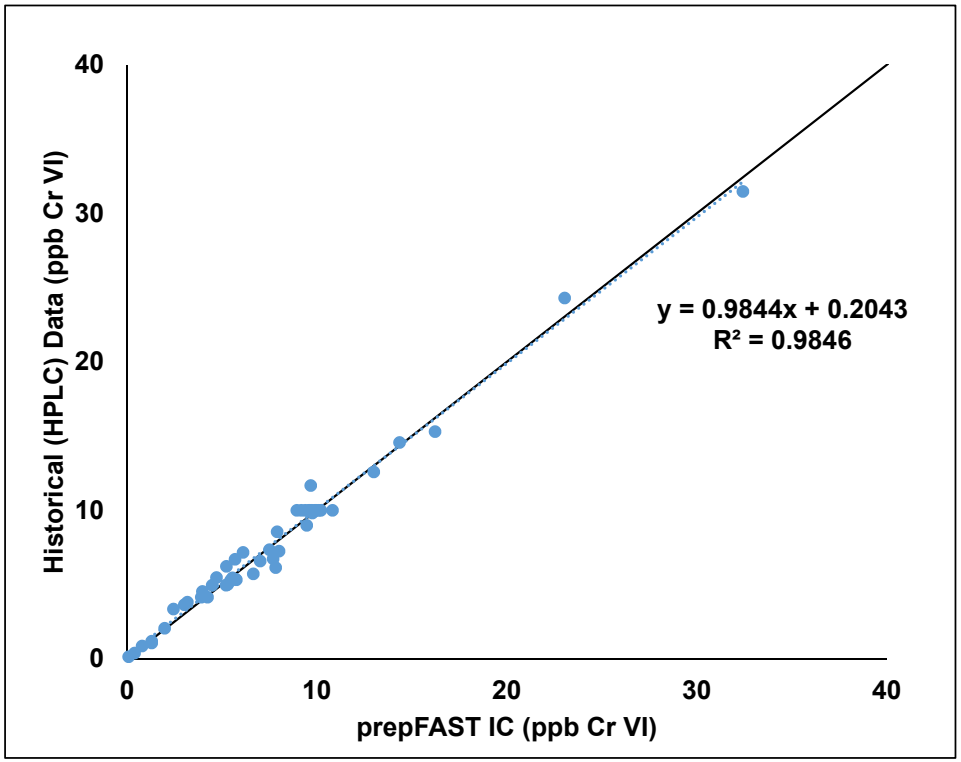
Comparison to Historical Data

Manual Prep vs prepFAST Inline Dilutions



HPLC vs prepFAST IC

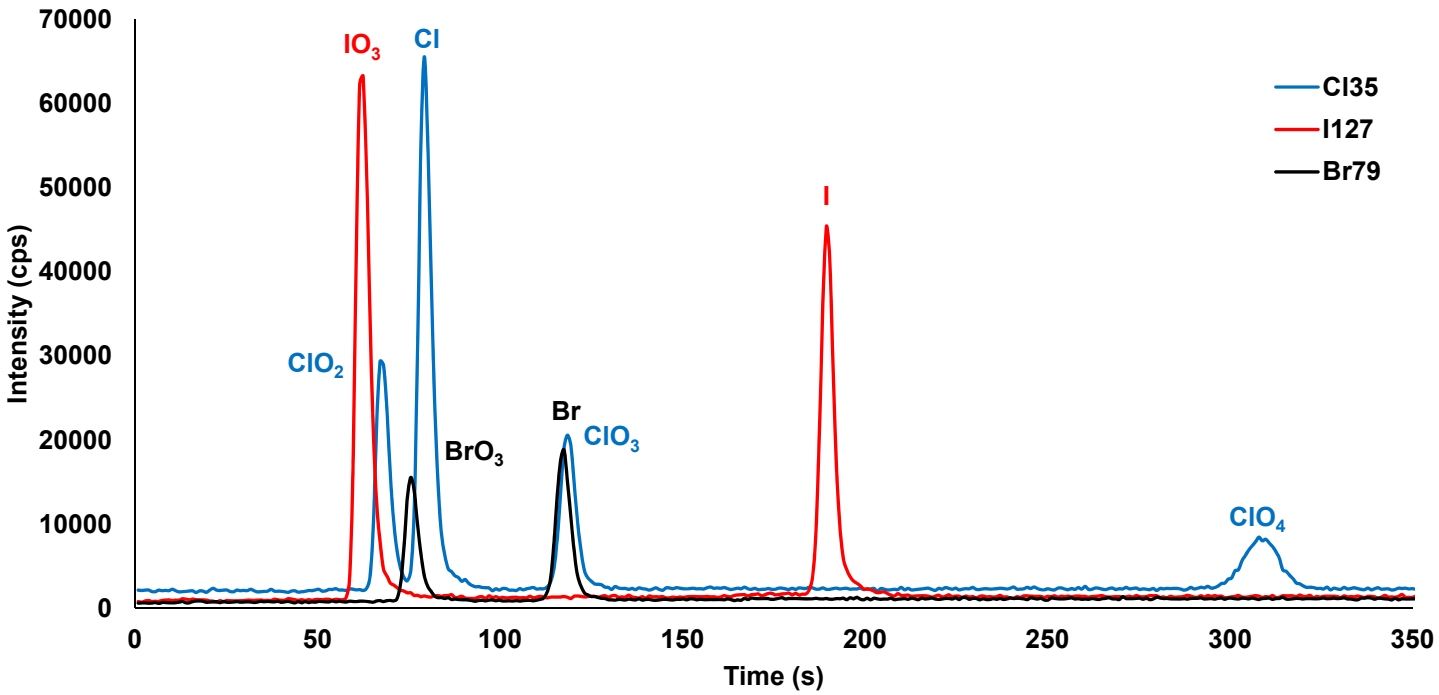


C D Quarles Jr., M Szoltysik, P Sullivan, M Reijnen, JAAS, 2019.

Halogen Speciation and Total Metals Environment Application

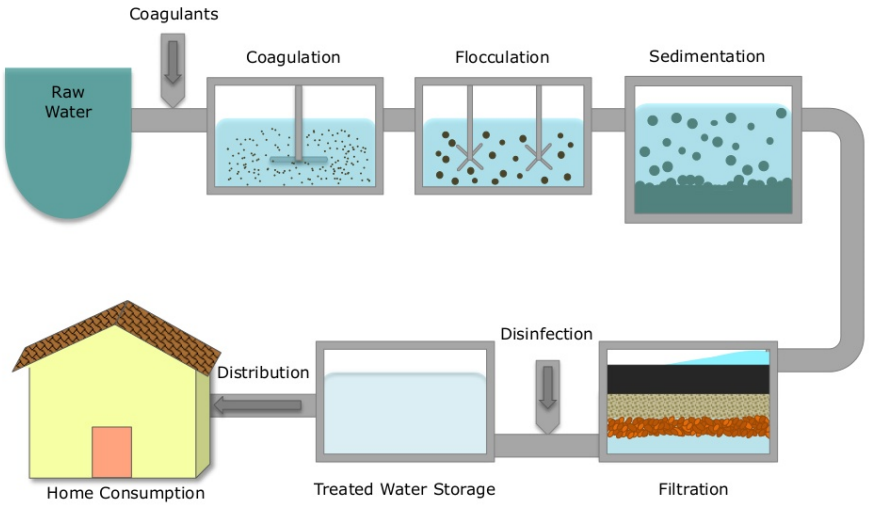
prep*FAST* IC *+* ICP-MS

Halogen Speciation



Drinking Water Disinfection Process

- **Early 1900's**: Traditionally used Cl_2 gas
- **1974**: EPA enacts Safe Drinking Water Act
  - Reauthorized in 1986 and 1996
- **1989**: Surface Water Treatment Rule
  - Increased use of disinfectants (e.g. ClO_2, HOCl, ozone)
  - Destroys pathogenic bacteria, fungi and viruses but introduces byproducts.
- **1998**: Stage 1 Disinfectants and Disinfection Byproducts Rule
  - Enforces maximum contamination levels for byproducts
- **2006**: Stage 2 Disinfectants and Disinfection Byproducts Rule
  - Switch from chlorine dioxide to chloramines
  - However, increases organic iodine's (most toxic)



https://www.slideshare.net/commgroup/drinking-water-treatment-process
https://www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules

Water Testing Locations

Clarke
- North Oconee River
- Middle Oconee River

Forsyth
- Lake Lanier

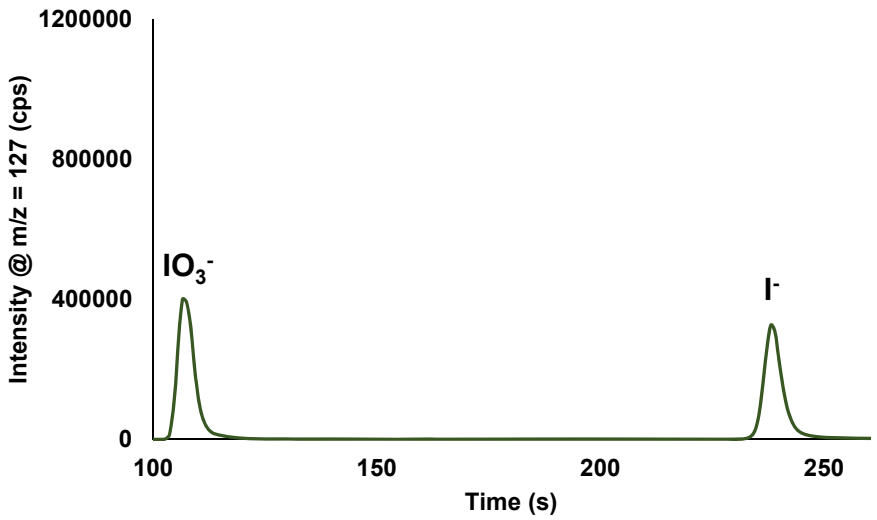
Fulton
- Chattahoochee River
- Morgan Falls Reservoir

Cobb
- Chattahoochee River
- Lake Allatoona

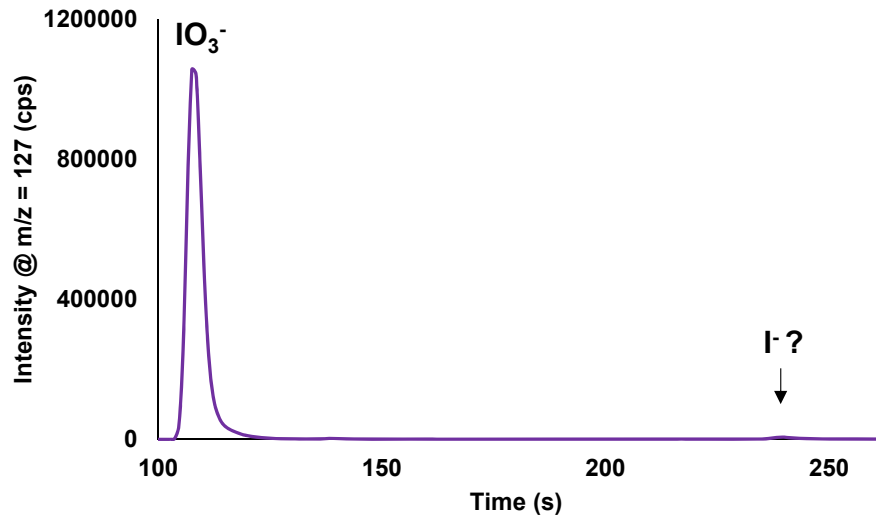
Barrow
- Mulberry River
- Fort Yargo Lake

Stability of Standards: Iodide and Iodate (10 ppb)

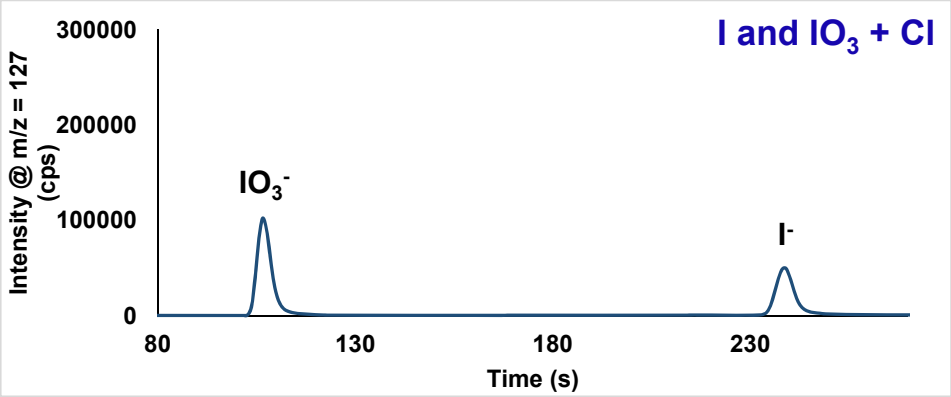
Iodide and Iodate Standard

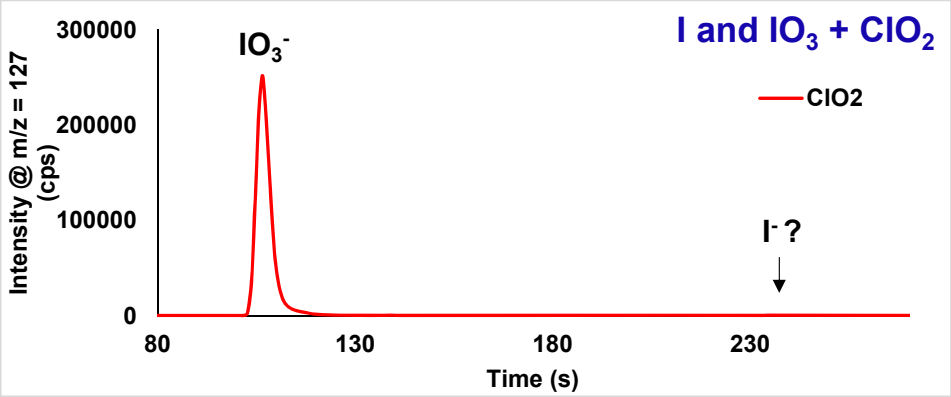


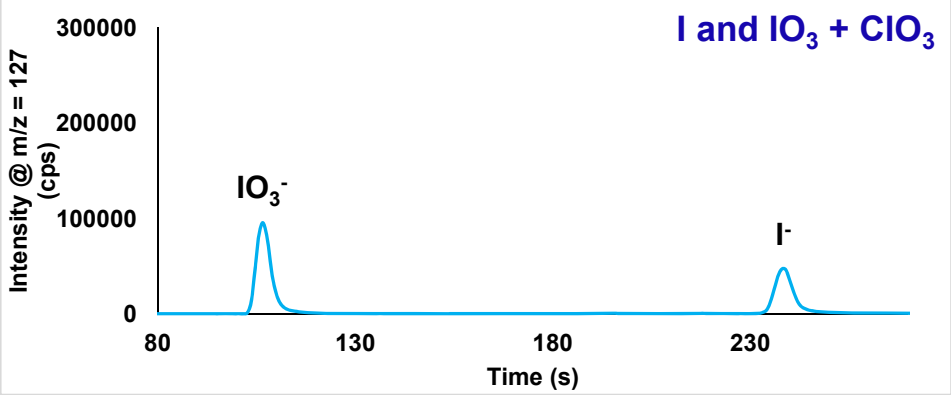
I, Br, and Cl Standards Mixed

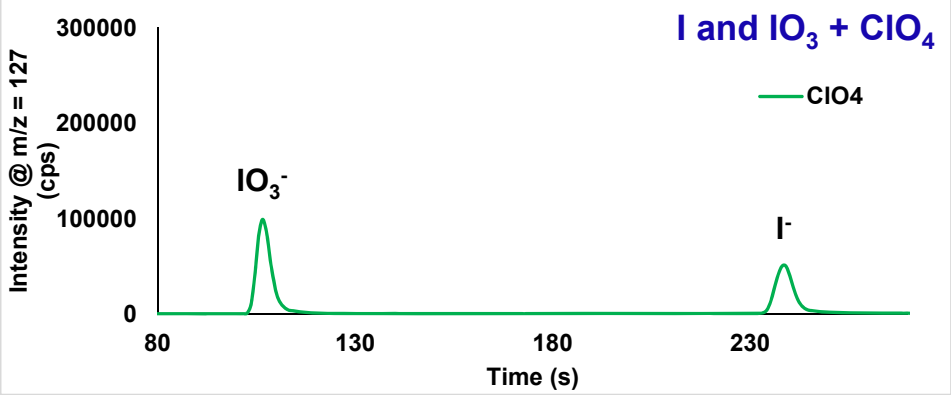


Stability of Standards: Iodide and Iodate (10 ppb)



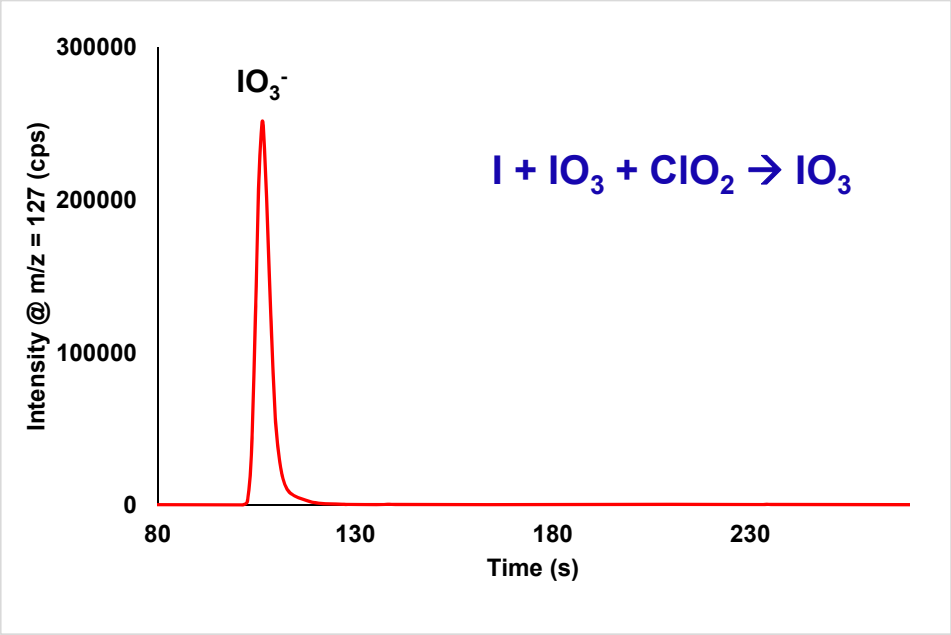


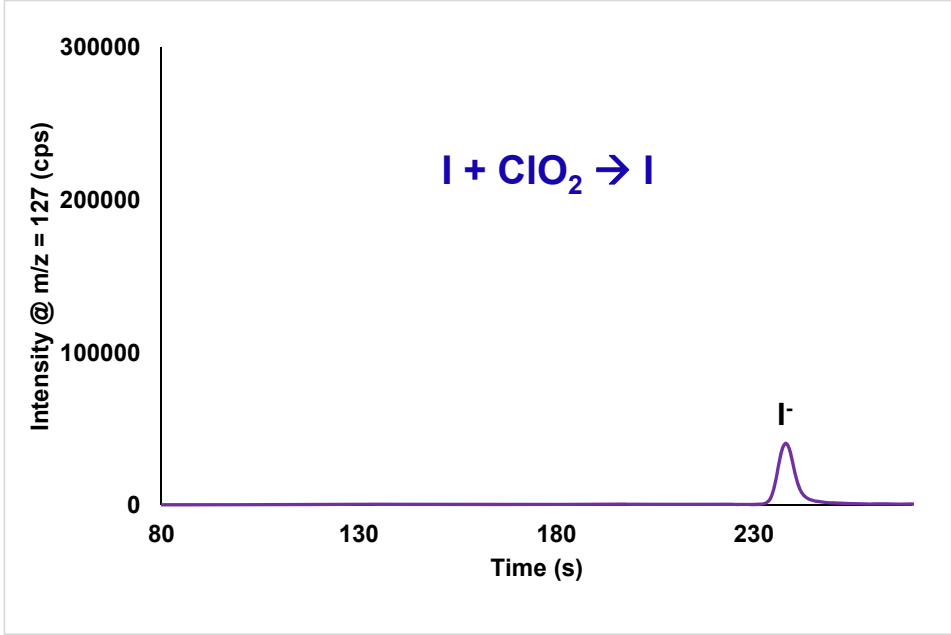




*All Chlorine species = 500 ppb

Stability of Standards: Iodide and Iodate (10 ppb)



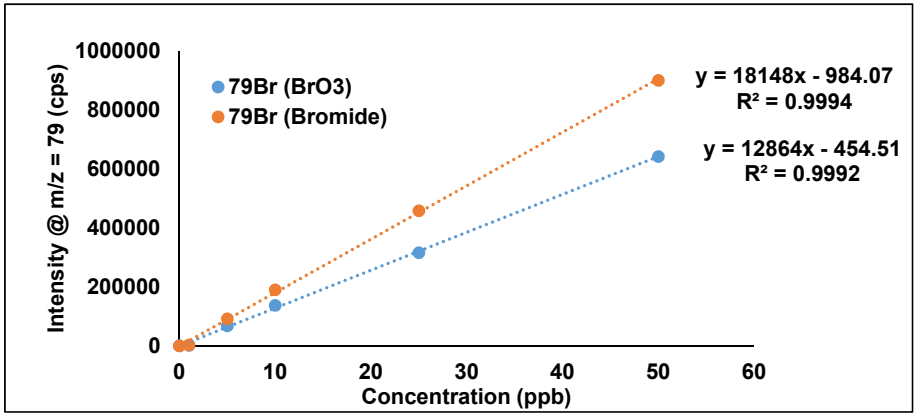


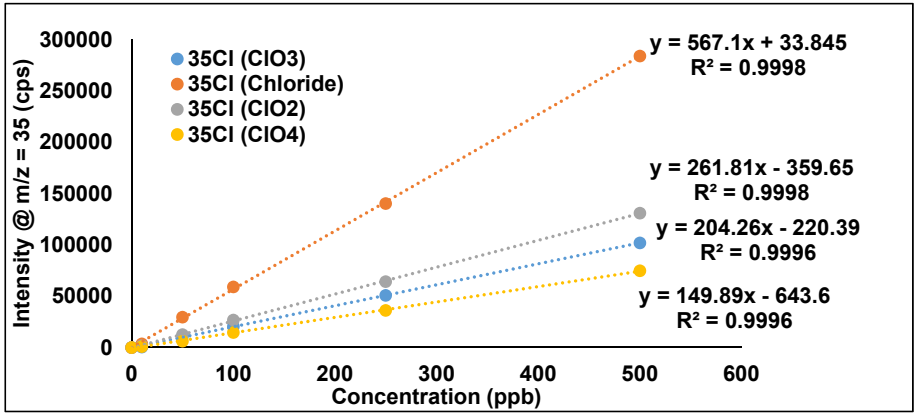
*All Chlorine species = 500 ppb

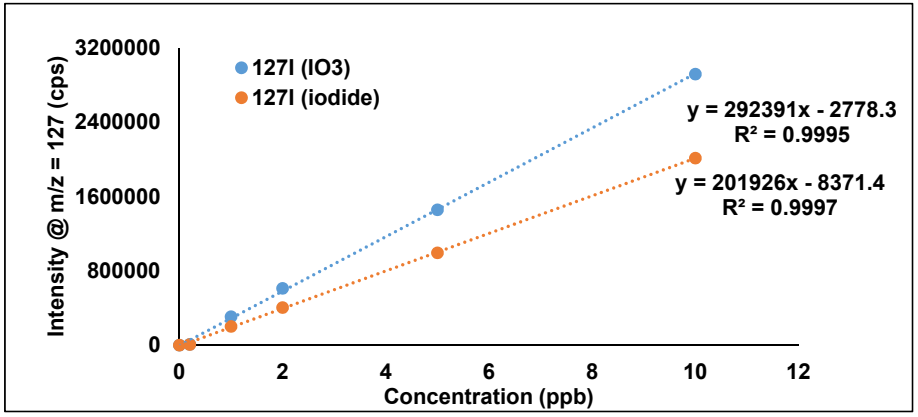
Calibration Curves and Limit of Detection

	BrO_3	Br	I	IO_3
LOD (ppt)	62	55	33	23

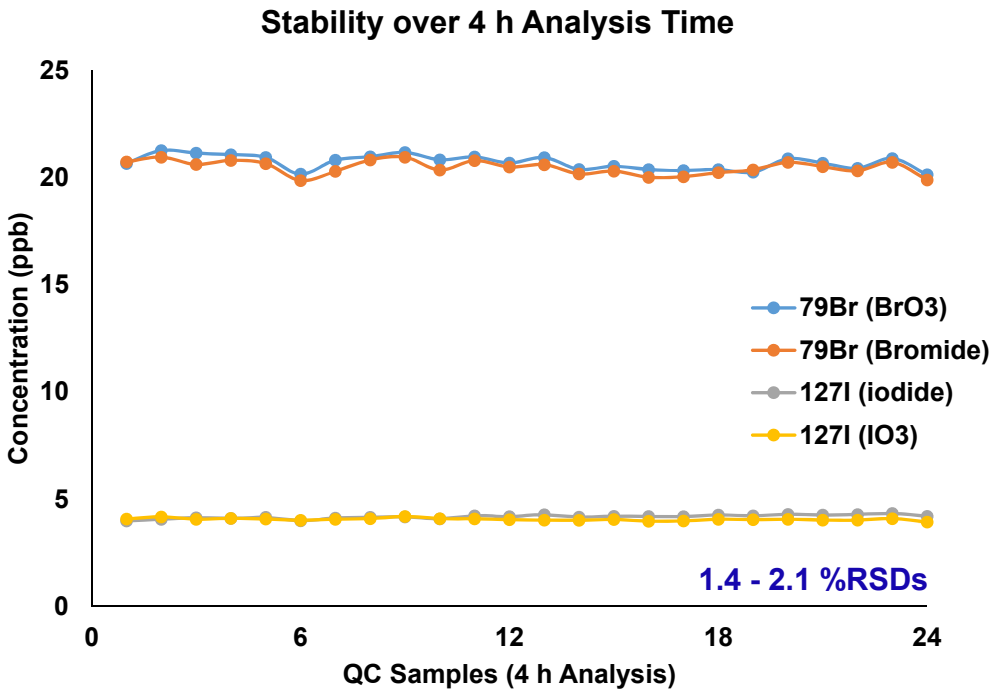
	ClO_2	Cl	ClO_3	ClO_4
LOD (ppb)	7.2	2.5	6.8	37

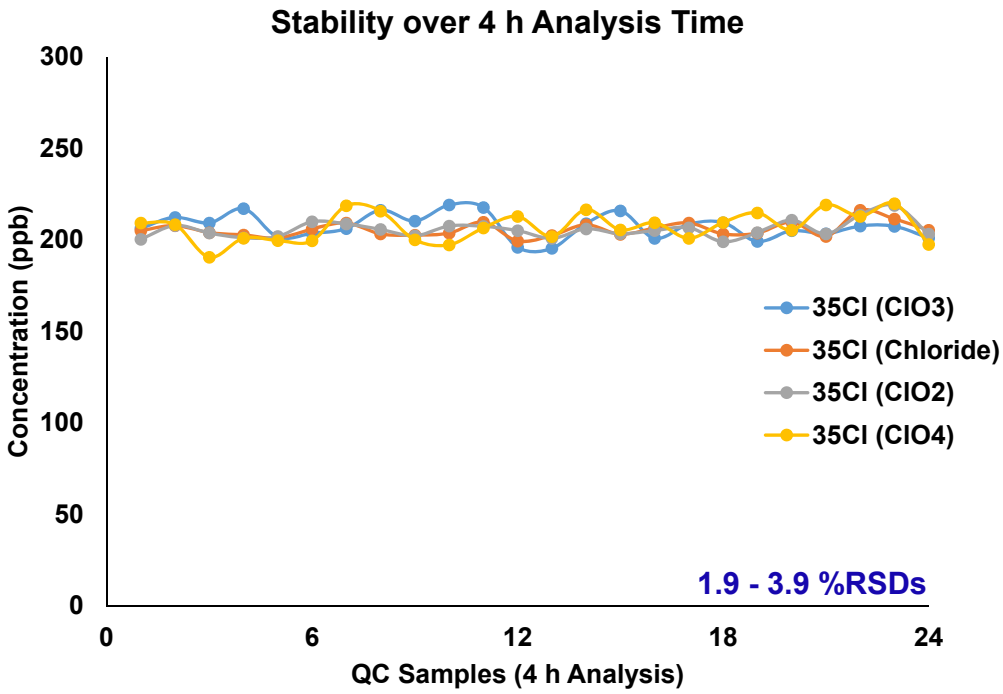






Halogen Speciation - Stability





Drinking Water – Halogen Speciation Results (Br)

County	Sample	Br^- (ppb)	BrO_3^- (ppb)
Barrow	Mulberry River	29	0
	Fort Yargo Lake	20	0
	Residential	1.6	0.11
	Commercial	0.20	1.1
Cobb	Cauble Park	19	0
	West Palisades	21	0.24
	Residential	0.99	1.4
	Commercial	0.38	1.4
Fulton	Morgan Falls Reservoir	18	0.29
	Chattahoochee River	17	0.25
	Residential	2.6	0.92
	Commercial	1.5	0.82

County	Sample	Br^- (ppb)	BrO_3^- (ppb)
Forsyth	West Bank	13	0
	Residential	1.8	0
	Commercial	0.83	0.22
Clarke	Middle Oconee River	30	0
	North Oconee River	21	0
	Residential	5.0	4.4
	Commercial	2.4	4.4

prepFAST IC – 2X Inline Dilution Factor

Drinking Water – Halogen Speciation Results (I)

County	Sample	I^- (ppb)	IO_3^- (ppb)
Barrow	Mulberry River	7.4	3.0
	Fort Yargo Lake	12	0.28
	Residential	0.12	14
	Commercial	0	11
Cobb	Cauble Park	1.2	0.23
	West Palisades	1.8	1.4
	Residential	0	14
	Commercial	0	13
Fulton	Morgan Falls Reservoir	2.2	1.4
	Chattahoochee River	1.6	1.3
	Residential	0.09	14
	Commercial	0.05	14

County	Sample	I^- (ppb)	IO_3^- (ppb)
Forsyth	West Bank	0.88	0.42
	Residential	0.04	10
	Commercial	0.05	9.8
Clarke	Middle Oconee River	0.83	6.5
	North Oconee River	2.0	0.51
	Residential	0.23	19
	Commercial	0	19

prepFAST IC – 2X Inline Dilution Factor

Drinking Water – Halogen Speciation Results (Cl)

County	Sample	Cl^- (ppb)	ClO_2^- (ppb)
Barrow	Mulberry River	5834	0
	Fort Yargo Lake	3802	0
	Residential	7308	0
	Commercial	7336	0
Cobb	Cauble Park	3396	0
	West Palisades	7612	0
	Residential	8099	304
	Commercial	8607	373
Fulton	Morgan Falls Reservoir	6805	0
	Chattahoochee River	6635	0
	Residential	8531	0
	Commercial	8617	0

County	Sample	Cl^- (ppb)	ClO_2^- (ppb)
Forsyth	West Bank	3973	0
	Residential	7763	0
	Commercial	7444	0
Clarke	Middle Oconee River	7863	0
	North Oconee River	3554	0
	Residential	18144	0
	Commercial	17627	0

prepFAST IC – 2X Inline Dilution Factor

Drinking Water – Halogen Speciation Results (Cl)

County	Sample	ClO_3^- (ppb)	ClO_4^- (ppb)
Barrow	Mulberry River	44	0
	Fort Yargo Lake	0	0
	Residential	280	0
	Commercial	0	0
Cobb	Cauble Park	0	0
	West Palisades	0	0
	Residential	235	0
	Commercial	252	0
Fulton	Morgan Falls Reservoir	0	0
	Chattahoochee River	0	0
	Residential	169	0
	Commercial	149	0

County	Sample	ClO_3^- (ppb)	ClO_4^- (ppb)
Forsyth	West Bank	0	0
	Residential	74	0
	Commercial	71	0
Clarke	Middle Oconee River	0	0
	North Oconee River	0	0
	Residential	58	0
	Commercial	60	0

prepFAST IC – 2X Inline Dilution Factor

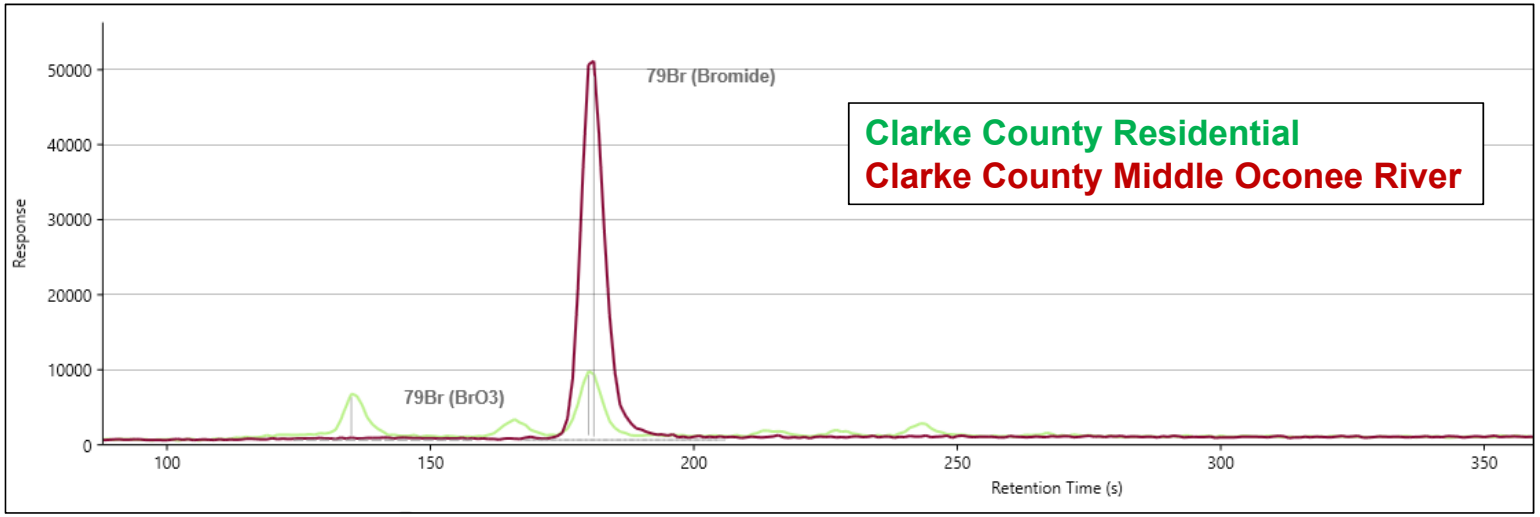
Filtering vs Non-Filtering of Collected Samples

	Br (µg L^{-1})		BrO_3 (µg L^{-1})		I (µg L^{-1})		IO_3 (µg L^{-1})	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
Barrow Mulberry River	29	30	< DL	< DL	7.4	7.6	3.0	3.1
Barrow Fort Yargo Lake	20	22	< DL	< DL	12	12	0.28	0.27
Cobb Cauble Park	19	20	< DL	< DL	1.2	0.97	0.23	0.25
Cobb West Palisades	21	21	0.24	0.12	1.8	1.6	1.4	1.3
Fulton Morgan Falls Reservoir	18	18	0.29	0.18	2.2	2.7	1.4	1.3
Fulton Chattahoochee River	17	18	0.25	0.13	1.6	2.4	1.3	1.2
Forsyth West Bank	13	14	< DL	< DL	0.88	0.75	0.42	0.43
Clarke Middle Oconee River	30	29	< DL	< DL	0.83	1.2	6.5	6.5
Clarke North Oconee River	21	23	< DL	< DL	2.0	1.9	0.51	0.41

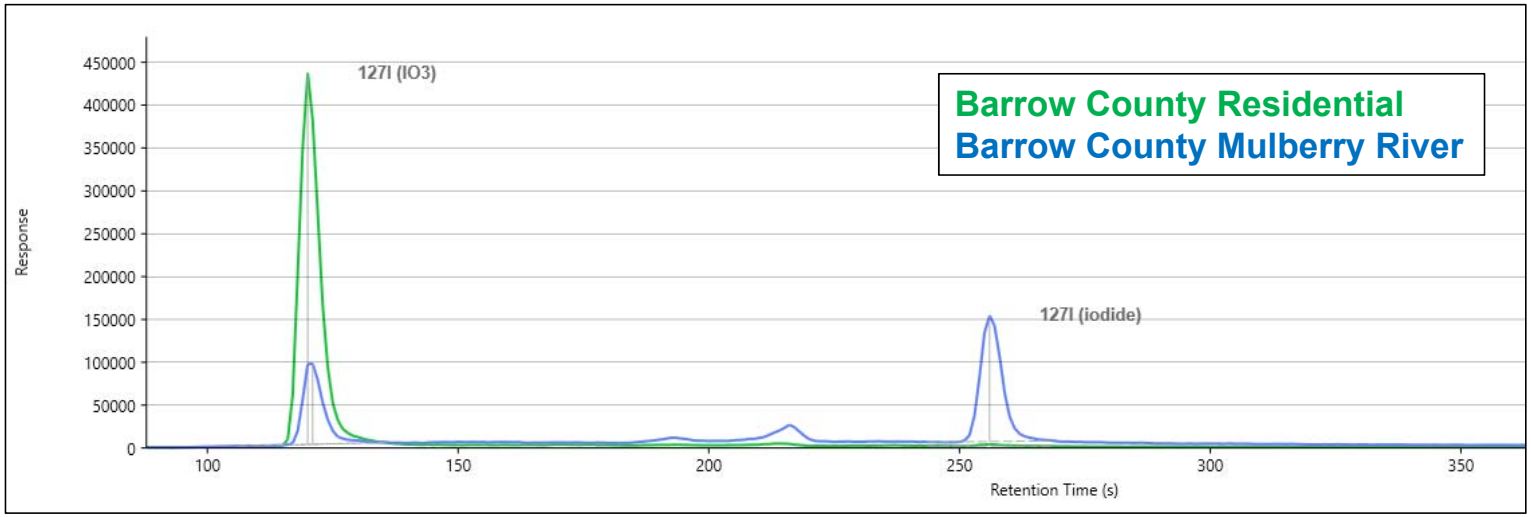
Filtering vs Non-Filtering of Collected Samples

	ClO_3 (µg L^{-1})		Cl (µg L^{-1})		ClO_2 (µg L^{-1})		ClO_4 (µg L^{-1})	
	Unfiltered	**Filtered**	**Unfiltered**	**Filtered**	**Unfiltered**	**Filtered**	**Unfiltered**	**Filtered**
Barrow Mulberry River	44	44	5834	5621	< DL	< DL	< DL	< DL
Barrow Fort Yargo Lake	< DL	< DL	3802	4094	< DL	< DL	< DL	< DL
Cobb Cauble Park	< DL	< DL	3396	3544	< DL	< DL	< DL	< DL
Cobb West Palisades	< DL	< DL	7612	8062	< DL	< DL	< DL	< DL
Fulton Morgan Falls Reservoir	< DL	< DL	6805	7002	< DL	< DL	< DL	< DL
Fulton Chattahoochee River	< DL	< DL	6635	6454	< DL	< DL	< DL	< DL
Forsyth West Bank	< DL	< DL	3973	3786	< DL	< DL	< DL	< DL
Clarke Middle Oconee River	< DL	< DL	7863	7301	< DL	< DL	< DL	< DL
Clarke North Oconee River	< DL	< DL	3554	3944	< DL	< DL	< DL	< DL

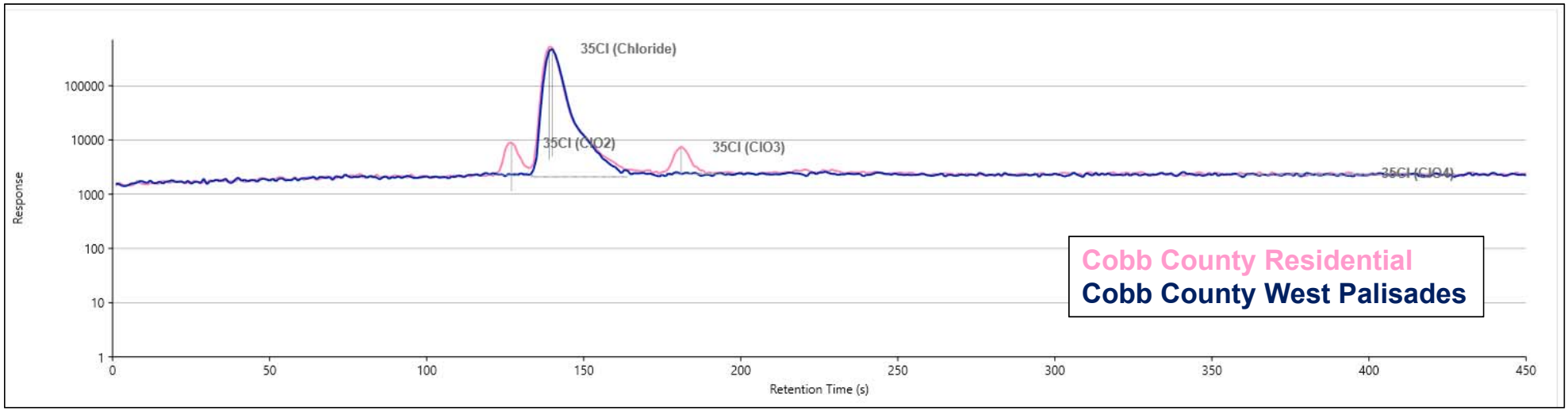
Clarke County – (Br) Results



Barrow County – (I) Results



Cobb County – (Cl) Results



Halogen Speciation Combined with EPA 6020B

NIST SRM 1643f – Trace Elements in Water

Element	Reference Value (µg/L)	Measured Value (µg/L)	% BIAS
Aluminum (Al)	133.8 ± 1.2	143.2 ± 4.4	7.1
Antimony (Sb)	55.45 ± 0.40	53.40 ± 0.27	-3.7
Arsenic (As)	57.42 ± 0.38	52.28 ± 0.31	-8.9
Barium (Ba)	518.2 ± 7.3	520.2 ± 6.8	0.4
Cadmium (Cd)	5.89 ± 0.13	5.73 ± 0.21	-2.7
Calcium (Ca)	29430 ± 330	29281 ± 440	-0.5
Chromium (Cr)	18.50 ± 0.10	19.52 ± 0.18	5.5
Cobalt (Co)	25.30 ± 0.17	25.65 ± 0.71	1.4
Copper (Cu)	21.66 ± 0.71	21.92 ± 0.33	1.2
Iron (Fe)	93.44 ± 0.78	91.29 ± 5.6	-2.3
Lead (Pb)	18.488 ± 0.084	18.164 ± 0.559	-1.8

Element	Reference Value (µg/L)	Measured Value (µg/L)	% BIAS
Magnesium (Mg)	7454 ± 60	7462 ± 100	0.1
Manganese (Mn)	37.14 ± 0.60	37.57 ± 0.66	1.2
Molybdenum (Mo)	115.3 ± 1.7	113.4 ± 1.3	-1.6
Nickel (Ni)	59.8 ± 1.4	60.0 ± 0.86	0.4
Potassium (K)	1933 ± 9	1984 ± 61	2.7
Selenium (Se)	11.700 ± 0.081	12.717 ± 0.690	8.7
Sodium (Na)	18830 ± 250	18565 ± 290	-1.4
Thallium (Tl)	6.892 ± 0.035	6.671 ± 0.021	-3.2
Vanadium (V)	36.07 ± 0.28	36.78 ± 1.0	2.0
Zinc (Zn)	74.4 ± 1.7	70.6 ± 0.5	-5.1

prepFAST IC – 2X Inline Dilution Factor

EPA 6020B - Results

County	Sample	Na 23 (ppb)	Mg 24 (ppb)	Al 27 (ppb)	K 39 (ppb)	Ca 44 (ppb)	Cr 52 (ppb)	Mn 55 (ppb)	Fe 56 (ppb)	Ni 60 (ppb)	Cu 63 (ppb)	Zn 66 (ppb)	As 75 (ppb)	Pb 208 (ppb)
Permissible Limits	**EPA Office of Water**			**50 - 200**			**100**	**50**	**300**		**1300**	**5000**	**50**	**15**
Barrow	Mulberry River	8306	2217	**335**	3242	8713	0.3	2	**330**	0.3	2	2	0.2	0.1
	Fort Yargo Lake	4455	939	**242**	2719	3320	0.1	5	62	0.4	3	2	0.4	0.1
	Residential	**27821**	3172	23	1929	**25677**	0.8	1	5	0.4	21	12	0.2	0.3
	Commercial	4108	1446	95	2026	9676	0.2	6	6	0.4	19	4	0.2	0.2
Cobb	Cauble Park	2913	2549	14	2581	7802	0.1	1	11	0.3	2	6	0.4	0.0
	West Palisades	7196	2377	100	2856	5039	0.1	1	42	0.3	1	2	0.1	0.0
	Residential	7048	1927	153	1873	**10981**	0.2	1	15	0.3	2	4	0.2	0.2
	Commercial	7016	1934	149	1806	**11269**	0.3	1	14	0.5	5	10	0.2	0.2
Fulton	Morgan Falls Reservoir	6729	2349	64	2649	4266	0.1	0	31	0.3	4	5	0.1	0.1
	Chattahoochee River	6074	2240	**302**	2598	3928	0.1	10	188	0.2	4	2	0.1	0.1
	Residential	7849	2098	43	2350	6055	0.2	0	3	**4.5**	38	357	0.1	0.1
	Commercial	7736	2036	**599**	2356	5812	0.2	0	1	0.6	25	31	0.1	0.1
Forsyth	West Bank	3936	1435	120	2068	2505	0.1	1	12	0.1	3	1	0.2	0.0
	Residential	4974	1541	114	2086	8462	0.1	2	7	0.2	7	6	0.2	0.1
	Commercial	4935	1495	114	2079	6898	0.1	1	8	0.2	16	5	0.1	0.1
Clarke	Middle Oconee River	9234	2615	8	3448	3180	0.1	0	43	2.7	4	3	0.1	0.0
	North Oconee River	4610	2598	128	2679	2482	0.2	2	**435**	0.9	4	1	0.2	0.1
	Residential	**14034**	2425	54	2763	**12621**	0.3	1	3	**696**	13	94	0.2	0.1
	Commercial	**14120**	2127	15	2891	5595	0.3	1	6	**12**	6	8	0.2	0.3

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