Method Optimization for the Analysis of Challenging Organic Samples by ICP-OES

Presented by: Sabrina Antonio
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Selection of Sample Introduction Components
- Selection of appropriate sample introduction components for organic samples
- Hardware accessories available for organic samples

Method Development and Validation
- Optimization of plasma and standard settings
- Interferences
- Method validation

Example Applications for Organic Analysis by ICP-OES
- AN43209 – Trace elements in naptha (volatile organic)
- AN43158 – Lubricating oils analysis according to ASTM 5185
- AN40876 – Elemental analysis of canola oil
Features include:
• Single- or multi-element analysis
• Low-cost, high-throughput systems
• Space-saving ergonomic design with low gas consumption

Measure elemental impurities:
• Any sample matrix
• Measurement at concentrations from parts per trillion to percent
The iCAP 7000 Plus Series ICP-OES Core Technologies

• **Lowest cost ICP-OES analysis, the highest quality data**
  • *iCAP 7200 ICP-OES* - Entry level, cost-effective analysis for low sample thru-put requirements.
  • *iCAP 7400 ICP-OES* - For routine analysis requirements and mid-range sample thru-put.
  • *iCAP 7600 ICP-OES* - Highest productivity and maximum sample thru-put with advanced, flexible accessory support, such as laser ablation.
Selection of Sample Introduction Components for Organic Samples

**Organic Samples – 2 Classifications**

- **Non-volatile**
  - V-groove neb
  - Baffled spray chamber
  - Small bore center tube

- **Volatile**
  - V-groove neb
  - Cooled spray chamber
  - Small bore center tube

**e.g. Kerosene, Xylene, MIBK, Toluene**

**e.g. Petrol, Benzene, Hexane, Naphtha**

**Chemical resistant pump tubing**

Temperature controlled Spray Chamber using the IsoMist (can operate from -10°C to 60°C) and the new IsoMist XR (extended range, from -25°C to 80°C)
Selection of Sample Introduction Components – Considerations

- The following properties of organic samples influence the selection of sample introduction components:
  - **Volutility** – organic solvents with vapor pressure higher than 30 mm Hg should be cooled for stability of analysis
  - **Viscosity** – thick oils and fats need to be heated prior to introducing to the ICP-OES
  - Due to volatility, the nebulization efficiency of organic solvents is enhanced, hence, more aerosol droplets are produced and can overload the plasma and cause it to shut-off
  - Also, carbon can quickly be deposited on the tip of the torch and center tube which may also cause the plasma to shut-off
  - Hence, the approach when selecting sample introduction components for organic samples is to minimize the amount of aerosol going into the plasma
Selection of Sample Introduction Components: Considerations

• To reduce the amount of organic sample aerosol reaching the plasma, use the following:
  • Small bore center tube – e.g. 1.0 mm
  • Baffled Cyclonic Spray Chamber
  • V-groove Nebulizer

• However, the effect of this combination of sample introduction components is decrease in sensitivity and increase in DLs

• Options to overcome this effect:
  • Dilute sample rather than use organics sample introduction
  • Increase integration times
  • Use an accessory to enhance sensitivity
Sample Introduction Kits for Organic Samples

Non-Volatile Organics Kit Includes:
- Baffled cyclonic spray chamber
- V-groove nebulizer
- 1.0 mm quartz center tube
- Quartz EMT Torch

Volatile Organics Kit Includes:
- V-groove nebulizer
- 1.0 mm quartz center tube
- Quartz EMT Torch
- Baffled cyclonic spray chamber or IsoMist (better option, purchase separately)

Peristaltic Pump Tubing Not Included!
Use of Hardware Accessories for Organic Samples

- Temperature controlled spray chamber – Introduction of volatile/viscous samples
- Homogenizing autosampler for oils
- Ceramic D-Torch

IsoMist Programmable Spray Chamber  
ASX-1400 Homogenizing Autosampler  
Ceramic D-Torch
• **Problem 1:**
  - High volatile samples make plasma unstable/extinguish plasma
  - If the solvent has a vapour pressure of ~30 mmHg or more at room temperature

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Formula</th>
<th>Molecular weight</th>
<th>Vapor pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>C2H4O2</td>
<td>60.06</td>
<td>15.7</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>C2Cl4</td>
<td>165.82</td>
<td>18.5</td>
</tr>
<tr>
<td>MiBK</td>
<td>C6H12O</td>
<td>100.18</td>
<td>19.9</td>
</tr>
<tr>
<td>1-Prepanol</td>
<td>C3H8O</td>
<td>60.11</td>
<td>21</td>
</tr>
<tr>
<td>Toluene</td>
<td>C7H8</td>
<td>92.15</td>
<td>28.4</td>
</tr>
<tr>
<td>Dioxan</td>
<td>C4H8O2</td>
<td>88.12</td>
<td>38.1</td>
</tr>
<tr>
<td>Petrol</td>
<td></td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Formic acid</td>
<td>CH2O2</td>
<td>46.03</td>
<td>42.6</td>
</tr>
<tr>
<td>Ethanol</td>
<td>C2H6O</td>
<td>46.07</td>
<td>44.6</td>
</tr>
<tr>
<td>2-Prepanol</td>
<td>C3H8O</td>
<td>60.11</td>
<td>45.4</td>
</tr>
</tbody>
</table>
• **Problem 1:**
  • High volatile samples make plasma unstable/extinguish plasma
  • If the solvent has a vapour pressure of ~30 mmHg or more at room temperature

• **Solution 1:** Cool down volatile samples
  • Peltier element with temperature range between -25 °C and 80 °C
  • 1 mm center tube
  • The more volatile the solvent the colder you go
Alternative Solutions for Volatile Samples

- Dilute the sample with a non-volatile solvent
  - Reduces the volatility of the sample
  - Reduces sensitivity
  - The more volatile the initial sample the greater the dilution factor
  - Internal standards are recommended but if the matrix is matched they can be negated

- Use of a low flow nebulizer at room temperature
  - Reduces the amount of sample reaching the plasma
  - Reduces sensitivity
  - Analysis of solvents with a vapour pressure of ~50 mmHg or below
  - Internal standards are recommended
  - Long sample uptake times due to the low flow
Problem 2:

Very viscous samples lead to inefficiencies in aerosol creation

Solution: Warm up viscous samples

Peltier element with temperature range between -25 °C and 80 °C
Homogenizing Autosampler for Oils

- **Problem**: Particulates accumulate at the bottom of the vial
  - The result obtained without stirring is higher as the probe is near the bottom of the tube where the particulates are
  - Old oil is especially affected

- **Solution**: Use a Stirring autosampler
  - Stirring probe and sample probe
  - While one sample is analyzed the next is being stirred
Homogenizing Autosampler for Oils

- Oil Samples are not stable
- Can separate into phases

- ASX-1400 stirs prior to analysis to obtain a homogenized, consistent sample
- Drip cup utilized
- Separate rinse station
**Problem:** Quartz torch cracking due to devitrification and thermal stress

**Solution:** Ceramic D-Torch
- Improved robustness for organic samples
- Fully demountable for simplified maintenance
- Increased torch lifetime for cost efficiency
Method Development and Validation

Method Development –
Plasma Parameters, Wavelength Selection, Interferences, Validation

Plasma Optimization
Use this method to optimize your plasma conditions for a specific analysis.
A plasma which has an organic solvent being introduced into it rather than an aqueous solvent will:
- Appear green due to carbon emission
- Edges of the plasma are more clearly defined when compared to aqueous plasmas

View of the duo axial (left) and dedicated radial (right) plasma upon aspirating an organic solvent
Plasma Parameters - Optimization for Organic Samples

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Range</th>
<th>Step Size</th>
<th>Aqueous Settings</th>
<th>Organics Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Power (Watts)</td>
<td>750-1500</td>
<td>25</td>
<td>1150</td>
<td>1150 &amp; Up</td>
</tr>
<tr>
<td>Nebulizer Flow (L/min)</td>
<td>0-1.5</td>
<td>0.01</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Pump Speed (rpm)</td>
<td>0-125</td>
<td>1</td>
<td>45-50</td>
<td>25-30</td>
</tr>
<tr>
<td>Auxiliary Flow (L/min)</td>
<td>0-2.0</td>
<td>0.1</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Coolant Flow (L/min)</td>
<td>0-20</td>
<td>1</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

1. Suggested starting point/default values for low TDS aqueous solutions
2. Suggested starting point for organics, higher power settings required for volatile organic solvents

![iCAP OES Spectrometer](image)
• Carbon can form on the intermediate and centre tubes due to incorrect plasma conditions
Carbon Formation Solution – Increase Auxiliary Gas Flow

0.5 L/min Auxiliary  1 L/min Auxiliary  1.5 L/min Auxiliary  2 L/min Auxiliary
Plasma Parameter Consideration – RF Power and Nebulizer Flow

- RF power and nebulizer flow have the greatest effect on signal
- Hard and soft wavelengths react differently to RF and nebulizer flow

![Graph showing relative intensity changes with increasing RF power and nebulizer flow influence on intensity.](image)
Automated Plasma Optimization

- Plasma conditions can be optimized automatically using the Method Development tool within the Qtegras ISDS software
- Different element wavelengths require different optimal conditions
- Range of wavelengths require set of comprised conditions

- Optimization of RF Power, Coolant and Nebulizer Gas Flows depending on
  - Selected wavelength(s)
  - Matrix (aqueous or organic)
  - Optimization parameter (intensity, detection limits, etc.)
Wavelength Selection

• Wavelength selection considerations:
  • Spectral interference effects
  • Matrix
  • Required Linear Range
  • Sensitivity
    • Plasma view (axial or radial)

- P at 177 nm – Yes
- Na at 588 nm – No
Required Linear Range

- Often set by regulation or protocol, e.g. ASTM
- Determining the linear range of an element can be done by continually increasing the concentration of the top standard by 10%
- Then read this back as an unknown
- If it is in range, add it to the calibration curve and continue using this process until the response is no longer linear
- To extend the linear range, you can:
  - Dilute the sample (this raises D.L.s)
  - Use alternate wavelengths
  - Employ use of radial view
  - Employ line switching and multi-calibration trace
  - De-optimize the plasma conditions
Interferences – Where do they come from?

Three Types of Interferences in ICP-OES

Samples + Standards
- Metals
- Organic Matter
- Oils and Fats
- Suspended Solids
- DI Water
- Acids & Reagent
- Organic Solvents

Samples + Plasma
- Desolvation
- Vaporization
- Atomization
- Ionization
- Emission

Spectrometer
- Separation of Light from the Plasma into Wavelengths and Spectral Orders

Physical Interferences
Chemical Interferences
Spectral Interferences
Physical Interferences

“A characteristic difference between sample and standard which affects sample introduction or nebulization”

**Causes**
- Viscosity
- Density
- Surface tension
  - High dissolved solids
  - Acid type or concentration

**Solutions**
- Dilution (degrades detection limits)
- Matrix matching (must be known to be effective)
- Internal standardization
- Method of Standard Addition
What is an internal standard?

- An Internal Standard (IS) is used as a dynamic drift correction for physical differences between samples and standards by giving a point of reference to detect an enhancement or suppression of signal.
- A correction is applied to samples according to the enhancement or suppression of the IS element.

Guidelines for use:

- IS MUST NOT be present in the sample.
- IS MUST be added accurately and precisely to ALL standards and samples (Use an IS Mixing Kit for continuous online addition of IS).
- IS should be affected the same way as analyte.
- IS should be interference free.
- Use background correction points.
- Match the plasma view of the IS wavelength to that of the analyte wavelength.
  e.g. Low Axial, Low Radial, High Axial, High Radial for duo view instruments.

IS Concentration – should be high enough to get good signal and %RSDS, e.g. 10 mg/kg Yttrium in Kerosene.

<table>
<thead>
<tr>
<th>IS Wavelength</th>
<th>Plasma View</th>
<th>Example Wavelengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y 371.030</td>
<td>High wavelength, Radial view</td>
<td>Mg 280.270, Fe 273.074</td>
</tr>
<tr>
<td>Y 224.306</td>
<td>Low wavelength, Axial view</td>
<td>As 189.042, Pb 220.353</td>
</tr>
<tr>
<td>Y 360.073</td>
<td>High wavelength, Axial view</td>
<td>Ag 328.068, Cu 324.754</td>
</tr>
<tr>
<td>In 230.606</td>
<td>Low wavelength, Axial view</td>
<td>Co 228.802, Ni 221.647</td>
</tr>
</tbody>
</table>
Typically oil samples are **weighed** due to viscosity.

Typical organic solvents used for standard preparation and sample dilution are:
- kerosene, xylene, toluene
- PremiSolv – an extremely low odor and toxicity alternative to kerosene or xylene

Oil-based standards used for calibration standards, e.g., Conostan S21 standard.

To avoid physical interferences, standards and samples need to be diluted resulting in approximately the same amount of sample and standard:
- **addition of base oil to match the amount of oil in calibration standard to that in the sample**
- E.g. A calibration standard using 0.5 g of S21 standard will need 0.5 g of base oil diluted to 10 g with kerosene to match a 1:10 dilution of samples

If the matrix cannot be adjusted between sample and calibration, internal standards have to be used:
- Internal standard is added to the solvent that is used for dilution of the sample.
Chemical Interferences

“A sample matrix characteristic which causes an analyte to behave differently in the sample and standard”

**Causes**
- Ionization (Na, K, Rb, Cs, Li)
- Molecule formation (i.e. oxides)
- Plasma loading

**Solutions**
- Dilution (degrades DLs)
- Ionization buffer
- Oxygen addition for organics
- Optimize plasma
- Matrix matching
- Internal standardization (can reduce plasma loading)
Spectral Interferences

- Spectral interferences are common in ICP-OES due to the numerous emissions from elements, molecules and matrix present in the plasma.
- There are 3 types of Spectral Interferences:
  - Flat baseline shift
  - Slopping baseline shift
  - Spectral overlap – partial or direct
Spectral Interferences – Baseline Shift

Flat Baseline Shift

- A flat baseline shift is when both sides of the peak go back down to baseline, however, smaller interfering peaks may be present.
- If a background point is placed on an interfering peak, this must be moved so that signal from the baseline shift is not integrated or included with the corrected peak calculation.
- Place background point away from the interfering peak, on a flat area of the peak.
- Or, remove the background point that is on the interfering peak and use the one background point that is on the flat side of the peak.
• **Sloping Baseline Shift**

  - Sloping shifts occur when the baseline of the analyte peak is on the side of a large interfering emission line.
  - Two background points must be used since the amount of baseline shifting is not the same on both sides.
  - A sloping baseline also makes it difficult to find a single location that accurately represents the background.
  - The background points must be placed as close to the on-peak measurement as possible so that the analyte emission is not over subtracted.
  - To help determine the proper placement of background points, switch to the Pixel Plot.
  - Where the peak starts on both sides of the baseline can be seen in Pixel Plot and this helps position the background points.

  *Need two points to average the asymmetric shifting*. 
Spectral Interferences – Direct Spectral Overlap

How to detect spectral Overlaps:

- Determine by overlaying image data of sample and calibration standard
- Analyzing a pure solution of the likely interference; a resulting apparent analyte concentration confirms the presence an interference
- Cannot be determined by matrix spikes

How to correct for Spectral Overlaps:

- Choose an alternative wavelength – the preferred choice
- Precise Matrix Matching
- Use Inter-element Correction Factors (IECs)
Spectral Interferences Are Also from Carbon Based Emissions
• **Optimization of the nebulizer gas flow**
• The bright green sample channel must be in the correct position
• This will reduce the background in the visible region
• **Synthetic air (SA)** can be added to the plasma via a mass flow controller or a “T” with pump tubing
• As the flow of synthetic air increases the carbon based emissions are removed
• Typical flows of 60 mL or less a minute
Method validation is required to ensure that the sample introduction components, plasma parameters, wavelengths and overall method developed results to data that is accurate, precise, reproducible and not drifting throughout the analysis.

Method validation can be achieved through:

- MDL or IDL determination
- Good calibration curve with a correlation coefficient of at least 0.995
- Linear range study
- Sufficient sensitivity for requirement (detection limit study)
- RSDs (short term precision and accuracy)
- Quality control (QC; e.g. readback of calibration standards) or CRM (certified reference material) analyses
- Repeat of above tests over several days (long term precision and accuracy)
Quality Control Tests

- **Blank tests** - Concentration has to be below a certain level
- **Initial and Continuing Calibration Verification tests** - A known concentration will be analyzed for the % recovery after calibration and periodically throughout the analysis, e.g. Every 10 samples
- **Spike tests** - Spiked and unspiked sample are compared
- **Internal standard tests** - Recovery of the internal standard has to be within certain limits
- Quality Control (QC) protocol built in the Qtegra ISDS software
  - For method validation, but also for continuous monitoring of the analysis
  - Includes actions that can be selected upon failure of a QC standard
  - Additional custom standards can be added to the QC protocol for added flexibility with laboratory requirements
• Chose appropriate sample introduction according to application
  • Volatile/Organics

• Accessories to be used to improve analysis
  • IsoMist for volatile/viscous samples
  • Stirring autosampler for oils to avoid false results from particulates
  • Ceramic D-Torch for enhanced matrix robustness

• How to optimize plasma parameters

• How to overcome interferences
  • Internal standards
  • Proper sample and standard preparation and dilution
  • Background and Inter-element correction

• Method validation and quality control tests to ensure accuracy of results
• Thermo Scientific™ iCAP™ 7400 ICP-OES Radial
  • GE IsoMist Peltier cooled spray chamber: -10°C
  • 1.5 mm center tube
  • Optimized radial viewing height: 8 mm

• Sample and standard preparation
  • Oil based standards
  • Weight basis in naphtha
  • Calibration blank naphtha
  • Spiked blank

<table>
<thead>
<tr>
<th>Solution</th>
<th>Concentration (mg·kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-21+K</td>
</tr>
<tr>
<td>Low standard</td>
<td>0.96</td>
</tr>
<tr>
<td>High standard</td>
<td>4.88</td>
</tr>
<tr>
<td>Spike</td>
<td>2.34</td>
</tr>
</tbody>
</table>
Improved Stability for Volatile Organics

IsoMist XR Extended Range Spray Chamber for Analysis of Volatile Organic Solvents

New IsoMist XR spray chamber for the analysis of volatile organic solvents

- Temperature range -25°C to 80°C
- Data showing analysis of Naphtha (vapor pressure greater than 30 mm Hg)

- 8h stability measurement without temperature control
- 8h stability measurement temperature controlled at -20°C

![Graph showing relative intensity vs. time for different elements]
AN 40876, AN 3161 and AN 43158 - Analysis of Trace Elements in Oils

**AN 40876 - Elemental analysis of canola oil using the Thermo Scientific iCAP 7400 ICP-OES**

**Food Oils** – vegetable, canola, peanut oil
- Edible oils – used for cooking
  - Elemental impurities affect flavor and shelf life
- Biodiesel production – raw stock
  - Elemental impurities affect combustion

**AN 3161 - Sprint analysis of lubricating oils using the Thermo Scientific iCAP 7000 Plus Series ICP-OES**

**Wear Metals**
- Used engine oil, gear oil, transmission oil
- Presence of certain elements indicate wear of metallic parts

**AN 43158 - Lubricating oil analysis according to ASTM D5185 using the Thermo Scientific iCAP 7400 ICP-OES**

**Lubricating Oils** – gear and engine oil
- Clean (unused) oils
- Elemental contaminants degrade oil and affect lubrication properties
- Additive concentrations guarantee performance of oil
### Trace Elements in Oils – Instrument Settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Food Oil Settings</th>
<th>Lubricating Oil Settings</th>
<th>Wear Oil Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nebulizer</td>
<td></td>
<td>V-groove</td>
<td>Sample introduction components and nebulizer flow rate selected to prevent plasma overload</td>
</tr>
<tr>
<td>Spray Chamber</td>
<td></td>
<td>Baffled glass cyclonic</td>
<td></td>
</tr>
<tr>
<td>Torch Injector</td>
<td></td>
<td>1.0 mm I.D.</td>
<td></td>
</tr>
<tr>
<td>Pump Tubing – Sample</td>
<td>Solvent Flex orange/white</td>
<td>Solvent Flex white/white</td>
<td></td>
</tr>
<tr>
<td>Pump Tubing – Drain</td>
<td>Solvent Flex white/white</td>
<td>Solvent Flex yellow/blue</td>
<td></td>
</tr>
<tr>
<td>Nebulizer Gas Flow</td>
<td>0.4 L/min</td>
<td>0.35 L/min</td>
<td>0.4 L/min</td>
</tr>
<tr>
<td>Auxiliary Gas Flow</td>
<td>1.5 L/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coolant Gas Flow</td>
<td>14 L/min</td>
<td>12 L/min</td>
<td>14 L/min</td>
</tr>
<tr>
<td>RF Power</td>
<td>1150 W</td>
<td>1150 W</td>
<td>1350 W</td>
</tr>
<tr>
<td>Radial Viewing Height</td>
<td>14 mm</td>
<td>12 mm</td>
<td>12 mm</td>
</tr>
<tr>
<td>Exposure Time</td>
<td>UV 15 s, Vis 5 s</td>
<td>UV 10 s, Vis 5 s</td>
<td>1 s</td>
</tr>
</tbody>
</table>

Higher auxiliary flow to prevent carbon build-up on torch and injector. Higher power to break up heavy matrix.
## Food Oil Results – Canola Oil

- Results for canola oil at 4 different stages of the refining process

<table>
<thead>
<tr>
<th>Element and Wavelength</th>
<th>Sample Results (mg/kg) and Detection Limits (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Oil</td>
</tr>
<tr>
<td>Ca 317.933</td>
<td>162.1</td>
</tr>
<tr>
<td>Cu 324.754</td>
<td>0.036</td>
</tr>
<tr>
<td>Fe 259.940</td>
<td>1.17</td>
</tr>
<tr>
<td>Mg 280.270</td>
<td>61.6</td>
</tr>
<tr>
<td>Na 589.592</td>
<td>0.12</td>
</tr>
<tr>
<td>Ni 231.604</td>
<td>&lt;DL</td>
</tr>
<tr>
<td>P 177.495</td>
<td>282.1</td>
</tr>
<tr>
<td>Pb 220.353</td>
<td>&lt;DL</td>
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<tr>
<td>S 180.731</td>
<td>7.03</td>
</tr>
<tr>
<td>Sn 189.989</td>
<td>0.11</td>
</tr>
</tbody>
</table>

<DL indicates measured concentration is below detection limit
<table>
<thead>
<tr>
<th>Element &amp; Wavelength</th>
<th>Sample Results (mg/kg)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New oil</td>
<td>Intermediate oil (200 hrs)</td>
<td>Old oil (400 hrs)</td>
</tr>
<tr>
<td>Ag 338.389</td>
<td>0.76</td>
<td>0.87</td>
<td>0.94</td>
</tr>
<tr>
<td>Al 308.215</td>
<td>0.09</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>B 208.959</td>
<td>2.14</td>
<td>1.63</td>
<td>2.46</td>
</tr>
<tr>
<td>Ba 223.527</td>
<td>ND</td>
<td>0.46</td>
<td>0.82</td>
</tr>
<tr>
<td>Ca 184.006</td>
<td>1103</td>
<td>2293</td>
<td>3014</td>
</tr>
<tr>
<td>Cd 214.438</td>
<td>0.15</td>
<td>0.17</td>
<td>0.27</td>
</tr>
<tr>
<td>Cr 267.716</td>
<td>0.12</td>
<td>1.15</td>
<td>2.54</td>
</tr>
<tr>
<td>Cu 324.754</td>
<td>0.58</td>
<td>2.03</td>
<td>3.49</td>
</tr>
<tr>
<td>Fe 238.204</td>
<td>2.76</td>
<td>23.2</td>
<td>30.8</td>
</tr>
<tr>
<td>Mg 279.553</td>
<td>870.8</td>
<td>631.2</td>
<td>323.4</td>
</tr>
<tr>
<td>Mn 293.930</td>
<td>0.21</td>
<td>0.63</td>
<td>0.89</td>
</tr>
<tr>
<td>Mo 281.615</td>
<td>ND</td>
<td>0.16</td>
<td>0.38</td>
</tr>
<tr>
<td>Na 589.592</td>
<td>5.71</td>
<td>5.2</td>
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<td>Zn 213.856</td>
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<td>1143</td>
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ND indicates measured concentration is below detection limit
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<tr>
<th>Element</th>
<th>Sample Results (mg/kg)</th>
<th></th>
<th>Element</th>
<th>Sample Results (mg/kg)</th>
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<td>Spike Recovery (%)</td>
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<td>Mn</td>
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Instrument utilizes built-in switching valve and Sprint mode setting
Sample analysis based on 2 replicates (27 s sample to sample)
Spike recovery based on 50 mg/kg spike
• Key technologies and dedicated features allow us to easily overcome challenges when analyzing organic samples and other difficult matrices in ICP-OES
  • Selection of appropriate sample introduction components for organic samples
  • Accessories and how they are used to improve your analysis
  • Application notes are available for a variety of organic sample matrices that can be used as reference guides for method development
  • Preconfigured sample introduction kits available based on sample matrix, e.g. volatile and non-volatile organic samples
  • Tips for method development and plasma setting optimization for organic samples
  • Smart Note available to assist in selection of sample introduction system
Conclusion

- There are specific sample introduction systems according to application
  - Volatile organics vs. Non-volatile organics

- Hardware accessories aid performance, robustness and speed of analysis
  - Stirring autosampler, Ceramic D-Torch and Sprint Valve

- Certain features help to facilitate method development
  - Internal standards
  - Inter-element correction
  - Quality control tests
  - Plasma optimization