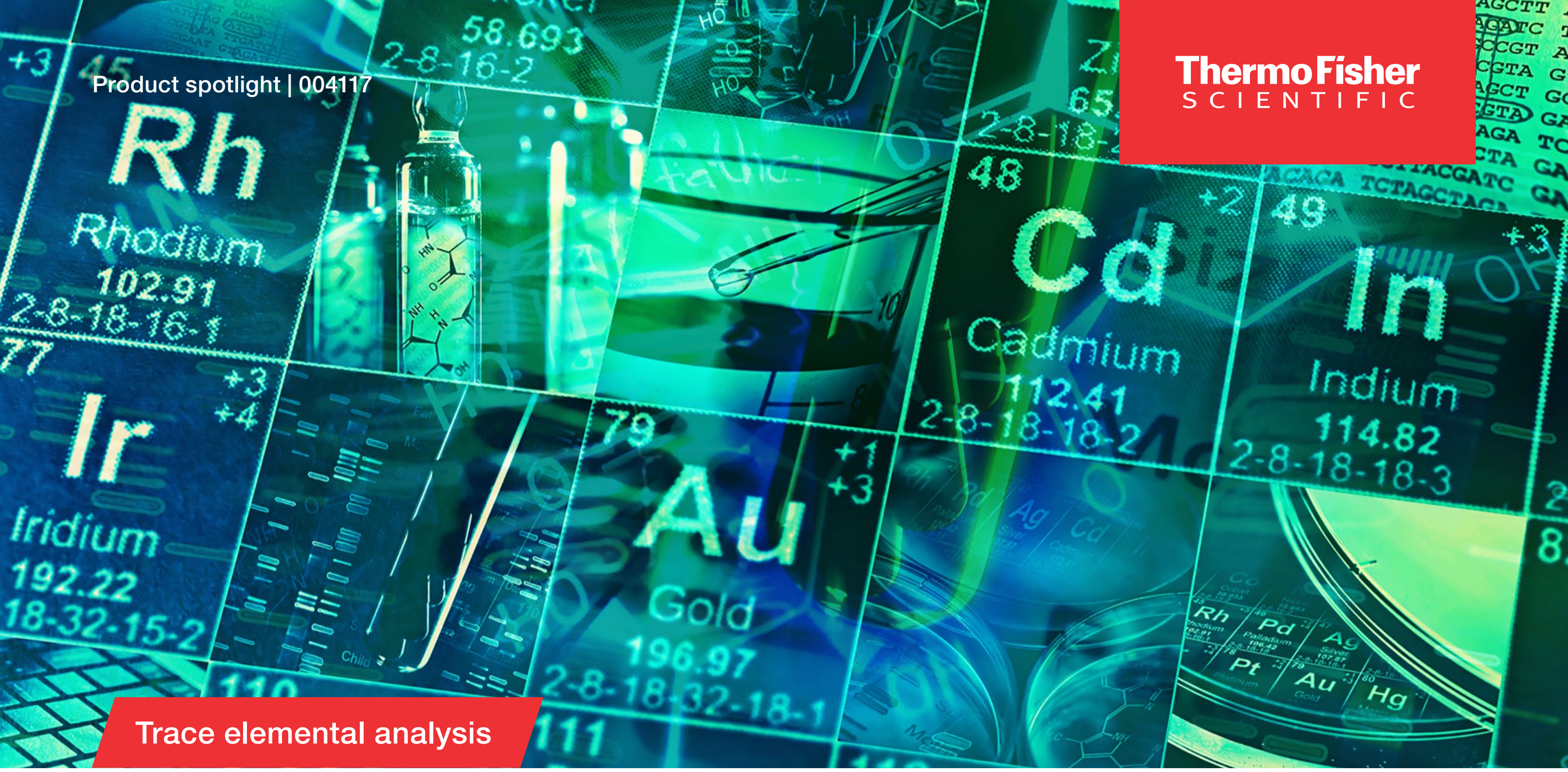


Product spotlight | 004117

Trace elemental analysis

Breaking away from the limitations of atomic absorption spectroscopy (AAS)

Improving speed of analysis and analytical performance

Atomic absorption spectroscopy (AAS) is an analytical technique that can quantify elements in a variety of samples based on the absorption of a characteristic wavelength of electromagnetic radiation from a light source (hollow cathode lamp, HCL). After transferring the sample to the gas phase by provision of (thermal) energy, absorbance of a sample is measured against standards. Depending on the analytical requirements, two different types of atomization techniques are available. Conventional flame atomic absorption spectrometers (FAAS), such as the Thermo Scientific™ iCE™ 3300 AAS, utilize acetylene/air or acetylene/nitrous oxides as the combustible, whereas graphite furnace systems (GF-AAS), for example the Thermo Scientific™ iCE™ 3500 AAS, leverage electrical heating in a graphite furnace.

Although AAS is a well-established technique and has been used for decades, the analysis of trace elements is nowadays often accomplished using other techniques, such as inductively coupled plasma optical emission spectroscopy (ICP-OES) or inductively coupled plasma mass spectrometry (ICP-MS). State-of-the-art instrumentation, for example the Thermo Scientific™ iCAP™ PRO Series ICP-OES and Thermo Scientific™ iCAP™ MX Series ICP-MS, can overcome common limitations or barriers to productivity often encountered with AAS. A few examples are:

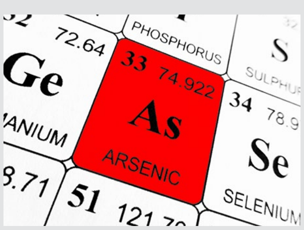
1. **Limitations in the number of accessible analytes:** AAS can only measure one element at a time, leading to inefficiencies and increased operational costs due to the need for repeated measurements and multiple calibrations.
2. **Tedious and complex sample preparation:** The sample preparation process for AAS is often lengthy and labor-intensive, requiring extensive digestion, sample pretreatments, and dilution procedures that slow down the overall workflow.
3. **Narrow linear range**: AAS offers limited linear range, making it difficult to analyze samples with varying concentrations of an analyte. It is often necessary to dilute over-range samples and then re-analyze them. This adversely affects sample throughput and productivity.
4. **Inferred data quality:** Interferences from background emission and matrix components are severe, which necessitates careful method development and validation.

Did you know? *FAAS typically covers higher concentration ranges (mg·L⁻¹), whereas GF-AAS can achieve detection limits in the sub µg·L⁻¹ range. ICP-OES can achieve comparable or better detection limits in most cases.*

Conversely, ICP-OES offers simultaneous multi-element analysis and handles complex matrices efficiently, while ICP-MS provides superior detection limits and a wide dynamic range. These techniques increase throughput, minimize matrix interferences, and accommodate more elements, making them preferred for comprehensive elemental analysis in environmental, food safety, clinical, and industrial applications.

Common scenarios of laboratories using AAS for elemental analysis

Laboratories operating in the field of elemental analysis typically measure heavy metals and metalloids, both qualitative and quantitative. Common analytes include Pb, Cd, As, Hg, Cu, Zn, Ni, Sn, Sb, Se, and Ni due to their potential health risks and environmental impact. In addition, accurate analysis of minerals such as Na, K, Ca, Mg, and Fe is important for these types of sample matrices. This panel of analytes (or relevant segments of it) can be found across a wide range of established methods, such as environmental testing (i.e., EPA Method 200.9[1]), analysis of food and feed (AOAC Method 999.10[2] and ISO 6869:2000 Standard[3]), industrial applications (ASTM methods and ISO standards), and/or pharmaceutical products (general pharmacopeial methods and product specific monographs). OSHA (Occupational Safety and Health Administration) utilizes various methods for elemental analysis to ensure workplace safety and compliance with regulatory standards.



Did you know? *Analysis of elements such as As, Se, Sn, Sb, and Hg at low levels using hydride generation requires specific sample pre-treatment and additional hardware. The required detection limits can be readily achieved by ICP-MS with reduced sample preparation.*

To screen all these 15 common analytes at regulatory levels, up to three atomization techniques (FAAS, GF-AAS, and hydride generation) may be required. Figure 1 shows the typical distribution of analytes per atomization technique based on requirements.

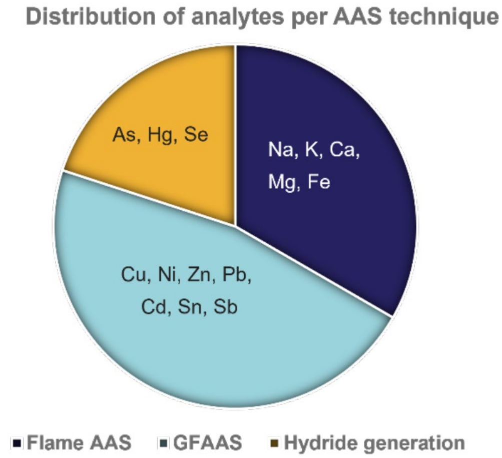
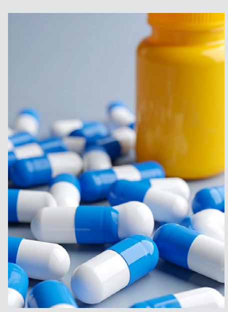


Figure 1. Overview of the typically required method for analysis of 15 common analytes across a variety of regulatory methods and different market areas.

One of the fundamental limitations of AAS is that it can measure only one analyte at a time. For additional elements, it is necessary to at least repeat the analysis using a different light source, or even use a different technique (flame, furnace, or hydride generation). This requirement for repetitive analysis of the same sample leads to the consumption of large sample volumes and increases the analysis time per sample significantly, thereby adversely affecting the overall productivity of an analytical laboratory.

Mitigating the challenges of AAS by adapting ICP-OES and ICP-MS

ICP-OES and ICP-MS are powerful alternatives to AAS for elemental analysis, offering numerous benefits. For laboratories migrating FAAS methods, ICP-OES is often a suitable replacement, whereas ICP-MS allows a laboratory to consolidate multiple methods, for example, by combining methods from GF-AAS and hydride generation. Both techniques offer significant advantages over AAS, as summarized in Table 1.



Did you know? *Both ICP-OES and ICP-MS allow screening of an unknown sample for its composition—independent of a defined list of analytes. With ICP-OES, semiquantitative analysis is possible without the need to run calibration standards.*

Table 1. Comparison of atomic absorption spectroscopy with other elemental analysis techniques based on inductively coupled plasma (ICP-OES/ICP-MS).

Parameter	FAAS	ICP-OES	GF-AAS	ICP-MS
Initial investment	Low	Moderate	Moderate/High	Highest
Multi-element analysis	No	Yes	No	Yes
Typical sample turnover time	30 seconds per analyte	3 minutes per sample	3–4 minutes per analyte	2–3 minutes per sample
Detection limits	$mg \cdot L^{-1}$	$\mu g \cdot L^{-1}$	$\mu g \cdot L^{-1}$ to $ng \cdot L^{-1}$	$ng \cdot L^{-1}$
Sample volume required	Several mL per analyte	3–5 mL per sample	30–50 µL per analyte	1–5 mL per sample
Linear dynamic range	Limited: Two orders of magnitude maximum	Wide: Several orders of magnitude possible	Limited: Two orders of magnitude maximum	Highest: Up to 10 orders of magnitude
Application versatility	Limited	High	Limited	Highest

- **Improved efficiency and throughput:** ICP-OES and ICP-MS can analyze multiple elements simultaneously, reducing analysis times and increasing throughput.
- **Operational simplicity:** Both techniques require argon gas for high energy plasma generation, simplifying operational requirements. ICP-MS needs an additional low flow of helium for interference removal using a collision cell.
- **Expanded scope of applications:** ICP-OES and ICP-MS cover more analytes compared to AAS and provide flexibility of advanced applications, ensuring a laboratory is future-proofed.
- **Low cost of analysis and reduced maintenance:** Reduced sample volume, minimal maintenance, and increased sample throughput contribute to higher productivity, better data quality, and lower operational costs.

Did you know? *Adding a new analyte to a method requires significantly more method development compared to ICP-OES or ICP-MS. AAS is a single element technique; as a result, a single sample may need to be analyzed multiple times on different setups to fulfill analytical requirements.*

Did you know? *Modern ICP-MS systems are capable of handling high amounts of total dissolved solids (TDS)—up to 25%. Together with their unmatched linear dynamic range, they can provide a full analysis of trace level impurities up to percent level for major analytes in single measurement.*

Conclusion

Modern laboratories need to keep up with fast-changing analytical requirements, making the shift from AAS to ICP-based techniques is a smart and inevitable choice. ICP-OES and ICP-MS offer proven multielement analysis and can therefore help laboratories unlock access to lower detection limits, better elemental coverage, and faster analysis times. Further, migration to ICP-based techniques can help to consolidate methods or reduce the amount of sample volume required. ICP-based techniques can therefore be attractive alternatives to AAS. Both instruments use Thermo Scientific™ Qtegra™ Intelligent Scientific Data Solution (ISDS) Software, and as a package, they excel in environmental monitoring, food safety, industrial testing, clinical diagnostics, pharmaceutical development, and advanced research.

References

1. EPA Method 200.9
2. AOAC Method 999.10
3. ISO 6869:2000 Standard

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