Agilent

Trusted Answers

April 2020 Edition

Atomic Spectroscopy Applications in the Environmental Laboratory

Applications compendium

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Agilent atomic spectroscopy solutions for the analysis of drinking water, wastewater, soils, and sludges

Today, environmental analysis must be done faster, more reliably, and more cost-effectively than ever before.

The Agilent atomic spectroscopy instruments slash cost-per-sample analysis for laboratories performing trace and ultratrace analysis of heavy and toxic metals in drinking, ambient and wastewaters, and soil and sludges. Our instruments routinely achieve significantly lower limits of detection (LOD) for trace and heavy metal contaminants, ensuring compliance with regulatory standards for environmental samples of all types.

The Agilent atomic spectroscopy portfolio includes ICP-MS, ICP-OES, MP-AES, and AA. These instruments deliver sensitive, accurate, and precise measurements across the widest dynamic range – from percentage down to low ppt, independent of matrix composition and concentration.

Agilent ICP-MS: complete elemental analysis of environmental samples

Agilent is the leading supplier of quadrupole ICP-MS instruments for environmental testing:

- Improve multi-element accuracy by eliminating matrix and plasma-based polyatomic ion interferences using Agilent's Octopole Reaction System (ORS). ORS uses helium (He) cell mode for simple and reliable removal of polyatomic interferences, even in complex, and variable matrices
- Simplify the measurement of complex environmental samples such as sludges with High Matrix Introduction (HMI) technology. This technology is standard on the Agilent 7800 ICP-MS, or Ultra HMI (UHMI), available as an option for the Agilent 7900 ICP-MS. HMI lets you analyze samples containing up to 3% total dissolved solids (TDS) without dilution, reducing sample preparation, extending maintenance, intervals, and saving time. UHMI extends the matrix tolerance of the 7900 ICP-MS to TDS levels of up to 25%. This minimizes the need for sample dilution and almost eliminates matrix suppression
- Increase productivity and decrease reruns with a detector that provides 10 (7800) or 11 (7900) orders dynamic range
- Conform to regulatory requirements, including US EPA 200.8, 6020, & 1638. Agilent quadrupole ICP-MS instruments measure all regulated elements in natural and drinking waters, wastewater, soil, and solid waste digests. From major elements at 100s–1000s parts per million to trace elements at parts per trillion levels

The unique Agilent 8900 Triple Quadrupole ICP-MS (ICP-QQQ) extends the capability of ICP-MS for environmental analysis:

- The 8900 adds the power of MS/MS to support methods that require the use of reactive cell gases
- Extend environmental applications to include the measurement of trace levels of difficult elements (Si, P, S...), ultratrace environmental contaminants, and elements that suffer from doubly-charged ion overlaps
- Measure silica nanoparticles at sub-50 nm particle sizes, with high sensitivity, lower backgrounds, and effective removal of interferences

Agilent ICP-OES: high-volume, high-productivity analysis of trace metals in water

Agilent ICP-OES is the most productive high-performance system available:

- Achieve maximum sensitivity for trace-level applications, including the determination of trace and toxic elements in waters
- Easily satisfy all the required regulatory QC limits tests without unnecessary recalibrations – the thermally stabilized optics contain no moving parts, ensuring excellent long-term stability
- Double system productivity and reduce argon consumption by 50% with dichroic spectral combiner technology that captures the radial and axial views of the plasma in one reading
- Conform to all regulatory requirements, including US EPA 200.7, 6010 and ILM05.3. The ICP Expert software automates all US EPA protocols, while configurable QC tests enable you to satisfy the requirements of other regulatory bodies

Agilent MP-AES and AA: cost-effective process and routine water testing

The Agilent 4210 MP-AES is suitable for nonregulated environmental applications, such as process monitoring or screening applications. The revolutionary 4210 MP-AES runs unattended without flammable or expensive gas supply, dramatically reducing operating costs.

Agilent's AA range is suitable for government and contract laboratories routinely running regulated applications. This includes labs testing elements in effluents, sludges and soil at major levels, and toxic elements at trace levels.

Inorganic and elemental analysis

Detecting potentially harmful levels of trace and minor elements

Inorganic elemental contamination of water supplies may occur from natural deposits, as well as from industrial, agricultural, and household sources. But no matter what the cause, monitoring the levels of these contaminants in drinking, natural, and environmental waters is essential for ensuring water quality and protecting human health.

One of the biggest challenges is monitoring multiple metals in samples is the variation in the quantity of each element. Concentrations may range from trace levels to high concentrations. Agilent's portfolio of high-productivity atomic spectrometers deliver sensitive, accurate, and precise measurements across a wide dynamic range – from percentage down to low ppt, and in the presence of matrix interferences.

Each instrument has unique performance characteristics, allowing you to choose the technique that meets your analytical needs (detection limits, measurement range, and elemental coverage). You can accommodate your demands for sample matrix levels, throughput, and budget.

Atomic Spectroscopy Techniques

Atomic spectroscopy describes several analytical techniques used to determine the elemental composition of a sample by examining its electromagnetic spectrum or its mass spectrum. In an environmental laboratory, atomic spectroscopy techniques are used to determine the composition and concentration of regulated metals in environmental samples such as air samples, waters, wastewaters, soils, sludges, and waste materials. Atomic spectroscopy techniques are also used to determine the metal content of biota that might be exposed to contaminated water or soil.

Atomic spectrometry techniques can be divided into two broad categories; those techniques which identify an analyte element by its electromagnetic spectrum, and those which identify an element by its mass spectrum. In the environmental laboratory, the most common electromagnetic spectrometric techniques are atomic absorption and atomic emission. Note that X-ray based techniques such as X-ray fluorescence (XRF) and X-ray diffraction (XRD) are technically electromagnetic spectrometric techniques as well.

Atomic absorption spectroscopy (AA)

Atomic absorption techniques use the fact that an atomized element absorbs light of a characteristic wavelength, elevating it from the ground state to an excited state. The amount of light energy absorbed is proportional to the number of analyte atoms in the light path. The technique is calibrated by introducing known concentrations of analyte atoms into the light path and plotting the absorption versus concentration curve. The source of light characteristic of each analyte element used is a hollow cathode lamp (HCL) or electrodeless discharge lamp (EDL). Typically each lamp is used for the analysis of a single element, though sometimes a few elements can be combined into a single lamp. Atomic absorption is generally used for a small number of analyte elements per sample, even though it can measure 67 elements (not at the same time).

The analyte elements must be atomized (converted to the atomic state) using high temperature. Elements are atomized by introducing a liquid sample via a nebulizer into a high temperature acetylene flame in flame atomic absorption spectroscopy (FAA). Alternatively, they are atomized by resistively heating a dried sample in a small diameter graphite cylinder – graphite furnace atomic absorption spectroscopy (GFAA) (Figure 1).

FAA is simple and inexpensive but has the limitation of transient and relatively diffuse atom density in the flame resulting in poor sensitivity when compared to other techniques. Typical detection limits are in the high ppb to ppm range. GFAA has the advantage of programmable temperature control, which allows the solvent and matrix to be separated from the analyte as a function of boiling point. Also, once the analyte is atomized in GFAA, it is retained within the small volume of the graphite tube for extended measurement. As a result, detection limits using GFAA are much lower than FAA, typically in the sub ppb range. GFAA suffers from the same limitation on number of analytes which can be measured per sample as FAA, and is much slower.

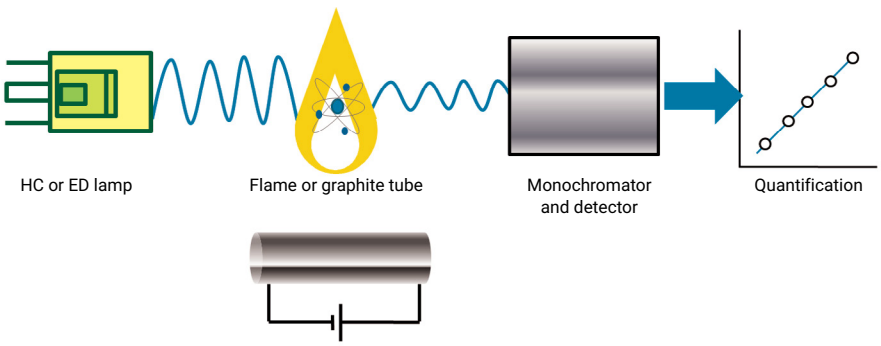


Figure 1. Schematic diagram of flame or graphite furnace atomic absorption spectrometer system

Atomic emission spectroscopy

FAA is limited in the number of elements which can be measured in a single sample and has relatively poor sensitivity. GFAA is slow, and both techniques require dedicated lamps for each element. Atomic emission techniques have come into use to overcome these limitations. Atomic emission techniques, use the fact that once an atom of a specific element is excited (as in atomic absorption), it emits light in a characteristic pattern of wavelengths – an emission spectrum, as it returns to the ground state. While it is possible to perform atomic emission spectroscopy using a flame type instrument similar to a FAA instrument, the flame is not an ideal excitation source for atomic emission. Typical temperatures for an acetylene flame used in AA are 2,000 to 3,000 K. Air-acetylene flames are at the lower end of the temperature range and nitrous oxide-acetylene flames at the upper end. Alternative sources for atomic emission include the microwave plasma (MP) and the inductively coupled argon plasma (ICP). Both sources are significantly hotter, and are therefore excellent atom and excitation sources for atomic emission spectroscopy.

Microwave plasma – atomic emission spectroscopy (MP-AES)

The nitrogen MP is considerably hotter than the acetylene flame, reaching temperatures nearing 5,000 K. At these temperatures, atomic emission is strong for most elements, leading to improved detection capability, and linear dynamic range over flame AA for most elements. As the MP runs on nitrogen, on-going operating costs can be significantly reduced compared to flame AA. The use of a nitrogen generator as the nitrogen source for the plasma offers further cost savings. Safety is improved compared to flame AA, as inert nitrogen is used rather than acetylene (a flammable gas). Using inert nitrogen also allows for unattended and overnight sample analysis, which is not recommended for FAA.

Using a scanning monochromator and a solid-state detector, the MP-AES eliminates the need for individual lamps. The technique also offers faster sample to sample analysis times compared to FAA, particularly as the number of elements (analytes) increases beyond a few elements. MP-AES can run samples up to around 3% total dissolved solids (TDS), using the appropriate sample introduction configuration.

As MP-AES is a relatively new technology, it may not be accepted in some regulated environments where an environmental lab must use a regulated method and technique for particular analysis. Other environments accept performance-based validation depending on the regulated methodology.

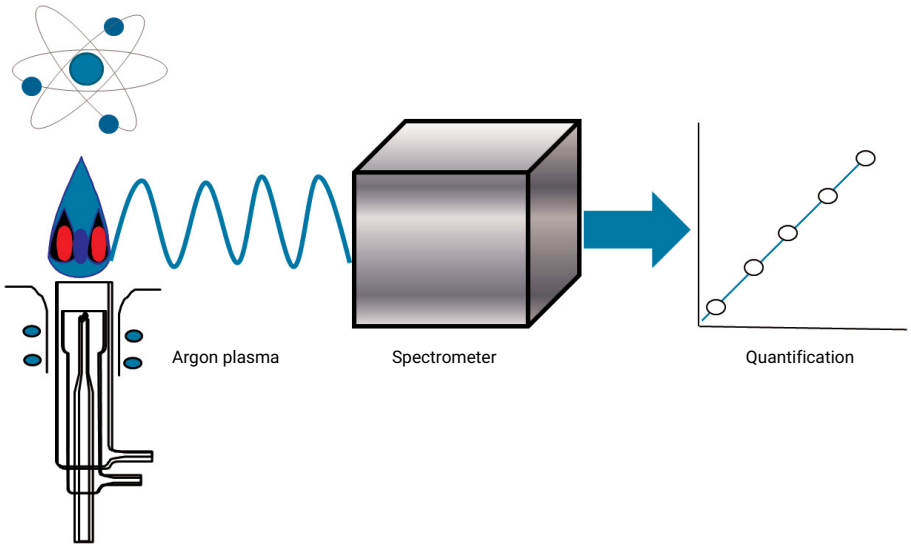
Inductively coupled plasma – optical emission spectroscopy (ICP-OES)

The argon ICP is hotter than the nitrogen MP and is much hotter than the acetylene flame. ICP can reach temperatures nearing 10,000 K, which allows complete atomization and significant ionization of the sample. Molecular interferences are reduced and the available atom and ion emissions for detection are maximized. Similar to the MP-AES, the ICP-OES uses an inert gas (argon) rather than flammable gas (such as acetylene for FAA) allowing unattended and overnight sample analysis, and improving safety. As a result, ICP-OES, also called ICP-AES (ICP-atomic emission spectroscopy) has become the workhorse for elemental determinations in many industries including environmental monitoring. In addition to not requiring a lamp for each element, ICP-OES has numerous advantages over FAA. It is a true multi-element technique, capable of simultaneously, or near simultaneously measuring up to 78 elements at low ppb detection limits.

The high temperature of the argon plasma also means that the ICP-OES can tolerate complex matrices containing total dissolved solids (TDS) up to ~25%, depending on the specific configuration. Also, ICP-OES sensitivity falls between that of FAA, MP-AES, and GFAA (low ppb to percent range). This means that ICP-OES can measure all elements that were previously determined using FAA, and some of the elements that, because of lower required reporting limits, may have required the use of GFAA.

However, ICP-OES does not equal GFAA or ICP-MS for ultimate sensitivity in the ppt range. For this reason, laboratories which use ICP-OES for primary elemental analysis, will still require GFAA for ultratrace analysis of elements such as As, Se, Cd, Pb etc. As sample numbers increase, GFAAS becomes the limiting factor for a laboratory's productivity. Labs with high sample numbers may consider moving their trace element analysis onto another multi-element technique (ICP-MS).

Figure 2. Simplified schematic diagram of ICP-OES spectrometer system



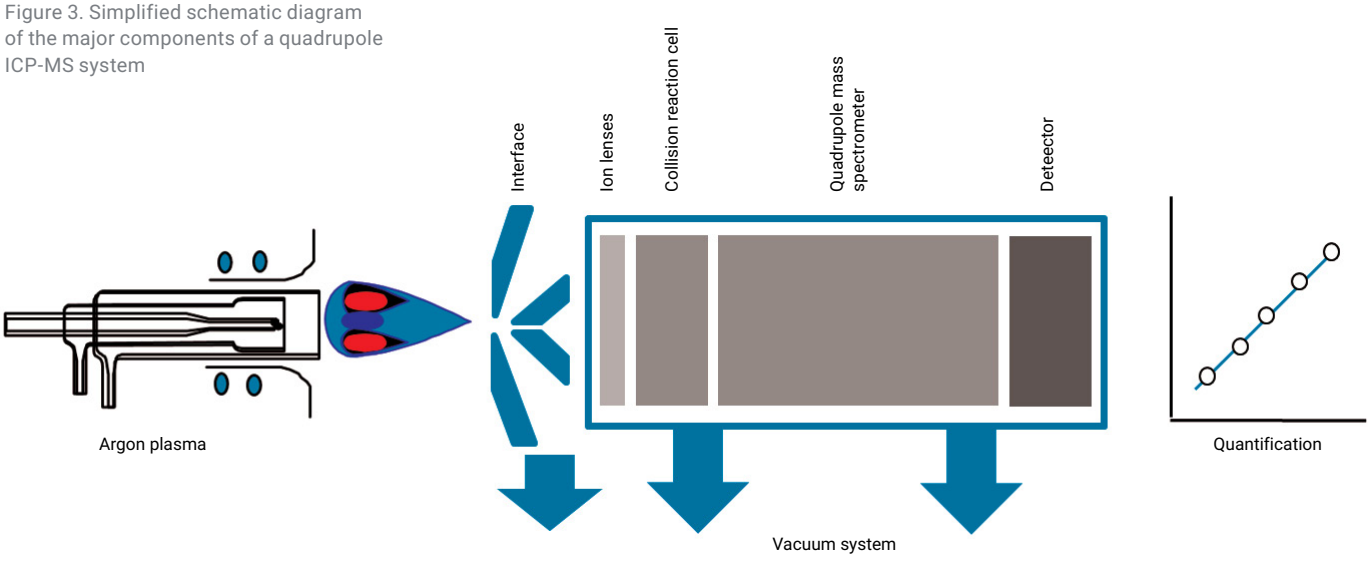
Inductively coupled plasma – mass spectrometry (ICP-MS)

In the mid 1980s, the argon ICP was first coupled to a quadrupole mass spectrometer resulting in the first ICP-MS instruments. The goal was to take advantage of the argon ICP as a highly efficient ion source, coupled to the quadrupole mass spectrometer for its high sensitivity, simple spectra, and fast scanning capability. The result is an instrument that combines the rapid, simultaneous, multi-element capability of ICP-OES and the sensitivity of GFAA. In an ICP-MS instrument, the argon plasma operates as an ion source. The ions pass into the high vacuum region containing the quadrupole mass analyzer via a set of interface cones and ion lenses. Ions are separated by the quadrupole and transmitted to an electron multiplier for detection (Figure 3).

While the argon plasma in an ICP-MS is similar to the plasma used in ICP-OES, the purpose is different. In ICP-MS, only ions are measured, so the plasma is optimized to ionize elemental atoms. The argon plasma is ideal for this task, as the ionization potential (IP) – the energy required to remove the first electron from the neutral atom – of Ar is 15.76 electron volts (eV). This is above the first IP of nearly every other element, but below their second IP, which means that most elements form singly-charged positive ions.

High ionization efficiency is achieved by maintaining a high temperature in the central channel of the plasma. A high temperature is achieved by using a highly efficiency solid state generator, wide internal diameter torch injector, and optimized operating conditions. The result is a "robust" plasma which delivers >95% ionization for most elements. Even poorly ionized elements such as Be, As, Se, Cd, and Hg are substantially ionized, so can be measured at trace (ppt) levels on the Agilent 7800 and 7900 ICP-MS. Operating the ICP-MS with a high plasma temperature also provides better decomposition of the matrix, leading to less matrix deposition, and lower maintenance. Many potential interferences are also dissociated in the plasma, a performance characteristic that is usually monitored using the strongly bound molecular ion CeO^+. A robust ICP-MS plasma would provide a CeO^+/Ce^+ ratio of around 1.5% or below.

Figure 3. Simplified schematic diagram of the major components of a quadrupole ICP-MS system



The ions are extracted from the plasma and passed into the high vacuum region for separation and detection. Photons and neutral species are rejected using an off-axis ion lens, and polyatomic interferences are removed using Kinetic Energy Discrimination (KED) with helium cell gas in the collision/reaction cell. The quadrupole mass spectrometer separates ions based on their mass to charge ratio (*m/z*). The ions are then passed sequentially to an electron multiplier detector, which generates a pulse for each ion reaching it. Since the charge on a singly ionized element is 1, the *m/z* is equal to the mass, so ICP-MS measures the elements as a simple spectrum of characteristic atomic (isotopic) mass from ^{6}Li to ^{238}U. Many elements have multiple isotopes with different masses and for these elements the ICP-MS can also provide isotopic ratio and abundance information.

With its wide elemental coverage (up to 70 elements can be measured routinely) and linear dynamic range from <1 ppt to 1000s of ppm, ICP-MS overlaps the capabilities of both ICP-OES plus GFAA instruments. However, adoption of ICP-MS in many commercial environmental laboratories has been slow due to the historical limitations of the technique: poor tolerance of high total dissolved solids (TDS) levels, and errors due to matrix-based interferences.

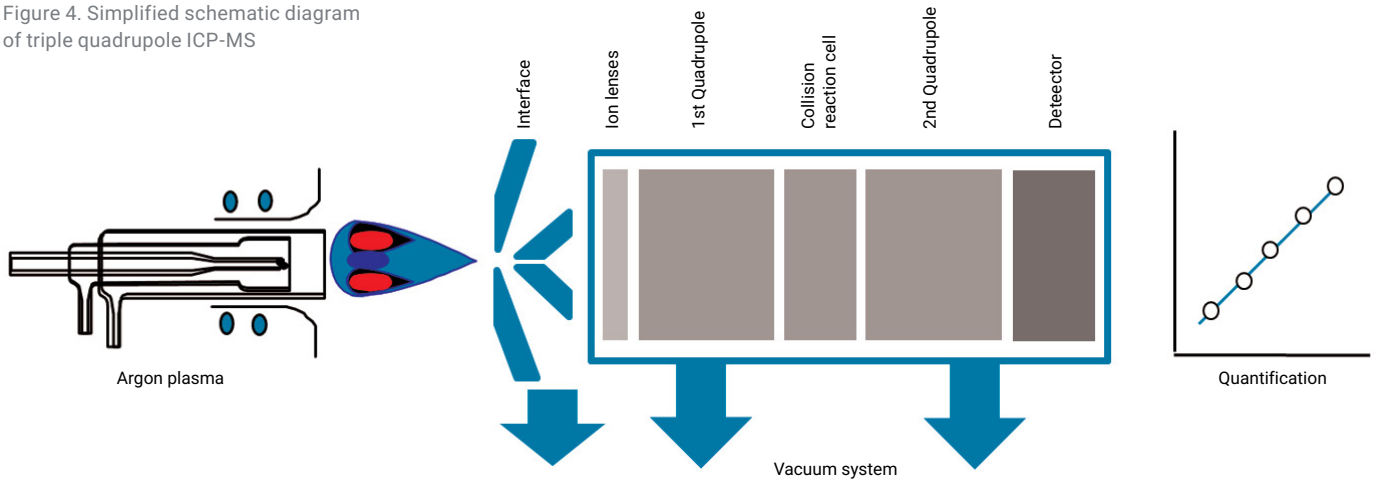
Continual advances in ICP-MS technology have addressed those early limitations, but most modern ICP-MS instruments are still limited to a maximum TDS level of about 0.2% (2000 ppm). This is a factor of 100 lower than their OES cousins. To improve matrix tolerance and permit direct analysis of higher TDS samples, Agilent has developed unique High Matrix Introduction (HMI) aerosol dilution technology. HMI uses automatically calibrated argon gas addition between the spray chamber and ICP torch, which reduces the amount of aerosol reaching the plasma, eliminating the need for conventional liquid sample dilution. Since the dilution occurs in the gas phase, no potential contamination from aqueous diluents can occur, and plasma robustness is improved by reducing the solvent (water) load on the plasma. HMI is standard on the 7800 ICP-MS, allowing direct measurement of samples with a TDS content up to 3%. Ultra HMI (UHMI), available as an option for the 7900 ICP-MS, extends matrix tolerance up to 25% TDS.

ICP-QQQ

The latest advance in atomic spectrometry is the development of an ICP-MS based on a tandem mass spectrometer – ICP-MS/MS. The Agilent 8900 Triple Quadrupole ICP-MS (ICP-QQQ) uses two hyperbolic profile quadrupole mass analyzers. The mass analyzers are separated by an Octopole Reaction System (ORS) collision/reaction cell, as used in the quadrupole ICP-MS systems.

The first quadrupole (Q1) is used to control the ions which enter the collision/reaction cell. Collisions or reactions in the cell eliminate interferences and the analyzer quadrupole (Q2) is used to transmit the separated analyte ions to the detector. A simplified schematic diagram of the ICP-QQQ configuration is shown in Figure 4. The term “triple quad” is used for any mass spectrometer configuration that uses two transmission quadrupole mass spectrometers in series. The mass spectrometers are separated by a cell containing an RF only (nonselecting) multipole ion guide (see IUPAC definition Term 528). In the Agilent 8900 ICP-QQQ, the ORS cell uses an octopole ion guide.

Figure 4. Simplified schematic diagram of triple quadrupole ICP-MS



Why ICP-QQQ?

The 8900 ICP-QQQ has significantly higher sensitivity and much lower backgrounds than are typical for quadrupole ICP-MS systems. The 8900 offers far superior abundance sensitivity to separate trace peaks from major peaks (Mn in Fe, for example).

The ICP-QQQ configuration supports MS/MS operation, where both Q1 and Q2 are operated as unit mass filters. Q1 selects the analyte ion mass that enters the cell, rejecting all other masses. This ensures that the ions in the cell are consistent and independent of the sample composition, so reactive cell gas methods can be used reliably. This control of the reaction chemistry allows ICP-QQQ to resolve interference problems that cannot be addressed using conventional quadrupole ICP-MS. These include separating direct isobaric overlaps (such as ^{204}Hg on ^{204}Pb), doubly charged ion overlaps (for example REE^{2+} overlaps on As and Se), and removing very intense background interferences (N_2 on ^{28}Si, O_2 on ^{32}S, etc.).

The Agilent ICP-MS advantage for environmental applications

Agilent's quadrupole ICP-MS portfolio has been perfected over almost 30 years of working with and supporting the environmental monitoring and testing industries. Environmental testing is Agilent's largest single market for ICP-MS and we have grown from being the newcomer to the dominant global player over that time. The reasons are simple; we understand environmental testing. We fully appreciate the concurrent needs for accuracy, reliability, simplicity, productivity, and excellent support that are critical to the contract laboratory. The Agilent 7800 and 7900 ICP-MS and 8900 ICP-QQQ were designed and tested with these requirements at the forefront.

The 7800 and 7900 ICP-MS combine the simplicity of a single collision cell mode (helium mode) for polyatomic interference removal with superior matrix tolerance. Matrix tolerance can be further extended with High Matrix Introduction (HMI) technology. HMI is standard on the 7800 and UHMI is optional on the 7900. Octopole Reaction System (ORS) cell technology provides higher sensitivity and more effective interference removal in complex, high matrix samples. ORS eliminates the need for reactive cell gases in routine analysis. Helium mode on the ORS is so effective that interference correction equations can also be eliminated. These two factors remove two common causes of errors in multi-element analysis of samples such as wastewaters and brackish waters, soils, and sludges.

To maximize sample throughput and productivity, the 7800, 7900 and 8900 are compatible with Agilent's SPS 4 autosampler and Integrated Sample Introduction System (ISIS 3). The SPS 4 is a fast, high capacity autosampler designed to meet the needs of high-throughput laboratories and ISIS 3 provides high-throughput discrete sampling (DS), reducing sample run times to <60 s, without compromising interference removal.

In addition, Agilent ICP-MS and ICP-QQQ systems link seamlessly with Agilent HPLC and GC systems with field proven interfaces, integrated software control, documentation, and application kits. Other hyphenated techniques including CE, IC, and FFF are also easily configured.

Nanoparticle analysis

Nanoparticles are microscopic particles, either naturally occurring or engineered, of any shape with dimensions in the 10^{-9} to 10^{-7} m range (IUPAC). Because of the novel physical and chemical characteristics of these materials, much remains unknown of their environmental fate and toxicological properties. As a result, there is growing need for a rapid, accurate, sensitive technique for characterizing and quantifying nanoparticles in a wide range of sample types. ICP-MS has demonstrated the ability to meet these requirements through the recent implementation of some application-specific enhancements to both hardware and software.

The requirements for analyzing nanoparticles vary with the type of nanoparticles, the sample matrix, and the type of information that is needed. No single method is applicable to all nanoparticle applications. Agilent has a flexible portfolio of solutions ranging from support of FFF-ICP-MS for bulk characterization of samples containing multiple sizes and types of nanoparticles, to high-speed single particle mode (spICP-MS). The later is capable of determining the size, mass, and composition of a single nanoparticle in solution.

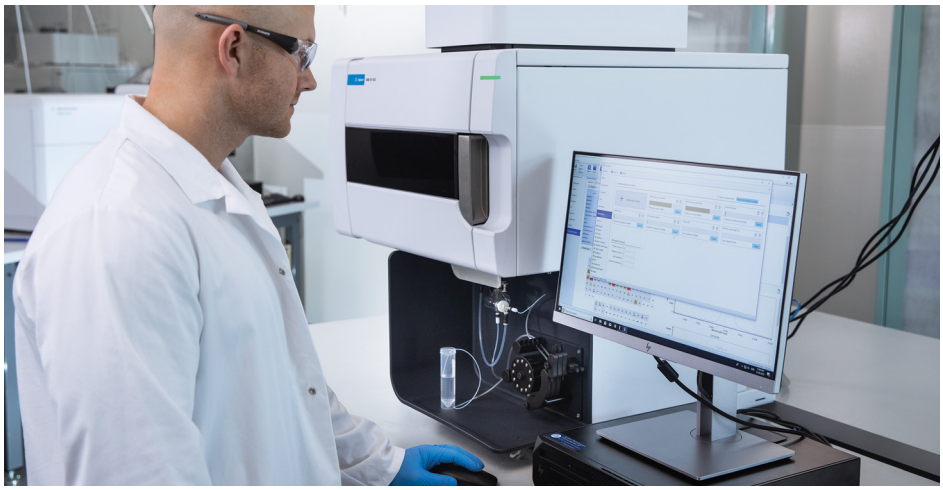
The 8900 ICP-QQQ can accurately measure small (sub-50 nm) nanoparticles composed of more difficult elements, such as Si or Ti. The 8900 is able to do this by using a unique combination of high sensitivity, low background, effective removal of interferences, and high-speed time resolved analysis (TRA) measurement for spICP-MS.

Dedicated software and short dwell times

Agilent's Single Nanoparticle Application Module for ICP-MS MassHunter software simplifies single particle-ICP-MS analysis using the 7800 and 7900 ICP-MS or 8900 ICP-QQQ. All three instruments are capable of using short dwell times (0.1 ms) and fast TRA mode. These settings permit single element acquisition at a sampling rate as fast as 100 µs with no settling time. The capability to make multiple measurements during the signal pulse from a single particle significantly reduces the risk of overlapping signals from adjacent particles. Another advantage is the option to use a lower sample dilution and shorter sample acquisition time.

The Agilent Atomic Spectroscopy Portfolio

Agilent leads the way in atomic spectroscopy innovation. Our comprehensive and trusted portfolio offers you the most diverse application coverage for AA, ICP-OES and ICP-MS, while our unique MP-AES and ICP-QQQ technologies offer new possibilities for your lab.



AA Spectrometers

Flame Atomic Absoprtion

From the entry-point standalone 55B AA spectrometer to top of the range 200 series instruments, there is an Agilent AA to fit your analytical needs and budget.

The Agilent 55B AA instrument is rugged and reliable, making it ideal for remote sites requiring a simple, standalone, double beam AA that doesn't compromise on performance.

The 200 series AA FAA instruments provides the world's fastest flame AA and the flexibility to combine vapour generation or GFAAS techniques.

Fast Sequential mode featured on the 240FS and 280FS AA will:

- Boost productivity and slash running costs
- Determine the concentration of all elements from a single aspiration of each sample saving time and reducing handling errors.
- Halve your analysis time by reducing sample analysis delays

– Reduce sample consumption—with less delay throughout analysis and less sample waste
– Save labor and reduce running costs—the more elements you determine, the more you save on gas, reagent, and lamp usage

Get accurate results:

– Determine 10 elements per sample in less than 2 minutes without compromising data quality
– Provide full elemental coverage, no matter how many elements you require

The Agilent Sample Introduction Pump Systems (SIPS) improves productivity with a range of unique benefits for flame AA it:

– Eliminates tedious, manual preparation of multiple calibration standards. SIPS requires only one calibration standard
– Does fast, inline dilution—even if your sample is out of the calibration range, you'll get an immediate result
– Performs inline addition of ionization suppressants during analysis, eliminating manual preparation before analysis
– Automates the tedious task of flame standard addition calibrations when tackling samples with complex matrices

Zeeman Graphite Furnace AAS

The Agilent 240Z/280Z AA feature Zeeman background correction over the full wavelength range for structured backgrounds, spectral interferences, and high background absorbances.

High performance for challenging samples:

– Outstanding performance at ppb levels from the Constant Temperature Zone (CTZ) furnace design
– Maximum light throughput with high sensitivity and freedom from interferences from an uncompromised design with optimal transverse Zeeman geometry
– Accurate correction with superior uniform magnetic field, providing double the background correction speed of longitudinal Zeeman instruments and three point polynomial interpolation for an 11-fold improvement in correction accuracy

Simple setup and operation:

– The Tube-CAM provides viewing to accurately set the probe dispensing height and confirm the optimum drying temperature
– The Surface Response Methodology (SRM) furnace optimization software wizard simplifies method development, enabling you to easily select optimum conditions for your analysis

4210 MP-AES

The 4210 is the next generation of MP-AES technology – designed to handle a wide range of sample types and applications.

- Enhanced productivity – with safe, reliable, unattended multi-element analysis, the sample throughput of MP-AES is more than twice that of conventional FAAS systems.
- High performance – the magnetically-excited microwave plasma source provides improved sensitivity, linear dynamic range, and detection limits when compared to FAAS.
- MP-AES eliminates the need for costly consumables such as hollow cathode lamps and deuterium lamps for background correction, while avoiding problems like burner blockages.
- The cost of ownership associated with MP-AES is low by eliminating the need for on-going supply of flammable or expensive gases such as acetylene, nitrous oxide, and argon.
- Accessories such as a humidifier, the optional Advanced Valve System four port switching valve (AVS 4), MSIS for hydride generation, and IsoMist programmable temperature-controlled spray chamber, extend the instrument's capabilities.

5800 ICP-OES

The 5800 ICP-OES delivers accurate results with highest speed utilizing smart software features.

- Extended dynamic range and reduced interferences – easily ionized elements are automatically measured radially while other elements are measured axially. This capability allows % level and ppb level elements to be determined at the same time, in the same reading.
- A robust vertically orientated plasma ensures reliable and reproducible results, robustness, and, excellent long-term stability – even with the most complex matrices such as sludge and trade waste samples.
- A series of preset method templates and hardware developments such as plug-and-play torch ensure reliable and reproducible instrument set-up and simplified method development by all users.
- See all elements in your sample at a glance with an IntelliQuant mode that simplifies method development and enables rapid sample screening.
- Reduce sample uptake, stabilization times, and rinse delays using the optional Advanced Valve System (AVS) that features controlled bubble injection to achieve highest analytical precision.

5900 ICP-OES

The 5900 Synchronous Vertical Dual View (SVDV) ICP-OES is the world's most productive high-performance simultaneous ICP-OES. It incorporates all of the standard features of the 5800 delivering the lowest operating costs.

- Maximize productivity and reduce argon gas consumption by running axial and radial view analysis at the same time for all wavelengths, with unique dichroic spectral combiner technology.
- Achieve a sample-to-sample cycle time of < 1 minute with an SPS 4 autosampler and AVS switching valve.
- Extended dynamic range and reduced interferences – easily ionized elements are automatically measured radially while other elements are measured axially. This capability allows % level and ppb level elements to be determined at the same time, in the same reading.
- A robust vertically orientated plasma ensures reliable and reproducible results, robustness, and, excellent long-term stability – even with the most complex matrices such as sludge and trade waste samples.
- A series of preset method templates and hardware developments such as plug-and-play torch ensure reliable and reproducible instrument set-up and simplified method development by all users.
- See all elements in your sample at a glance with an IntelliQuant mode that simplifies method development and enables rapid sample screening.
- Reduce sample uptake, stabilization times, and rinse delays using the optional Advanced Valve System (AVS) that features controlled bubble injection to achieve highest analytical precision.

7800 ICP-MS

Agilent's 7800 ICP-MS simplifies method development, improves accuracy for environmental sample analysis, and includes Standard Operating Procedures for common applications.

- ICP-MS MassHunter software includes preset methods that can be loaded and run with predefined settings, from plasma conditions to analyte integration time and internal standards. ICP Go adds a simple, browser-based user interface to streamline routine analysis. For new methods, the Method Wizard builds the method based on sample type and application.
- Reduce sample preparation – HMI technology, standard on the 7800 ICP-MS, lets you analyze samples containing up to 3% TDS without dilution, reducing sample preparation and saving time.
- Minimize signal suppression – HMI reduces signal suppression, so high matrix samples can be measured accurately without requiring matrix matched calibration standards.
- Ensure accurate data with effective interference removal – Helium (He) collision mode simplifies method development and routine operation by removing polyatomic ion interferences under a single consistent set of conditions. He mode avoids the need for matrix or analyte-specific reaction cell conditions.
- Analyze major and trace analytes in a single run – the wide dynamic range Orthogonal Detector System (ODS) enables direct analysis of major elements (100s or 1000s of ppm) and trace level analytes (single or sub-ppt) in a single run. The high upper concentration limit reduces sample reruns caused by over range results.
- Maximize throughput and productivity – the optional Integrated Sample Introduction System (ISIS 3) and the SPS 4 Autosampler lower your cost per analysis without compromising data quality.

7900 ICP-MS

Agilent's 7900 ICP-MS offers unmatched matrix tolerance and interference removal, with significantly improved ease-of-use and productivity.

- ORS^4, the fourth-generation collision cell design with helium collision mode effectively removes polyatomic interferences, ensuring more accurate results in unknown or complex sample matrices.
- With significantly improved sensitivity and lower background, He mode can be applied to a wider range of elements. This includes ppt level analytes such as Cd and Hg.
- Simplified operation with extensive autotuning and a Method Wizard that automates the method setup process, ensuring that all users can create optimized and reliable methods.
- For high matrix sample analysis such as seawater and saline groundwater, the Ultra High Matrix Introduction (UHMI) option extends the matrix tolerance to 25% total dissolved solids (TDS). This is more than 100 times higher than the accepted maximum salt limit for conventional ICP-MS of 0.2% or 2,000 ppm.
- For high-throughput laboratories, the optional Integrated Sample Introduction System (ISIS 3) uses discrete sampling to reduce sample run times to approximately 1 minute or less.

8900 Triple Quadrupole ICP-MS

The 2nd generation 8900 ICP-QQQ offers a range of configurations to cover applications from routine contract analysis to advanced research and high-performance materials analysis. ICP-QQQ provides MS/MS mode for unprecedented control of reaction chemistry when using reactive cell gases.

- Unparalleled accuracy – in MS/MS mode, the first quadrupole (Q1) prevents all off-mass ions from entering the cell, allowing more controlled and efficient interference removal in reaction mode. The result is more accurate and reliable data – regardless of sample type.
- Incomparable performance – the 8900 also sets new performance benchmarks in no gas mode and collision mode, with outstanding signal-to-noise compared to conventional single quadrupole ICP-MS. And MS/MS gives the 8900 the highest abundance sensitivity ever seen in ICP-MS: $<10^{-10}$, further improving data integrity in high matrix samples.
- Exceptional robustness – UHMI increases matrix tolerance up to 25% total dissolved solids (TDS). UHMI is standard on the 8900 Standard and Advanced Applications configurations, ensuring high matrix samples can be measured routinely, and eliminating matrix suppression.
- Total flexibility – although it is designed to meet the demands of high throughput routine laboratories, the 8900 also offers complete flexibility in operation, making it a perfect research tool. An array of advanced MS/MS acquisition modes is available, enabling the study of ion molecule reactions, polyatomic ion formation and much more.

EPA 200.8 Drinking Water Analyzer

The Agilent EPA 200.8 Water Analyzer is an integrated package of hardware, software, consumables, professional services and documentation. It will quickly have you running samples using a verified method that is compliant with the US Safe Drinking Water Act.

Supplied with the 7800 ICP-MS the Water Analyzer includes:

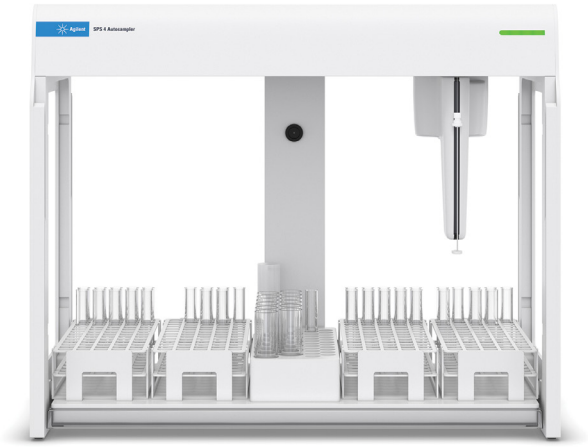
- An Agilent SPS 4 autosampler with an option to add an Integrated Sample Introduction System for increased productivity in high-throughput labs
- An EPA 200.8 method optimized by ICP-MS experts and includes all the US EPA 200.8 analytical, QC, and reporting requirements.
- 3 days of professional services to setup the instrument, transfer and verify the method and train operators.
- Standard Operating Procedure together with a guide to customize the SOP to meet your lab's requirements.
- The simple ICP Go software interface. The fully-featured ICP-MS MassHunter software is also included for method modification or troubleshooting
- The consumables you'll need along with a suite of documentation for regulatory compliance and to provide guidance for inexperienced or infrequent operators.
- The flexibility to extend your analytical capability using the 7800 ICP-MS to address virtually any sample type you may need to measure in the future.

ISO 17294 Water Analyzer

The Agilent ISO 17294 Water Analyzer is an integrated package of hardware, software, consumables, professional services and documentation. It will quickly have you running drinking, surface and/or waste water samples using a compliant method.

Supplied with the 7800 ICP-MS the Water Analyzer includes:

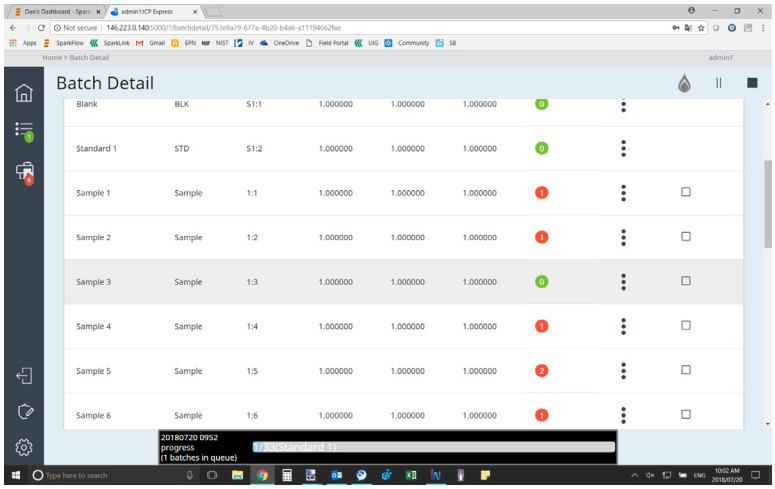
- An Agilent SPS 4 autosampler with an option to add an Integrated Sample Introduction System for increased productivity in high-throughput labs
- An ISO 17294 method optimized by ICP-MS experts and includes all the ISO 17294-2:2016 analytical, QC, and reporting requirements.
- 3 days of professional services to setup the instrument, transfer and verify the method and train operators.
- Standard Operating Procedure together with a guide to customize the SOP to meet your lab's requirements.
- The simple ICP Go software interface. The fully-featured ICP-MS MassHunter software is also included for method modification or troubleshooting
- The consumables you'll need along with a suite of documentation for regulatory compliance and to provide guidance for inexperienced or infrequent operators.
- The flexibility to extend your analytical capability using the 7800 ICP-MS to address virtually any sample type you may need to measure in the future.



SPS 4 Autosampler

The SPS 4 is a next-generation, high-performance autosampler for atomic spectroscopy applications. Designed to meet the needs of high-throughput laboratories requiring a fast, high-capacity, reliable autosampler, it is also small, quiet, easy-to-use, and affordable.

- Suitable for ultratrace analysis by ICP-MS and ICP-QQQ while being rugged and robust enough for FAAS, MP-AES, and ICP-OES users.
- Heavy-duty, powder-coated aluminum frame for light weight, maximum rigidity, and corrosion resistance.
- User programmable high-speed probe arm assembly and optimized movement for fastest sample-to-sample speed.
- USB plug-and-play connectivity allows fast and easy setup.
- Integrated environmental enclosure option protects your samples and your laboratory environment.
- Dual-wash reservoir option eliminates potential carry over.
- Three-channel peristaltic pump for ultimate flowthrough rinse flexibility.
- Multiple probe size options for a diverse range of applications
- Four sample rack capacity supports up to 360 samples, permitting long unattended runs in high-throughput labs.
- Eight 96-well microtiter plate capacity, with optional well plate kit, supports up to 768 samples (for ICP-MS only).



ICP GO Software

ICP Go is a simple, browser-based software interface that makes the routine operation of your Agilent ICP-MS easier than ever. It is compatible with Agilent 7700, 7800, 7900 ICP-MS and 8900 ICP-QQQ instruments and allows new or occasional users to run an analysis with confidence.

With ICP Go you can:

- Quickly set up and run sample batches from stored templates.
- Predefine batch settings to reduce the possibility of method errors that can cause inconsistent results and costly reruns.
- Control your entire analytical run, from igniting the plasma through to analyzing samples. During a run, you can easily queue urgent samples for immediate analysis, and monitor the instrument status remotely.
- Train new users in less than a day, which reduces the costs of initial training and makes it much easier for operators to transfer between analytical techniques. ICP Go's clear screen layout and simple workflow enable easy crosstraining of analysts, giving you more staffing flexibility. This means that your senior analysts can focus on more advanced tasks, such as optimizing lab efficiency.
- Enable an analyst or lab manager to control and monitor the sample run from anywhere with remote monitoring from any PC or tablet.
- Connect to several instruments to allow multiple ICP-MS systems to be monitored from within separate tabs of the browser.

Available Literature

More information and application notes released after publication of this compendium are available online at www.agilent.com.

This compendium includes application notes for the common environmental applications of Agilent atomic spectroscopy instruments.

Each application note describes the method and sample preparation used for the analysis. They also present results for typical samples and standard reference materials. Performance-related features, advantages and benefits of Agilent atomic spectroscopy instruments pertaining to the application are also presented.

Application notes by sample type

Water and waste water

Seawater

Soils, sludges and solids

Nanoparticles

Air filters

Bio-monitoring

Click on the title to view the full document.

Water and waste water

AAS

Determination of Boron by Graphite Furnace AAS: Comparison of different modifiers

Measuring Arsenic in Water on GFAAS

Measuring Lead in Water

ICP-MS

Automating EPA 6020 Analysis with ICP-MS and ESI prepFAST Autodilution System

High throughput water analysis using Agilent 7900 ICP-MS coupled with ESI prepFAST

Agilent 7900 ICP-MS simplifies drinking water analysis

An Examination of the Presence, Formation, and Transformation of Volatile Halogenated Organic Species in Wastewater Extracts Using GC-ICP-MS

Determination of speciated iopromide in environmental waters by ion chromatography-ICP-MS

Low-level speciated analysis of Cr(III) and Cr(VI) using LC(IC)-ICP-MS

On-line isotope dilution analysis with the 7700 Series ICP-MS: Analysis of trace elements in high matrix samples

The ultratrace determination of iodine 129 in aqueous samples using the Agilent 7700x ICP-MS with oxygen reaction mode

Analysis of flue gas desulfurization wastewaters by Agilent 7800 ICP-MS

Using qualifier ions to improve ICP-MS data quality for waste water analysis

Simple, reliable analysis of high matrix samples according to US-EPA method 6020A using the Agilent 7700x ICP-MS

The Agilent 7700x/7800 ICP-MS advantage for drinking water analysis

Click on the title to view the full document.

ICP-QQQ

Direct analysis of Zirconium-93 in nuclear site decommissioning samples by ICP-QQQ

Accurate determination of TiO_2 Nanoparticles in complex matrices using ICP-QQQ

Rapid analysis of Radium-226 in water samples by ICP-QQQ

Using ICP-QQQ for UO_2^+ product ion measurement to reduce uranium hydride ion interference and enable trace 236U isotopic analysis

Solving doubly charged ion interferences using an Agilent 8900 ICP-QQQ

The ultratrace determination of iodine 129 using ICP-QQQ in MS/MS mode

The accurate measurement of selenium in twelve diverse reference materials using on-line isotope dilution

Direct Analysis of Ultratrace Rare Earth Elements in Environmental Waters by ICP-QQQ

ICP-OES

Fast Analysis of Environmental Samples using the Agilent 5110 ICP-OES and ESI prepFAST

High throughput, low cost analysis of environmental samples according to US EPA 6010C using the Agilent 5100 SVDV ICP-OES

Ultra-fast determination of trace elements in water, conforming to US EPA 200.7 using the Agilent 5100 Synchronous Vertical Dual View ICP-OES

Fast Analysis of Water Samples Comparing Axially and Radially Viewed CCD Simultaneous ICP-OES

Water Analysis Using ICP-OES with an Ultrasonic Nebulizer

Analysis of Environmental Samples with the Agilent 710-ES Following US EPA Guidelines

Determination of mercury with on-line addition of stannous chloride using an Axial ICP-OES

Analysis of environmental samples with the Agilent 730-ES following US EPA guidelines

Analysis of potable water for trace elements by ICP-OES

MP-AES

Determination of metals in industrial wastewaters by microwave plasma-atomic emission spectroscopy

High Throughput, Multi-Element Analysis of Effluents by MP-AES

Click on the title to view the full document.

Seawater

AAS

Direct Determination of As, Cu and Pb in Seawater by Zeeman Graphite Furnace Atomic Absorption Spectrometry

Dealing with matrix interferences in the determination of the priority pollutant metals by Furnace AA

ICP-MS

High throughput, direct analysis of seawater using the Agilent 7800 ICP-MS with HMI for aerosol dilution

Simple, reliable analysis of high matrix samples according to US EPA Method 6020A using the Agilent 7700x/7800 ICP-MS

Performance of the Agilent 7900 ICP-MS with UHMI for High Salt Matrix Analysis

ICP-OES

Determination of mercury with on-line addition of stannous chloride using an Axial ICP-OES

Soils, sludges and other solids

AAS

Determination of Sb in sediment and road soil using Graphite Furnace AAS

ICP-MS

China soil pollution survey: elemental analysis of soil and sediment digests by ICP-MS

Simple and reliable soil analysis using the Agilent 7800 ICP-MS with ISIS 3

Maximizing productivity for high matrix sample analysis using the Agilent 7900 ICP-MS with ISIS 3 discrete sampling system

On-line isotope dilution analysis with the 7700 Series ICP-MS: Analysis of trace elements in high matrix samples

Simple, Reliable Analysis of High Matrix Samples According to US EPA Method 6020A using the Agilent 7700x/7800 ICP-MS

Click on the title to view the full document.

ICP-QQQ

Analysis of platinum group elements (PGE) in road dust CRM using the Agilent 8800 ICP-QQQ in MS/MS mode

Routine soil analysis using an Agilent 8800 ICP-QQQ

Routine determination of trace rare earth elements in high purity ^{203}Nd using ICP-QQQ

Lead isotope analysis: Removal of ^{204}Hg isobaric interference from ^{204}Pb using ICP-QQQ in MS/MS mode

The accurate measurement of selenium in twelve diverse reference materials using on-line isotope dilution

ICP-OES

Analysis of solid waste samples per Chinese method HJ 781

Analysis of DTPA extracted soils per Chinese standard HJ 804-2016 using the Agilent 5800 ICP-OES.

High throughput, low cost analysis of environmental samples according to US EPA 6010C using the Agilent 5100 SVDV ICP-OES

Analysis of environmental samples with the Agilent 730-ES following US EPA guidelines

Rapid measurement of major, minor and trace levels in soils using the Agilent 730-ES

Determination of mercury in a certified reference sludge material using the Agilent 710-ES

MP-AES

Determination of exchangeable cations in soil extracts using the Agilent 4100 microwave plasma-atomic emission spectrometer

Determination of metals in soil by MP-AES using DTPA extraction

Determination of metals in soil by microwave plasma - atomic emission spectrometry (MP-AES) using DTPA extraction

Determination of available nutrients in soil using the Agilent 4200 MP-AES

Direct determination of Cu, Fe, Mn, P, Pb, and Ti in HF acid-digested soils using the Agilent 4200 Microwave Plasma-Atomic Emission Spectrometer

Elemental analysis of river sediment using the Agilent 4200 MP-AES

Analysis of domestic sludge using the Agilent 4200 MP-AES

Click on the title to view the full document.

Nanoparticles

ICP-MS

Measuring multiple elements in nanoparticles using Single Particle ICP-MS

Automated, high sensitivity analysis of single nanoparticles using the Agilent 7900 ICP-MS with Single Nanoparticle Application Module

Single particle analysis of nanomaterials using the Agilent 7900 ICP-MS

Measuring Multiple Elements in Nanoparticles using spICP-MS

ICP-QQQ

Analysis of 10 nm gold nanoparticles using the high sensitivity of the Agilent 8900 ICP-QQQ

Quantitative characterization of silica nanoparticles by asymmetric flow FFF MALS-ICP-QQQ using ICP-QQQ

High sensitivity analysis of SiO_2 nanoparticles using the Agilent 8900 ICP-QQQ in MS/MS mode

Air filters

ICP-OES

Workplace air monitoring: multi-element analysis of air-filters using ICP-OES

Bio-monitoring

AAS

Sequential determination of Cd, Cu, Pb, Co and Ni in marine invertebrates by Zeeman Graphite Furnace Atomic Absorption Spectroscopy

ICP-MS

Application of the Agilent 7900 ICP-MS with Method Automation function for the routine determination of trace metallic components in food CRMs

ICP-QQQ

Multielement Analysis and Selenium Speciation in Cattle and Fish Feed using LC-ICP-QQQ

MP-AES

Total metals analysis of digested plant tissue using an Agilent 4200 MP-AES

Agilent CrossLab: Real insight, real outcomes

CrossLab goes beyond instrumentation to bring you services, consumables, and lab-wide resource management. So your lab can improve efficiency, optimize operations, increase instrument uptime, develop user skill, and more.

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U.S. and Canada
1-800-227-9770
agilent_inquiries@agilent.com

Europe
info_agilent@agilent.com

Asia Pacific
inquiry_lsca@agilent.com

DE.6838541667

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