Technical Overview

Agilent 9500 ICP-MS

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Air Cell Mode of the Agilent 9500 ICP-QQQ with Dual-Cell System

Simple and effective interference reduction using ambient air

Introduction to the Air cell

Interference reduction technology in single quadrupole and triple quadrupole ICP-MS instruments is essential for ensuring accurate analysis of a wide range of samples. Agilent triple quadrupole ICP-MS (ICP-QQQ) systems, including the Agilent 9500 ICP-QQQ, use two quadrupoles (Q1 and Q2) as unit mass filters, allowing MS/MS operation. MS/MS mode allows the controlled use of collision and reaction cell gases in the collision/reaction cell (CRC). In reactive gas mode, Q1 controls ions that enter the CRC and interact with the cell gas, and Q2 controls which ions reach the detector.

The 9500 ICP-QQQ features a unique Dual-Cell System (DCS) that can operate in both Advanced Helium Mode (AHM) and Air cell mode. AHM is an innovative collision cell mode that has been developed for the 9500 ICP-QQQ, while Air cell mode minimizes interferences without needing other reaction cell gases. Using ambient air from the laboratory, Air cell mode eliminates the need for an external gas supply, simplifying operation without compromising the stability or effectiveness of interference reduction.

This technical note describes the principles of Air cell mode and provides experimental evidence of its effectiveness, highlighting the flexibility of the 9500 ICP-QQQ for routine, interference free analysis.

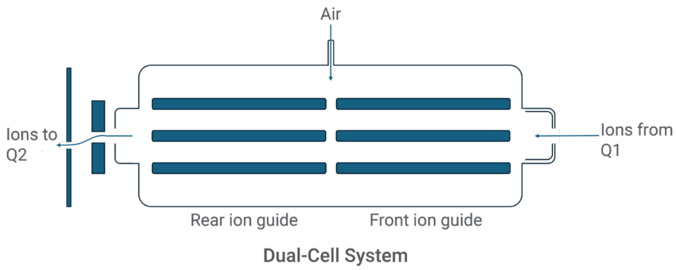

Figure 1. Schematic of the Agilent Dual-Cell System (DCS) pressurized using air cell gas. The innovative design of the DCS enables the use of atmospheric air as a reaction gas. Reactions using the ambient oxygen in air mean no oxygen cylinders are needed. Furthermore, atmospheric pressure is sufficiently high to provide air without needing a compressor.

A new approach to interference reduction using air

Ambient air consists primarily of nitrogen (N_2, approximately 78%) and oxygen (O_2, approximately 21%). Operating the DCS in Air cell mode uses O_2 in air to reduce interference through ion-molecule reactions. Because N_2 is less reactive than O_2, N_2 primarily contributes to the thermal relaxation of ions.

The DCS is fitted with an Air cell gas filter that efficiently removes reactive contaminants, such as moisture and hydrocarbons, from the air before it enters the cell. Removing these species prevents uncontrolled reactions occurring in the DCS, ensuring reliable results. An automatic control valve is installed before the filter to minimize exposure to ambient air, extending its service life.

Comparison of interference reduction techniques and the advantages of Air cell mode

There are two main methods for reducing interferences in ICP-MS and ICP-QQQ: reaction cell and collision cell modes. Reaction cell modes eliminate interferences through ion-molecule reactions. However, the effectiveness of a reaction cell method depends on the specific combination of the ion and the cell gas, so it cannot be applied universally to all elements.

In contrast, collision cell modes employ an inert gas, such as helium (He), to reduce interferences by exploiting collisional cross-section differences between analyte ions and interfering species using Kinetic Energy Discrimination (KED). This technique is commonly used for many polyatomic ion interferences, such as oxide ions (MO^+) and argon-based ions (ArM^+), making it effective for the determination of a wide range of elements. However, collision cell mode is less effective at suppressing doubly charged ion interferences (M^{++}), and sometimes, KED can even enhance the interferences.

With the 9500 ICP-QQQ, Air cell mode complements AHM by reducing doubly charged ion interferences through ion-molecule reactions with O_2. It can also be used to eliminate challenging polyatomic ion interferences.

The 9500 ICP-QQQ features a standard multitune method within the Agilent OpenLab ICP-MS software that combines AHM with Air cell mode. The multitune method enables efficient, simultaneous reduction of both polyatomic and doubly charged ion interferences across a range of sample matrices, including soils, seawater, and foods.[2-4]

For full flexibility, it is also possible to use external supplies of high-purity oxygen (O_2) or nitrous oxide (N_2O) in the DCS instead of air. Depending on the target element, these gases may offer higher sensitivity or lower background equivalent concentrations (BECs). For further details on reaction cell gases, refer to another of Agilent's technical notes.[5]

Examples of interference reduction using Air cell mode

Suppressing REE^{2+} and polyatomic ion interferences on arsenic and selenium

An example of interference reduction in Air cell mode involves suppressing interferences from doubly charged rare earth element (REE) ions on arsenic (As) and selenium (Se). Doubly charged ions of ^{150}Nd and ^{150}Sm interfere with ^{75}As, while ^{156}Gd and ^{156}Dy interfere with ^{78}Se. REEs are commonly found in food and soil samples.

To test the effectiveness of AHM and Air cell mode in reducing polyatomic ion interferences (such as $ArCl^+$ and $CaCl^+$) and doubly charged ion interferences (REE^{2+}) on As and Se, three samples were analyzed. The samples included 1% HNO_3, 2% HCl + 100 ppm Ca, and a 10 ppb REE solution.

As shown in Figure 2, AHM was highly effective in reducing polyatomic ion interferences on As and Se but was ineffective against doubly charged ions. In contrast, Air cell mode converted As and Se to reaction-product ions (AsO^+ and SeO^+), moving them away from the REE^{2+} and polyatomic ion interferences, thereby reducing both types of interference.

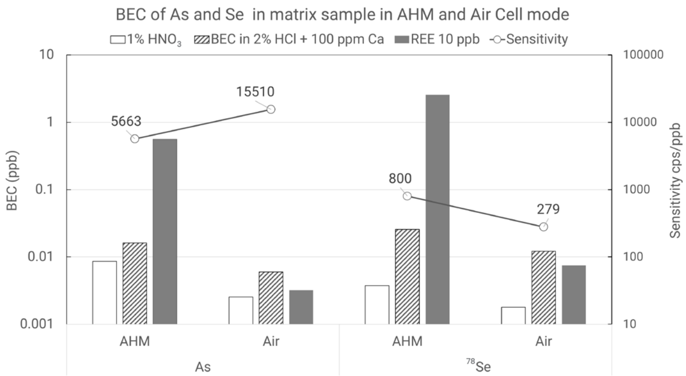

Figure 2. BECs and sensitivity of As (left) and Se (right) in 1% HNO_3, 2% HCl + 100 ppm Ca, and a 10 ppb REE solution determined by the Agilent 9500 ICP-QQQ in AHM and Air cell mode.

Suppressing REE^{2+} and REE-oxide ion interferences on germanium and gadolinium

Another challenging application involves analyzing germanium (Ge) and gadolinium (Gd) in samples containing light REEs such as La, Pr, Nd, and Sm. Ge is affected by doubly charged REE ions (Nd^{2+}, Sm^{2+}), while Gd is overlapped by REE-oxide ions (LaO^+, PrO^+).

As shown in Figure 3, AHM cannot reduce the M^{++} interferences on ^{72}Ge and ^{73}Ge (high BECs). However, Air cell mode enables low-level detection of the respective GeO^+ product ions. The mass-shift method significantly reduces interference compared to AHM. For ^{155}Gd and ^{157}Gd, AHM effectively reduces the interference from LaO^+ and PrO^+, resulting in lower BECs compared to no gas mode. However, Air cell mode further improves the BECs by detecting both Gd isotopes as GdO^+. These results demonstrate that Air cell mode can be more effective than AHM at reducing polyatomic ion interferences in some cases.

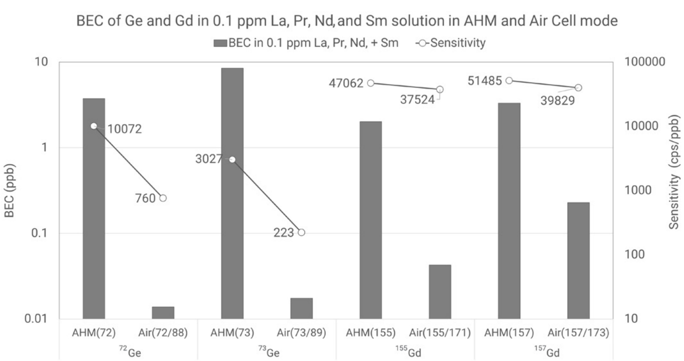

Figure 3. BECs of Ge and Gd in a light-REE solution determined by the Agilent 9500 ICP-QQQ in AHM and Air cell mode. The numbers in parentheses after AHM and Air indicate the mass numbers of Q1 and Q2, for example, AHM (72) indicates single quad scan mode and Air (72/88) indicates MS/MS mass-shift mode.

Sensitive analysis of sulfur, phosphorus, and silicon in Air cell mode

Sulfur (S), phosphorus (P), and silicon (Si) are difficult elements to analyze by ICP-MS due to severe interference from ions such as O_2^+, NO^+, and N_2^+. As shown in Figure 4, AHM reduces these interferences, while Air cell mode enables analysis with even lower BECs and detection limits (DLs) and higher sensitivity.

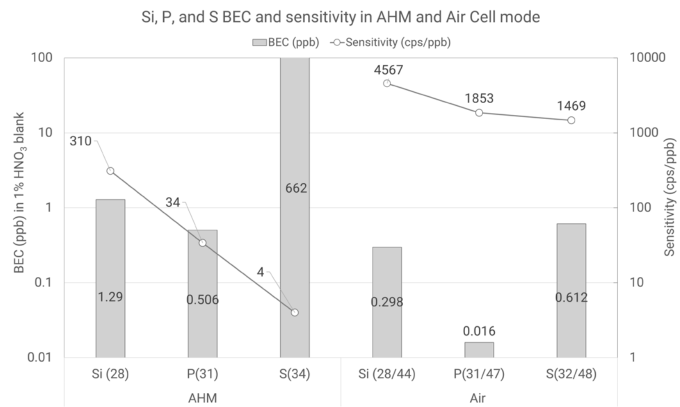

Figure 4. BECs of Si, P, and S in 1% HNO_3 determined by the Agilent 9500 ICP-QQQ in AHM (left) and Air cell mode (right). The numbers in parentheses indicate the mass numbers of Q1 and Q2.

Determination of gold in a tantalum-containing sample

Although most elements analyzed using Air cell mode are detected as reaction product ions (MO^+) through an MS/MS mass-shift method, on-mass analysis is effective in some cases. Figure 5 shows an example of gold (Au) analysis in a sample containing 0.5 ppm tantalum (Ta). The oxide ion, TaO^+, interferes with Au^+ detection. While AHM can reduce this interference to some degree, Air cell mode with on-mass analysis is more effective. Unlike As^+ or Ge^+, Au^+ has low reactivity with O_2, making mass-shift ineffective. However, the interfering ion, TaO^+, reacts efficiently with air to form $TaOO^+$, allowing Au to be analyzed free of interference at its original mass (*m/z* = 197).

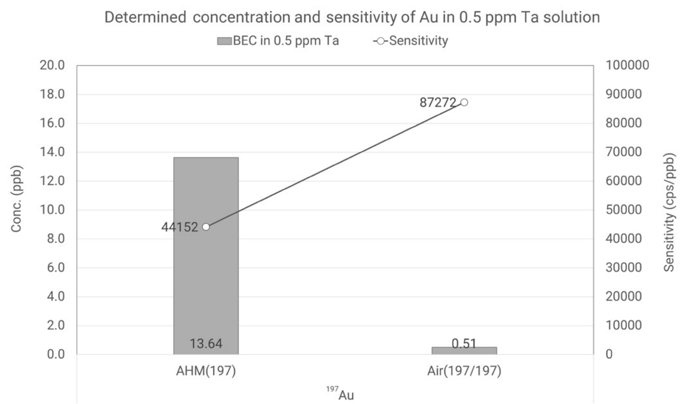

Figure 5. Concentration of Au in a 0.5 ppm Ta solution measured by the Agilent 9500 ICP-QQQ in AHM (left) and Air cell mode (right). The numbers in parentheses indicate the mass numbers of Q1 and Q2.

Molybdenum- and tungsten-oxide interferences on cadmium and mercury

Many environmental, food, and consumer products contain appreciable concentrations of molybdenum (Mo) and tungsten (W). These elements can form often overlooked oxide interferences on cadmium (Cd) and mercury (Hg). Both of these interferences, MoO^+ (on Cd^+) and WO^+ (on Hg^+), react with air to form $MoOO^+$ and WOO^+, while Cd and Hg do not readily react. Both Cd and Hg can therefore be quantified using the 9500 ICP-QQQ in Air cell mode with minimal interference from other species.

Conclusion: Simple and powerful interference reduction

Using the Agilent 9500 ICP-QQQ system's Dual-Cell System (DCS) in Air cell mode provides an effective, convenient solution for reducing interferences by utilizing only laboratory air as the reaction gas. The examples have highlighted the capabilities of Air cell mode in handling various spectral interferences more effectively than Advanced Helium Mode (AHM).

Combining AHM and Air cell mode within a standard multitune method enables the 9500 ICP-QQQ to perform simple, reliable, and interference-free analysis for a broad range of elements in challenging matrices. Because multitune preset methods operate without the need for external reaction cell gases, the 9500 offers a streamlined workflow and serves as a seamless, high-performance replacement for conventional single quadrupole ICP-MS systems.

References

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