Technical Overview

Agilent 9500 ICP-MS

Dual-Cell System (DCS) and Advanced Helium Mode (AHM)

Technological developments for higher sensitivity and better interference removal than traditional He-KED

Evolution of Agilent’s Collision Reaction Cell (CRC) technology

- **2001**: Launched the first ICP-MS with CRC—the Agilent 7500c with Octopole Reaction System (ORS)
- **2011**: Introduced High Energy Helium Mode (HEHe) using Collision Induced Dissociation (CID)
- **2012**: Released the world’s first Triple Quadrupole ICP-MS—the Agilent 8800 ICP-QQQ
- **2016**: Launched the second generation Triple Quadrupole ICP-MS with Axial Acceleration—the Agilent 8900 ICP-QQQ
- **2026**: Introduced the innovative Dual-Cell System (DCS) and Advanced Helium Mode (AHM) for the Agilent 9500 ICP-QQQ

Introduction

Collision/Reaction Cell (CRC) technology is now a standard feature in modern ICP-MS systems, providing a reliable means of eliminating spectral interferences that compromise data quality. ICP-MS systems with integrated CRCs range from single quadrupole (SQ) ICP-MS used in environmental and food analysis, to triple quadrupole ICP-MS (ICP-QQQ) for advanced research applications. For routine applications, Helium Kinetic Energy Discrimination (He KED) mode, commonly referred to as helium mode (He mode), is the most widely used CRC operational mode. The widespread use of He mode is due to its universal effectiveness in reducing a broad range of polyatomic interferences without the need for element-specific optimization.

Unlike CRCs that rely on reactive cell gases and require complex tuning (often referred to as reaction cells), He mode effectively mitigates many commonly occurring polyatomic ion interferences without the need for intricate adjustments. In contrast, reaction cells often require careful selection of gas type (such as ammonia or oxygen) and tuning parameters based on the specific interfering ions on analytes of interest.

Building on the simplicity of He mode, Agilent has developed Advanced Helium Mode (AHM) for the Agilent 9500 Triple Quadrupole ICP-MS (ICP-QQQ). AHM represents a breakthrough in interference removal technology, enabled by the newly designed Agilent Dual-Cell System (DCS) and high-speed cell voltage control. These innovations deliver high sensitivity across the mass range and superior interference removal performance for routine applications. Compared to conventional He mode, AHM demonstrates the following improvements:

- Around a 20-fold sensitivity improvement for low-mass elements, such as beryllium (Be) and boron (B)
- Around a 2-fold improvement for mid-to-high mass elements
- A reduction of more than 33% in data acquisition time while maintaining detection limits (DLs), accelerating analytical measurement times

AHM not only replaces traditional He KED but also consolidates multiple tuning modes including no gas, He, and HEHe into a single, streamlined mode. Integrated into the 9500 ICP-QQQ, AHM is a next-generation standard He mode that is faster, simpler, and delivers higher performance than its predecessor.

This technical note describes the performance enhancement mechanisms of the DCS and AHM. It also includes some comparative results with conventional He KED mode to highlight the analytical improvements of AHM.

DCS design features and interference removal capabilities

The DCS is a unique CRC that is integrated into the 9500 ICP-QQQ between two quadrupoles (Q1 and Q2). The configuration of the DCS is shown in Figure 1. Unlike conventional CRCs that use a single multipole ion guide, the DCS features two ion guides, one at the front, close to Q1, and one at the rear of the cell, close to Q2. Each of the two ion guides is independently controlled using bias voltages, referred to as the Front Cell bias voltage and Rear Cell bias voltage. It is these voltages that are used to move ions through the DCS.

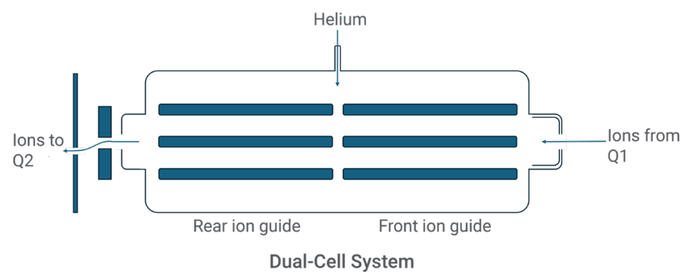

Figure 1. Schematic of the Agilent Dual-Cell System (DCS) pressurized using helium cell gas. The KED voltage of the cell is precisely controlled by applying a differential between the front- and rear-ion guide biases. The innovative design of the DCS enables optimized interference removal performance in Advanced Helium Mode (AHM) through a combination of Kinetic Energy Discrimination (KED) and Collision Induced Dissociation (CID) mechanisms.

Under standard operating conditions, the He gas flow rate is set to 14 mL/min, with the Front Cell bias voltage at –98 V and the Rear Cell bias voltage at –88 V. The voltage difference between the two cells (10 V) functions as the KED voltage. This configuration enables the DCS to effectively suppress interfering ions through a combination of KED and Collision Induced Dissociation (CID) mechanisms. The term "Dual" in DCS refers to both the dual ion guides and the dual interference removal mechanisms.

Abundance Sensitivity (AS) is a measure of the contribution that an intense peak makes to the adjacent masses. In HEHe mode using a multipole ion guide, AS performance tends to decrease when high-energy ions are present, limiting its use to certain elements. Conversely, the DCS achieves an AS performance similar to no gas mode by thermalizing high-energy ions through collisions in the rear ion guide. Also, setting the Front Cell bias voltage to a very low value (such as –90 V) enhances CID effectiveness, while KED continues to operate at He flow rates of 14 mL/min. These attributes of the DCS result in higher sensitivity and better interference removal compared to traditional He KED mode.

Explanation of He KED performance enhancement and DCS design

He KED is one of the most widely used cell modes in routine ICP-MS analysis. It reduces polyatomic ion interferences by exploiting the differences in collisional cross section between He atoms, analyte ions, and interfering ions. Because polyatomic ions have larger cross-sectional areas than analyte ions, they undergo more collisions with He in the cell and lose more Kinetic Energy (KE). A voltage barrier, known as the KE voltage or KED, is applied between the cell and Q2. This barrier suppresses the lower energy interference ions while allowing the higher energy analyte ions to pass to Q2 and the detector.

In He KED mode, performance can be enhanced by increasing the number of collisions between the ions and He gas atoms, which is achieved by increasing the He flow rate. In this case, "performance" refers to both the signal-to-noise ratio (S/N) between analyte ions and interfering ions, and the signal intensity (sensitivity) of the target analyte.

Figure 2 displays simulation results of the He collision cell fitted in the 8900 ICP-QQQ. It shows the KE distribution at the cell exit for vanadium (V^+) analyte ions and chlorine oxide (ClO^+) interference ions. V^+ ions lose KE and broaden their energy distribution due to collisions with He. As He flow increases, the number of collisions rises, causing the KE distribution to narrow. ClO^+ ions, having a larger collision cross-section than V^+, experience more collisions, which leads to greater KE loss and a more distinct separation from V^+.

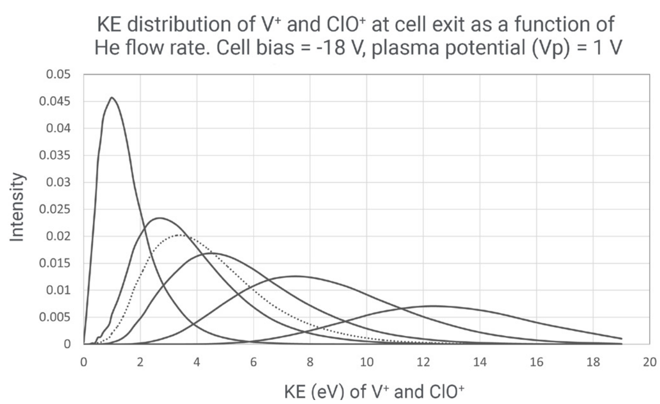

Figure 2. Calculated Kinetic Energy (KE) distribution of V^+ and ClO^+ at the cell exit. The solid lines represent the KE distributions of V^+ ions at the cell exit under He flow rates of 2, 4, 6, 8, and 12 mL/min. The dotted line shows the KE distribution of ClO^+ ions at a He flow rate of 4 mL/min. When comparing both ions at the same He flow rate of 4 mL/min, ClO^+ ions—due to their larger collision cross-section—exhibit a lower KE distribution than V^+ ions.

Applying an appropriate KED voltage at the cell exit can enhance the V^+/ClO^+ ratio. However, some V^+ ions are also lost, which reduces sensitivity. Figure 3 shows the calculated sensitivity and background equivalent concentrations (BECs) based on ClO^+/V^+ for different He flow rates and KED voltages as used in the simulation shown in Figure 2. As higher KED voltages are used, backgrounds decrease faster than sensitivity, giving an improvement in BEC.

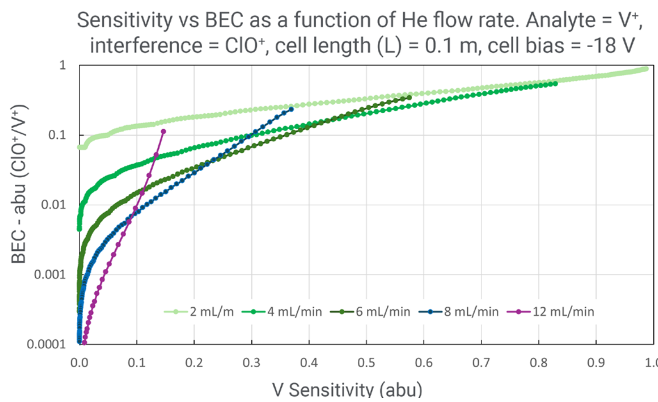

Figure 3. Calculated vanadium (V) sensitivity vs BEC in a ClO matrix at various He flow rates. At each He flow rate, the sensitivity of V (X-axis) and the BEC of V in the ClO matrix (Y-axis) were calculated using KED as a mediating variable. Both values are expressed as relative values, normalized to the baseline condition of He flow rate = 0 mL/min and KED = 0 V.

Insights from the simulation: Trade-off between KED voltage and sensitivity

From the simulation results, it is clear that increasing the KED voltage enhances BEC but reduces sensitivity. Also, while higher He flow rates boost both sensitivity and BEC, the gains plateau around 6 mL/min. This limitation occurs because excessive ion thermalization at high flow rates lowers the effectiveness of KED.

To maintain effective KED performance at higher He flow rates, it is necessary to increase the ion's cell entry energy, which is achieved by lowering the ion guide bias voltage.

To ensure high sensitivity and effective interference removal, the DCS is designed based on these principles. When using cell gases other than He (for example, O_2 or NH_3), the same bias voltage is applied to both the front and rear ion guides, which allows the system to operate like a conventional single ion guide.

Overview and advantages of AHM

Typically, multi-element ICP-MS methods apply no gas mode to the determination of low-mass elements like Be and B due to low sensitivity in traditional He KED mode. Consequently, many routine ICP-MS applications have required multiple tune setups, combining no gas, He, and HEHe. Each mode switch introduces a delay due to cell pressure stabilization requirements.

In practice, low-mass elements ($m/z < 23$) are generally unaffected by polyatomic ion interferences, so KED is often unnecessary. Therefore, in AHM, different voltages are applied to the DCS (effectively disabling KED) for low-mass elements, while keeping standard settings for elements with $m/z \geq 23$.

The DCS voltages are dynamically switched in sync with Q2 using a high-speed voltage control circuit, providing over 20× sensitivity improvement for low-mass elements compared to conventional He mode. AHM eliminates the need to run in no gas mode, greatly simplifying the method. As a default approach, AHM alone is suitable for most applications.[1]

Performance of AHM compared with conventional He mode

To assess the performance of the 9500 ICP-QQQ with DCS operating in AHM, a range of sample types was prepared to simulate routine or challenging applications. The results were then compared to those obtained using conventional He KED mode.

Low mass elements

As shown in Figure 4, AHM mode boosts sensitivity for low-mass analytes ($m/z < 23$) by around 20× compared to He mode. For Be, AHM achieves about one-third the sensitivity of no gas mode.

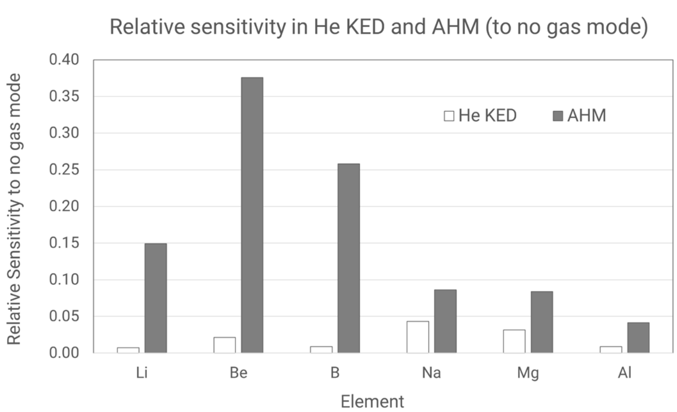

Figure 4. Relative sensitivity of the Agilent 9500 ICP-QQQ in AHM and He mode compared to no gas mode.

Carbon-rich matrices

As shown in Figure 5, Mg, Al, and Cr were determined in 15% isopropyl alcohol (IPA) using no gas, He, and AHM modes. Interferences included C_2^+ on $^{24}Mg^+$, $C_2H_3^+$ on $^{27}Al^+$, and ArC^+ on $^{57}Cr^+$. AHM showed around 2× higher sensitivity (cps/ppb) than He mode and lower BECs (ppb).

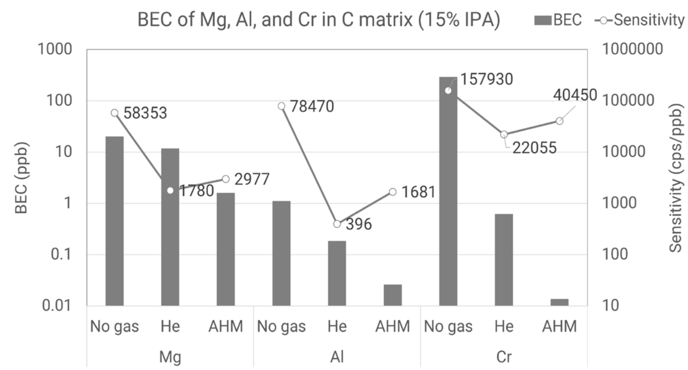

Figure 5. Sensitivity and BEC comparison for Mg, Al, and Cr in 15% IPA.

Chloride and calcium matrix

To simulate a challenging application, V, As, and Se were determined in a blank, 2% HCl, and 2% HCl spiked with 100 ppm Ca. Interferences included ClO^+ on $^{51}V^+$, $ArCl^+$ on $^{75}As^+$, and $ArClH^+$/$CaClH^+$ on $^{78}Se^+$. As shown in Figure 6, AHM provided higher sensitivity (cps/ppb) and lower BECs (ppb) than He mode. Notably, the Se BEC in the blank was at the single-digit ppt level in AHM.

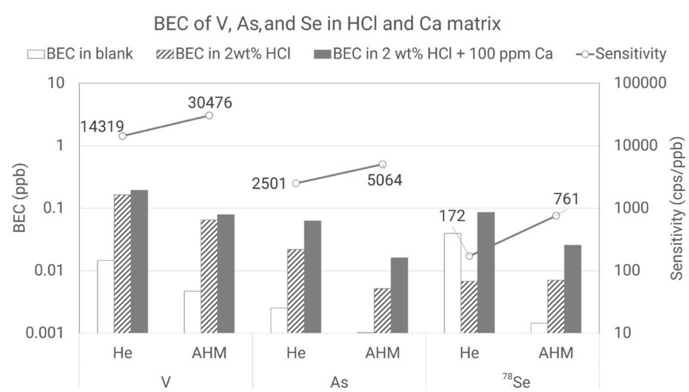

Figure 6. Comparison of Cl and Ca interference removal by He mode and AHM.

Europium (Eu) in a barium matrix

In a 20 ppm barium (Ba) matrix, both Eu isotopes (^{151}Eu and ^{153}Eu) are affected by BaO^+ interferences. As shown in Figure 7, AHM provided twice the sensitivity of He mode and lower BECs for the determination of Eu, confirming the effectiveness of the 9500 ICP-QQQ method.

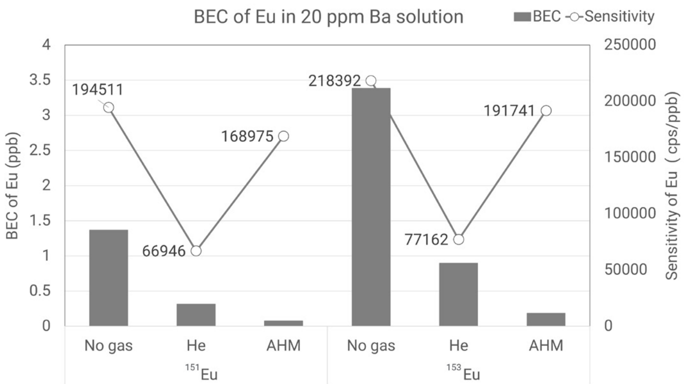

Figure 7. Sensitivity and BEC comparison for Eu in 20 ppm Ba. ^{151}Eu and ^{153}Eu were determined using no gas, He, and AHM modes.

Conclusion: A new standard for interference removal and sensitivity

The Agilent 9500 ICP-QQQ features innovative technologies, including the Dual-Cell System (DCS) and Advanced Helium Mode (AHM), two developments that mark a significant advance in ICP-MS performance.

Developed with a thorough understanding of ion behavior and collision dynamics, the DCS delivers exceptional interference removal and high sensitivity over a broad mass range. Its dual ion guide design and dual-mechanism approach (KED + CID) surpass the limitations of traditional high-energy HEHe and He KED modes, allowing for wider application and better abundance sensitivity.

AHM transforms He-based interference removal by intelligently optimizing cell conditions for both low- and high-mass elements in real time. With up to 20× sensitivity gains for low-mass elements and no need for multitune switching, AHM streamlines workflows, shortens analysis times, and improves data quality.

When combined, DCS and AHM set a new standard for performance, efficiency, and ease-of-use in ICP-MS. These innovations enable users to achieve faster, more accurate, and more reliable results—making the 9500 ICP-QQQ the ideal solution for laboratories seeking next-generation analytical capabilities.

Reference

1. Siva, S. Automated Analysis of Foods by ICP-QQQ with Discrete Sampling and Autodilution, Agilent publication, 5994-9095EN

www.agilent.com/chem/9500icpqqq

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