Technical Overview

Agilent
Trusted Answers

Critical Factors Affecting Cost-of-Ownership of ICP-MS

The impact of sample throughput and real-world maintenance intervals

ICP-MS in high-throughput commercial laboratories

ICP-MS is the technique of choice for metals laboratories, due to its unique combination of full coverage for all regulated analytes including mercury, low detection limits, and high sample throughput. But not all ICP-MS systems are equally suited to the needs of commercial laboratories.

Agilent's 7850 and 7900 ICP-MS systems provide a powerful, integrated solution for the most demanding applications. Software tools, auto-optimization, and method/report templates streamline setup and routine operation, while high matrix tolerance, simple, reliable helium cell gas mode, and wide dynamic range simplify routine analysis of varied sample types.

In this Technical Overview, we show how productivity gains and long-lifetime consumables contribute to making Agilent ICP-MS instruments the ideal choice for high-throughput commercial laboratories.

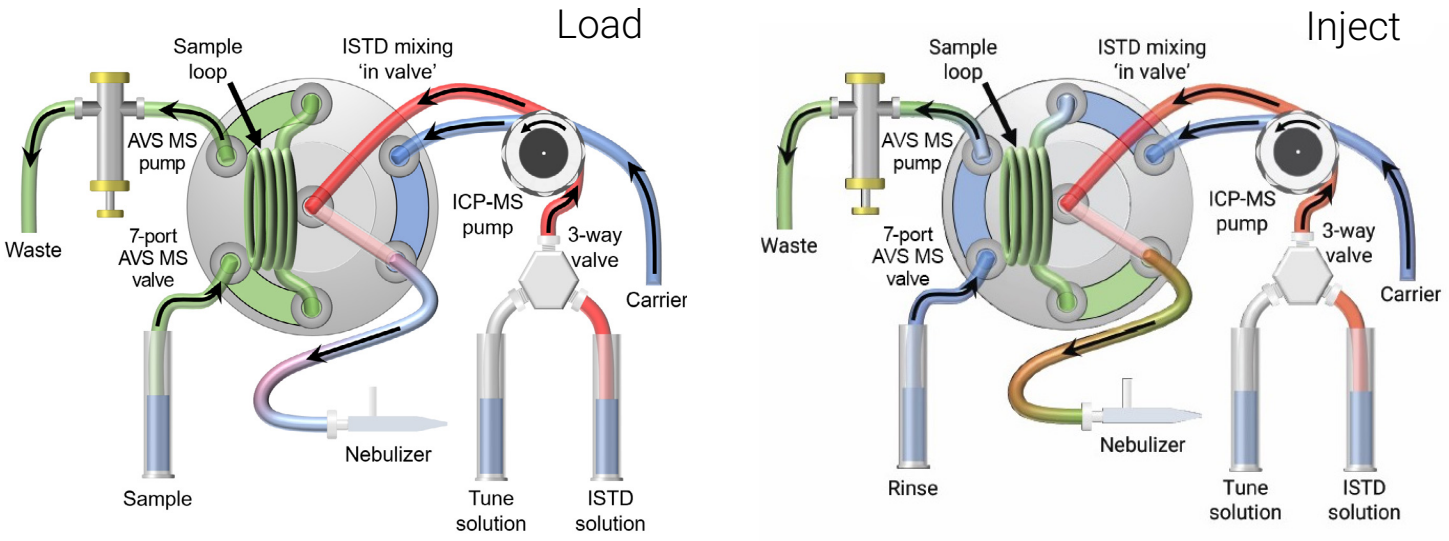

Figure 1. AVS MS discrete sampling system, showing the sample flow path in load (left) and inject (right) position.

ICP-MS Productivity

Sample Run Time

ICP-MS is a fast, multi-element technique. But the data acquisition time is only part of the analytical cycle. As well as the actual data collection, the time taken for the sample to reach the nebulizer and for the signal to stabilize must be considered, along with the rinse time between samples. If these steps occur sequentially, the total sample-to-sample time may be 4 ½ minutes or more, even for an analysis that requires less than 1 minute for data acquisition.

Discrete sampling can speed up the analysis by separating the sample uptake and rinse steps from the acquisition step, using a loop and valve arrangement. Agilent's third generation Advanced Valve System for ICP-MS (AVS MS), illustrated in Figure 1, is optimized for high throughput ICP-MS applications. AVS MS uses a high-flow piston pump to load the loop, and a robust, 7-port switching valve to inject the sample and automatically add the on-line internal standard.

In the load position, the AVS MS piston pump rapidly transfers the sample from the autosampler vial to the loop (Figure 1, left). The valve then switches to inject, so the sample volume contained in the loop is injected into the carrier flow and transported to the nebulizer for analysis (Figure 1, right). The solution is "pulled" into the loop by the AVS MS pump, and "pushed" out to the nebulizer by the ICP-MS pump, so the sample never passes through the pump tubing. This minimizes the potential for sample contamination.

During sample measurement, the autosampler probe and tubing are flushed, ready for the next sample to be loaded; the next sample acquisition follows with minimal delay. The timing is illustrated schematically in Figure 2.

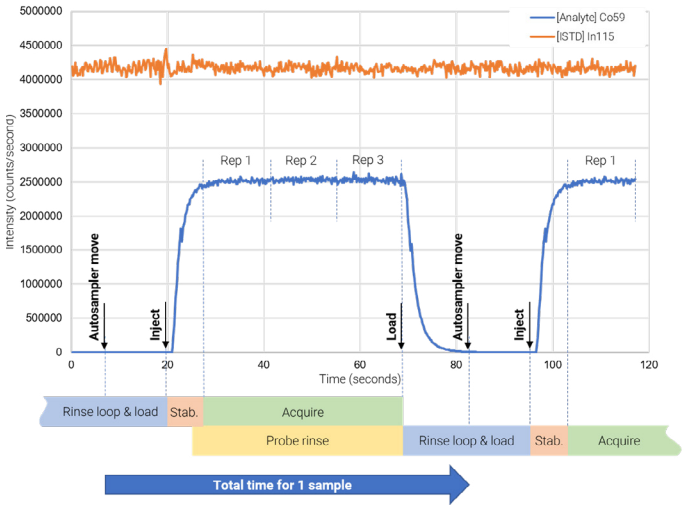

Figure 2. AVS MS signals showing how first sample acquisition overlaps with rinse and next sample load steps.

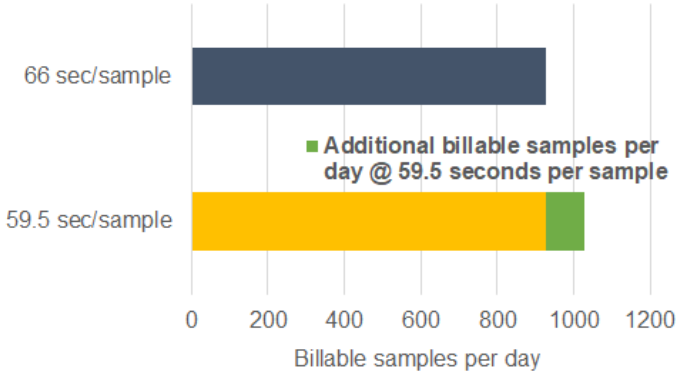

Figure 3. Agilent 7850 with AVS MS reduces sample-to-sample run time by around 6 seconds compared to alternative discrete sampling systems. This reduction in run time allows more than 100 additional billable samples to be run each day.

An optimized pump configuration and short tubing lengths mean that AVS MS offers significantly faster analysis compared to other commercially available, third party discrete sampling devices. The improvement of around 10% – a little over 6 seconds in a total sample-to-sample time of 66 seconds – may sound trivial. But this equates to being able to run more than 100 additional billable samples in a 20-hour day, assuming 15% QC overhead, as shown in Figure 3.

Matrix tolerance and long term stability

Agilent's ICP-MS systems offer market-leading matrix tolerance and stability, due to their robust, high-temperature plasma. A robust plasma (low CeO^+/Ce^+ ratio) gives better matrix decomposition, which minimizes matrix deposition and drift. AVS MS discrete sampling further improves long-term stability by reducing the amount of time that the sample is delivered to the nebulizer and plasma.

The excellent stability of the 7850 with AVS MS is illustrated in Figure 4, internal standards (ISTD), and Figure 5, Continuing Calibration Verification (CCV). With a sample run time of less than 60 seconds, the ICP exposure to the sample matrix is reduced, matrix deposition is minimized, so the ISTD signal and quantitative results are more stable. This means more reliable data, fewer QC failures, and higher productivity.

Accurate Spike Recoveries

The water sample analysis sequence run on the 7850 with AVS MS included a spike recovery check, shown in Figure 6. All elements except Hg were spiked at 10 µg/L (ppb); Hg was spiked at 0.1 µg/L. All recoveries were well within the required limits of ±15% defined in EPA 200.8.

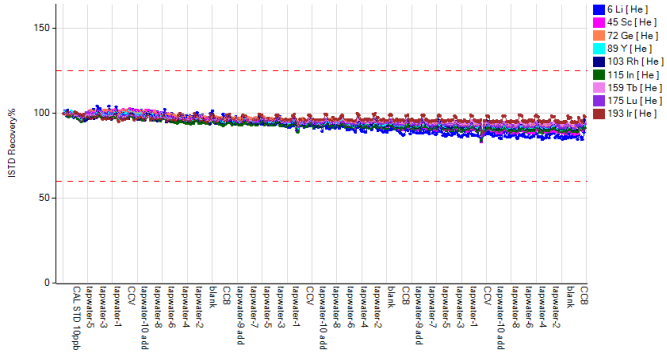

Figure 4. Agilent 7850 internal standard (ISTD) stability for 6-hour analysis of water samples. QC limits are set at 60% - 125% as defined in EPA 200.8. All ISTD recoveries were well within the limits throughout the run, there was minimal overall signal drift, and sample to sample precision was also excellent.

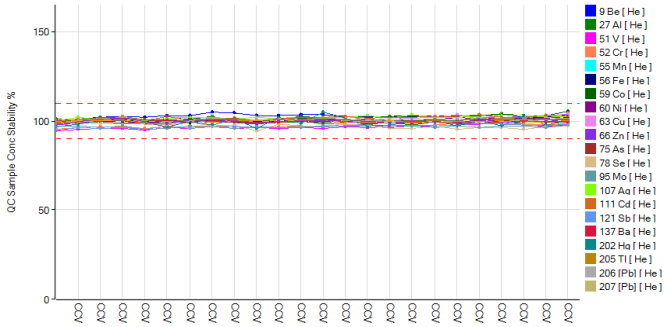

Figure 5. Continuing calibration verification (CCV) recoveries for 6-hour sequence analyzing water samples using the Agilent 7850. QC limits are set to ±10%, as defined in EPA 200.8. All CCV recoveries were easily within the required range.

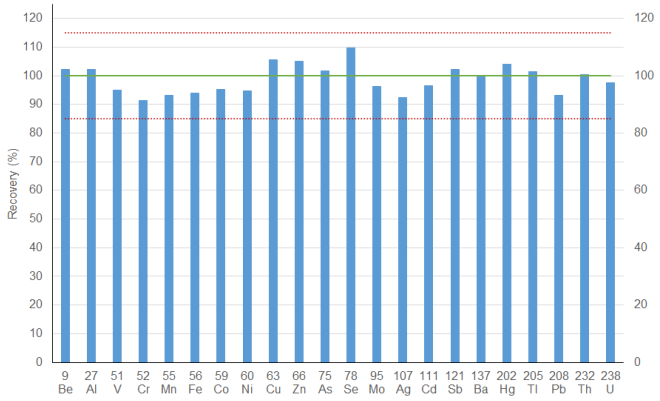

Figure 6. Spike recoveries for tap water sample measured using the Agilent 7850. All elements were easily within the EPA 200.8 required recovery range of ±15%, indicated by the red lines.

Real-World Maintenance Intervals

Routine Maintenance

The very robust plasma of the Agilent ICP-MS systems contributes to the low levels of routine maintenance required on these instruments. By ensuring that the sample matrix is decomposed effectively in the plasma, and using AVS MS to minimize the time that the system is exposed to the sample, the amount of undecomposed matrix that deposits on the ICP-MS interface and ion lens is minimized. This means that less routine maintenance is required, which means the instrument is productive for more of the time.

Most routine maintenance tasks (changing sample introduction tubing, cleaning glassware, interface cones, and ion lens) are quick and easy to perform on an Agilent ICP-MS. These tasks do not require access to the high vacuum region, and so cause minimal downtime. Less frequent maintenance tasks include changing vacuum pump oil, usually performed at the annual Preventative Maintenance (PM) visit, and replacing the detector.

Electron Multiplier (EM) Detector

Agilent ICP-MS systems use proprietary detector and amplifier circuit technology to deliver a unique combination of high sensitivity, low background, and long lifetime.

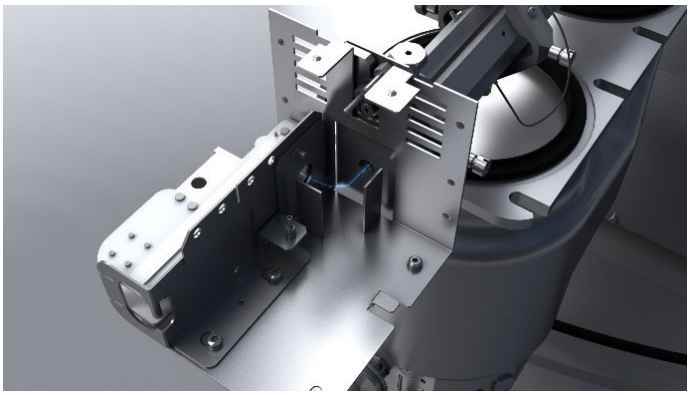

Figure 7. Orthogonal electron multiplier (EM) detector of the Agilent 7850 and 7900 ICP-MS.

With traditional discrete dynode (DD) EMs, users had a choice between:

- Operating with a high applied voltage, which gives higher sensitivity, but reduces the detector lifetime, or
- Operating with a low applied voltage, which gives a longer lifetime but lower sensitivity.

Agilent's optimized ion focusing design and proprietary detector system mean that Agilent ICP-MS users benefit from both high sensitivity and long EM lifetime as standard.

The EM detector is one of the most expensive consumable items required for an ICP-MS instrument, so its operating lifetime has a major impact on overall running costs. A survey of Agilent 7700 users conducted 4 years after the 7700 was launched indicated that ~80% of users had not had to change their detector.

The findings of the 7700 ICP-MS users' survey confirm Agilent's own calculations of EM lifetime in two typical contract analysis lab scenarios. Using a representative drinking water reference material and a high concentration standard (Table 1), we calculated the approximate detector lifetime of the Agilent 7900 ICP-MS, based on the overall EM capacity (Figure 8). EM capacity is defined as the total number of ions that the detector can "count" in its lifetime.

Element	NIST 1643e	High conc. STD
Be	13.98	100
Na	20,740	10,000
Mg	8,037	10,000
Al	141.8	100
K	2,034	10,000
Ca	32,300	10,000
V	37.86	100
Cr	20.4	100
Mn	38.97	100
Fe	98.1	10,000
Co	27.06	100
Ni	62.41	100
Cu	22.76	100
Zn	78.5	100
As	60.45	100
Se	11.97	100
Mo	121.4	100
Ag	1.062	100
Cd	6.568	100
Sb	58.3	100
Ba	544.2	100
Hg		100
Tl	7.445	100
Pb	19.63	100
Th		100
U		100

Table 1. Analyte element concentrations (ppb) used for EM detector lifetime estimations: NIST water CRM (NIST 1643e) and High Concentration standard. Does not include 10 internal standard masses.

System Suitability

The Agilent 7900 single quadrupole ICP-MS is optimized to deliver the high levels of performance needed for more difficult applications. As a result, the detector settings and thresholds are set to achieve the high sensitivity typically required in these demanding applications. Even so, for a typical suite of around 40 analytes and internal standard (ISTD) elements, the EM lifetime calculations indicate that a laboratory running 300 drinking water samples per day and operating 20 days per month can expect their Agilent 7900 ICP-MS EM detector will typically last more than 10 years. Even laboratories running high matrix samples with analyte levels between 100 ug/L (ppb) and 10 mg/L (ppm) can expect almost 6 years of operation from their Agilent 7900 ICP-MS detector.

The Agilent 7850 single quadrupole ICP-MS is optimized for more routine applications, where factors such as stability, sample throughput and low operating costs are typically more important than achieving the highest sensitivity. Consequently, the detector settings and thresholds of the 7850 detector are optimized for extended life with lower sensitivity than on the 7900. This means that the lifetime of the EM detector used in the Agilent 7850 ICP-MS is typically around twice as long as the figures quoted above for the EM detector used in the 7900.

As well as the lower cost of replacement detectors, this long lifetime also contributes to reduced maintenance downtime, further enhancing productivity.

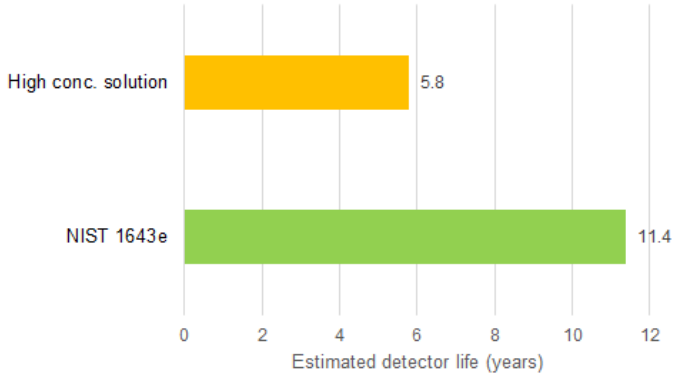

Figure 8. Estimated lifetime for Agilent 7900 ICP-MS EM detector. Two scenarios – routine drinking water and high matrix analysis; 300 samples per day; 20 days per month.

www.agilent.com/chem

DE54728919

Printed in the USA, May 16, 2024
5991-9342EN

Agilent
Trusted Answers