SPECIFICATIONS

NexION 5000 ICP-MS

ICP - Mass Spectrometry

Key Benefits:

- Outstanding accuracy at low levels
- Exceptional DLs and BECs
- Active control over reactions
- Most tightly-focused ion beam in the industry
- Cutting-edge ICP-MS technologies for flexible analysis

As a trusted leader in ICP-MS analysis for over three decades, PerkinElmer has been responsible for some of the most recent and novel developments in the field, including the Dynamic Reaction Cell (DRC), Axial Field Technology (AFT), Triple Cone Interface, the passively-cooled LumiCoil™ RF Coil and no maintenance beyond the cones, thanks to the combination of the Triple Cone Interface and Quadrupole Ion Deflector. Another PerkinElmer innovation was Universal Cell Technology which allowed either reactions with DRC, collisions with kinetic energy discrimination (KED) or Standard mode with correction equations to be used to remove spectral interferences, offering full analytical flexibility. Now, these technologies have come together with additional proprietary features to deliver the industry's first four-quadrupole system, the NexION® 5000 Multi-Quadrupole ICP-MS.

This state-of-the-art ICP-MS is available in two models: a cleanroom model for applications requiring the highest level of cleanliness and the lowest background equivalent concentrations (BECs); and a non-cleanroom model for general use. These systems offer a level of versatility and usability that surpasses other ICP-MS systems on the market and builds on the success of the NexION 1000 and 2000 ICP-MS systems. Designed with high versatility, low maintenance and ease-of-use in mind, the tandem four-quad design of the NexION 5000 can easily switch between Single Quad, Triple Quad, and Multi Quad modes within a single analysis. At the heart of this multi-quad instrument is Universal Cell Technology which utilizes dynamic bandpass tuning to eliminate spectral interferences and reaction by-products before they have a chance to form new interferences on the analyte of interest, delivering unsurpassed BECs for even the most demanding applications.

PerkinElmer®
For the Better

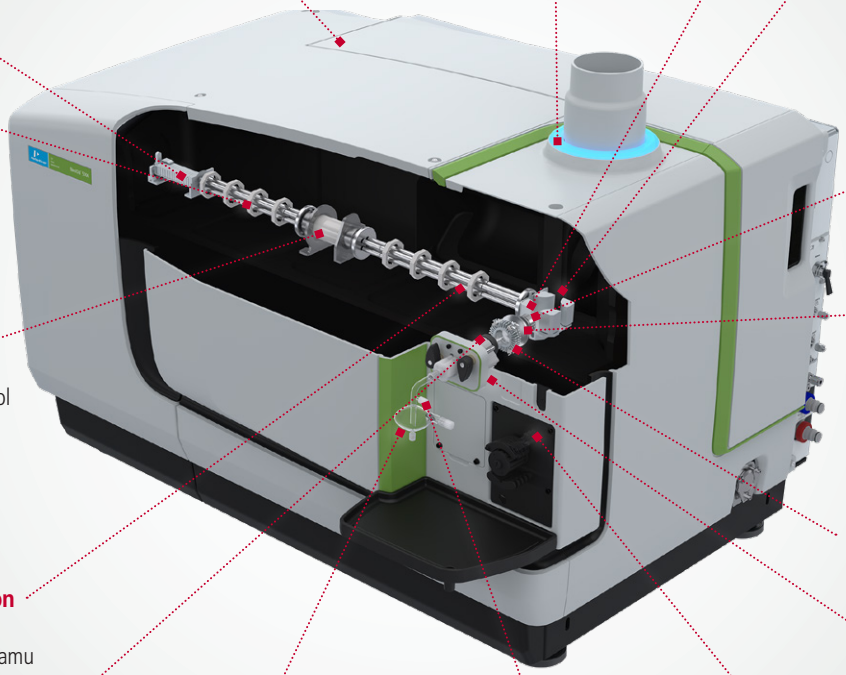

Figure 1. Key hardware components of the NexION 5000 Multi-Quadrupole ICP-MS.

Overview: Multi-Quadrupole ICP-MS

With most recent technological advancement in ICP-MS, in 2020 PerkinElmer introduced the industry's first four-quadrupole ICP-MS, the NexION 5000 – an instrument which surpasses the interference removal capabilities of conventional triple-quadrupole ICP-MS and high-resolution ICP-MS, delivering outstanding background equivalent concentrations even in hot plasma. This is important as hot plasma conditions do not suffer from the same matrix effects as cold plasma conditions, leading to robust, reliable and accurate analyses at ultra-low concentrations.

The NexION 5000 Multi-Quadrupole ICP-MS is a forward-looking instrument which not only leverages the technologies that our customers have found useful over the years, but also introduces additional innovations to anticipate future application needs, delivering:

- Superior interference removal
- Excellent stability
- Unmatched matrix tolerance
- Lowest maintenance

Superior Interference Removal

Unlike traditional triple-quad systems, the NexION 5000 Multi-Quadrupole ICP-MS delivers four stages of mass resolution. A clean, focused ion beam is introduced into the ion optics, enabling you to control interferences as early as the Quadrupole Ion Deflector (QID). In the NexION 5000 ICP-MS, the ion beam is shaped and directed within Q0 (Quadrupole Ion Deflector) and mass filtered in Q1 (first Transmission Analyzer Quadrupole). Thereafter, the mass of interest is passed into the Quadrupole Universal Cell (Q2) for either a controlled reaction, collision or no reaction, and the analyte, clear of interferences, is separated/focused in Q3 (second Transmission Analyzer Quadrupole). This combination allows the system to deliver outstanding BECs. Data generated using the cleanroom model of the NexION 5000, shown below, demonstrates how the instrument is able to achieve less than 1 ppt BECs in hot plasma even for elements such as calcium (Ca) and potassium (K) (Figure 2) and < 1.3 ppt detection limits (DLs) for challenging elements such as sulfur (S) and silicon (Si), even in a nitric acid matrix, which can introduce additional impurities and nitrogen-based polyatomic interferences (Figure 3). Since the system comes standard with pre-cleaned stainless steel cell-gas lines, these data were captured without any special gas tubing, special cone or lens configurations and are the lowest known reported values for these elements to date. If even lower detection limits are required for Si and S, cleaned argon gas lines and a high-purity argon regulator are available for purchase. These outstanding results set the new standard for achievable levels for these elements which suffer from CO^+, N_2^+ and O_2^+ interferences, meeting the demanding needs of semiconductor, life science, petrochemical, pharmaceutical and other application areas.

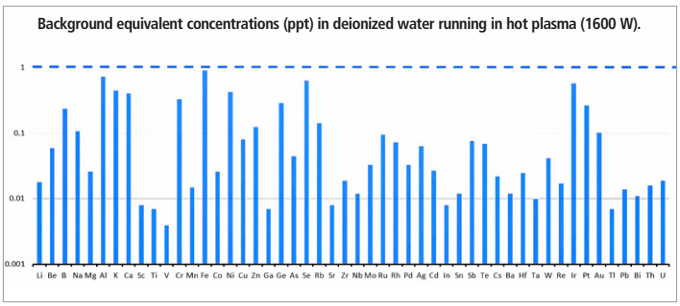

Figure 2. Sub-ppt BECs for a number of elements monitored in ultrapure water (UPW) acquired with the NexION 5000 ICP-MS cleanroom model with the standard cell, argon gas lines and standard regulator.

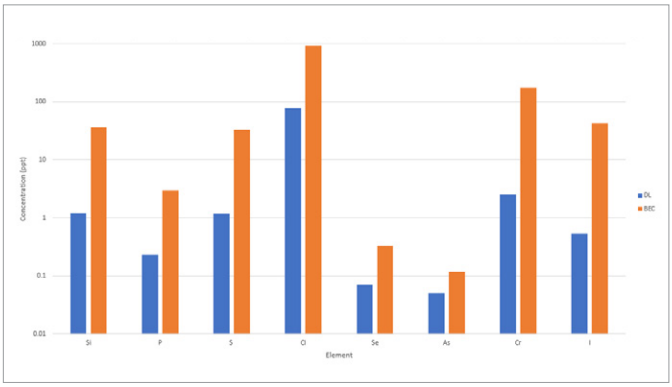

Figure 3. Sub-ppt DLs for non-metals which are pre-disposed to argon-based interferences in nitric acid. Analysis using the NexION 5000 ICP-MS cleanroom model with the standard cell, argon gas lines and standard regulator.

Excellent Stability

Everything about the NexION 5000 ICP-MS says stability – for your instrument and your results (Figure 4): for example, our free-running 34-MHz RF generator delivers the fastest impedance matching on the market. Our Triple Cone Interface with wide-aperture cones offers unparalleled resistance to clogging even for tough matrices. And the ability to use pure gases in our Universal Cell, a true quadrupole, ensures that the reaction is stable and reproducible.

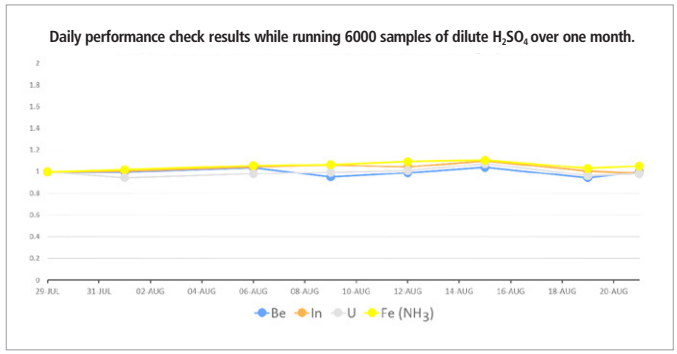

Figure 4. Long-term system stability evaluated by running a daily performance check solution in between the analysis of 6000 samples of dilute H_2SO_4 over one month.

Unmatched Matrix Tolerance

The NexION 5000 ICP-MS is perfect for laboratories requiring extremely low DLs and BECs in a variety of different matrices, from aqueous to organic, from ultrapure water (UPW) to high total dissolved solids (TDS). The patented design of our second-generation Triple Cone Interface provides unique solutions to space-charge effects, as a result of its coupling to the highly effective OmniRing™ technology. Furthermore, the innovative solid-state, free-running RF generator with unique LumiCoil™ technology provides accurate impedance matching to easily handle even the most difficult matrices. Plus, the powerful All Matrix Solution (AMS) sample introduction system is able to deliver up to 200x dilution and support samples even with 35% TDS without the need for off-line dilution.

Lowest Maintenance

Whatever your industry, uptime is key to keeping your lab running at peak performance. That's why the NexION 5000 system eliminates virtually all non-routine maintenance requirements for unsurpassed instrument uptime. First, our LumiCoil technology is guaranteed for the life of your instrument and requires no water or gas cooling. The system's Triple Cone Interface features a unique third cone (hyper-skimmer) with OmniRing technology that produces the most tightly focused ion beam – and cones are located outside the vacuum for quick, easy access. The wide-aperture cones maximize signal stability and minimize cone clogging during extended high-TDS sample runs. What's more, the patented combination of the Triple Cone Interface and Quadrupole Ion Deflector controls and focuses the beam in the downstream ion optics, ensuring that there is no cleaning beyond the cones. Furthermore, in contrast to many collision cells on the market, the Universal Cell does not require any replacement over the instrument's lifetime, ensuring you can rely on the robustness of the system for years to come.

Specifications

The four quadrupoles of the NexION 5000 Multi-Quadrupole ICP-MS can be outlined as follows:

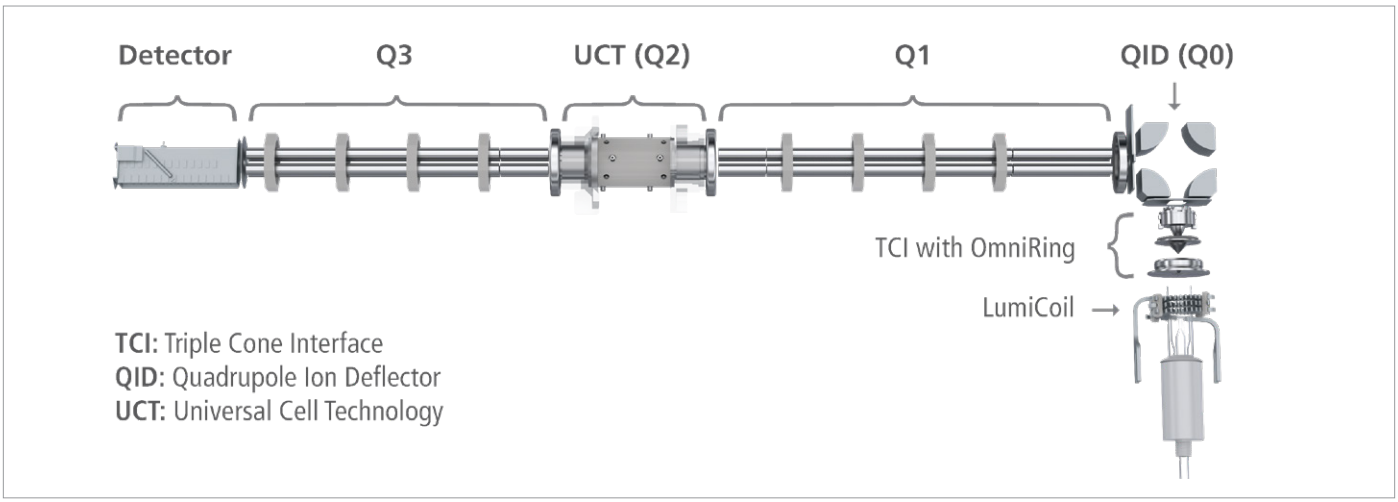

Figure 5. NexION 5000 ICP-MS ion optics with four quadrupoles.

- ***First:*** Quadrupole Ion Deflector (Q0) directs ions to the first Transmission Analyzer Quadrupole (Q1);
- ***Second:*** First Transmission Analyzer Quadrupole (Q1, full-sized with < 0.7 amu mass resolution for normal operation and custom resolution to < 0.3 amu), can act as a mass filter or as an ion guide to direct ions to the Universal Cell;
- ***Third:*** Quadrupole Universal Cell (Q2) empowered by dynamic bandpass tuning, which creates a controlled environment for effective interference removal through dynamic reactions with reactive gases or collisions using non-reactive gases;
- ***Fourth:*** Second Transmission Analyzer Quadrupole (Q3, full-sized with < 0.7 amu mass resolution for normal operation and custom resolution to < 0.3 amu), can act as a mass filter or as an ion guide to direct ions to the detector with the highest duty cycle on the market, ideal for applications requiring short dwell times.

Q0: Quadrupole Ion Deflector

The Quadrupole Ion Deflector (QID) acts as an electrostatic analyzer that turns the analyte ion beam 90 degrees. A software-controlled scanning voltage is applied to the QID to maximize the transmission of ions within a specific mass range into the first Transmission Analyzer Quadrupole (Q1), thereby improving sensitivity, reducing interferences on the mass range of interest, and eliminating the transmission of photons and neutral species to the mass spectrometer via the vacuum.

Since the ion beam is narrowly focused through the use of the hyper-skimmer cone and OmniRing, analyte ions and neutral species never touch any surfaces of the ion deflector, ensuring cleanliness and no maintenance beyond the cones as well as superior stability and robustness. Moreover, the kinetic energies of the ions exiting the QID are similar (< 10 eV) for optimal abundance sensitivity in the downstream mass resolving quadrupole, ensuring that sputtering of metallic surfaces does not take place which could result in a rise in the chemical background noise.

Q1: First Transmission Analyzer Quadrupole

A full-length Transmission Analyzer Quadrupole (Q1) has been engineered to deliver < 0.7 amu mass resolution (preferred for normal operation) with custom resolution to < 0.3 amu and is driven by a high-frequency 2.5-MHz power supply. Its carefully designed rods produce a perfect hyperbolic field, delivering optimal resolving power and ion-transmission efficiency. This quadrupole can work in mass filtering or Ion Guide modes. In Triple/Multi Quad modes, the mass filtering ability of Q1 allows only ions of a specific *m/z* to be passed through to the Universal Cell, while all other ions from the matrix, solvents and plasma are removed. This ensures that a "clean" beam of tightly focused ions with the same *m/z* enter the cell. In Ion Guide mode, all ions are allowed to proceed to the Universal Cell.

Q2: Quadrupole Universal Cell

The Universal Cell, standard in all NexION ICP-MS systems, is a true quadrupole-based cell driven by frequency modulation. This cell removes spectral interferences through reactions or collisions, allowing different modes of analysis to be run within the same method. Unlike higher-order multipoles which focus on collisions with kinetic energy discrimination, the Universal Cell has been designed to achieve the best out of reaction chemistry, which is predominantly used in MS/MS and Mass Shift modes. This delivers the best BECs and DLs for the application without suffering from the sensitivity losses experienced in interference removal via collision. The cell is further empowered by Axial Field Technology (AFT) which ensures that ions undergoing reaction do not lose kinetic energy, leading to improved performance and keeping the formation of higher-order product ions in check.

The modes of operation of the cell are summarized as follows:

Reaction (DRC) mode with selection of up to four reaction gases simultaneously via four gas channels at typical flows < 1 mL/min. System is compatible with a variety of pure and mixed gases. Reaction mode is ideal for applications demanding the best performance, with practically no loss of analyte sensitivity, and an unprecedented level of interference removal. Reactive gases – such as ammonia, oxygen, hydrogen, carbon dioxide, methane, etc. – are introduced into the cell to create predictable chemical reactions with either the analyte or interferent ions, as well as predictable and reproducible cluster formation for cluster-forming ions, such as Ti, Zn, Ge etc. Reaction by-products are instantly removed through dynamic bandpass tuning, preventing side reactions from taking place by rapidly destabilizing reaction by-products and any cell gas contaminants before they have a chance to form new interferences, a unique feature only available in quadrupole cells. In the Quadrupole Universal Cell, low and high mass cut-off windows can be applied as needed per analyte, allowing custom settings and providing full flexibility during the analysis, all of which contribute to accurate results and lower BECs.

Collision (KED) mode is compatible with a variety of collision gases. For the removal of unknown spectral polyatomic interferences, Collision mode is especially useful. In this mode, non-reactive gases, such as helium, or slightly reactive gas mixtures can be introduced into the cell to collide with the ions that are travelling through it. Since many interfering polyatomic ions tend to have larger diameters (collisional cross section) than the analyte ion, they will be subjected to more collisions than the analyte. These extra collisions mean that the interfering ions lose more kinetic energy and, as such, are removed through kinetic energy discrimination (KED). Although some elements may experience significant losses in sensitivity in this mode, it delivers better detection limits than Standard mode for elements which typically have polyatomic interferences on them.

Standard mode (no gases added) is typically used for elements which do not have interferences or have isobaric and minor polyatomic interferences. There is no loss of sensitivity using this mode of operation, and interferences are dealt with using correction equations but may result in the over- or under-estimation of results.

Q3: Second Transmission Analyzer Quadrupole

The second Transmission Analyzer Quadrupole is driven by a high-frequency 2.5-MHz power supply, delivering a perfect hyperbolic field which provides optimal resolving power and ion-transmission efficiency. Both the Q1 and Q3 are designed using state-of-the-art alloy materials, exhibiting negligible thermal expansion. This guarantees rigid structural integrity along the entire length of the rod, ensuring exceptional mass calibration stability. All rods are carefully inspected prior to assembly and aligned to ensure maximum ion transmission for greater sensitivity.

Abundance Sensitivity

Abundance sensitivity is reduced with increasing mass. Therefore, for the NexION 5000 ICP-MS, abundance sensitivity is measured at the highest naturally occurring isotope, 238U.

Owing to the novel design of the NexION 5000, the system delivers 10^{-8} abundance sensitivity in Single Quad mode. In MS/MS mode, abundance sensitivity far exceeds the dynamic range of the detector (10^{-10}), and therefore the guaranteed abundance sensitivity performance specification for the NexION 5000 in MS/MS mode is 10^{-10}.

Cell Gas Channels

The NexION 5000 ICP-MS is equipped with a four-channel cell gas control manifold that allows the introduction of pure gases or a mixture of gases, all of which can be mixed on-the-fly.

Vacuum System

Operating pressure is maintained in the event of an argon gas supply failure. In the event of a power failure, the ion optics backfill with argon to prevent contaminants from entering them.

Operating pressure is obtained in less than 15 minutes pumping time, which shortens the time taken to reach operating pressures.

Turbo Pump: The triple-inlet turbomolecular pump maintains vacuum $\leq 1e^{-6}$ Torr (with no cell gases) during operation. This system is purged by an inert gas during operation to prevent damage by reactive gases and/or corrosive vapors, such as those generated by the analysis of phosphoric acid.

Interface Pump: The system is backed by a high-performance external roughing pump, ensuring that there is only a single roughing pump to support and maintain. It uses ultra-long-life PFPE fluid. This pump is fully computer-controlled and automatically shifts into power-saving mode when the plasma is off.

NOTE: *A pump filter is highly recommended in applications involving high concentrations and the routine analysis of sulfur compounds. Please contact your PerkinElmer sales representative about available options.*

Detector

The highly sensitive and stable dual-stage discrete dynode detector ensures low electronic backgrounds while offering up to 10^{12} orders of linear dynamic range when used in combination with the NexION's unique Extended Dynamic Range (EDR) capability, which is able to attenuate the analyte signal in the cell (10 orders of magnitude in non-EDR operation – no extra parts/special configuration/extra gas usage required for EDR). This allows for the accurate analysis of both low- and high-concentration analytes within a single analytical run, resulting in fewer re-runs and less chemical consumption while ensuring longer detector lifetimes. Being applied selectively per analyte, the EDR functionality does not affect the signal response of other elements and does not call for the addition of gases into the cell.

The system delivers dwell times as short as 10 µs in both analogue and pulse-counting detection modes, essential to ensuring well-defined and resolved transient signals.

The system includes software-automated control of all operating voltages and the detector cross-calibration and has easy service access for detector exchange.

Sample Introduction System

4-Channel Peristaltic Pump

The NexION 5000 ICP-MS comes equipped with a fully software-controlled, high-precision peristaltic pump with four channels to draw sample through a capillary into the nebulizer for subsequent aspiration, droplet-filtration and ionization. The 36 mm peristaltic pump head has 12 inert rollers, improving flow consistency and reducing pulsations while also supporting a variety of different speeds from 0-100 rpm.

NOTE: *The NexION 5000 ICP-MS is compatible with optional high throughput sampling systems. Please contact your PerkinElmer sales representative about available options.*

Nebulizer

The sample is introduced into the plasma at a constant rate using a self-aspirating perfluoroalkoxy (PFA) polymer nebulizer, greatly improving measurement precision and long-term stability.

NOTE: *Optional compatible nebulizers are available, accommodating a variety of different flow rates, total dissolved solids concentrations and demonstrating resistance to organics or aggressive mineral acids. Please contact your PerkinElmer sales representative about available options.*

Spray Chamber

The system comes standard with a baffle-type cyclonic spray chamber (non-cleanroom model: glass; cleanroom model: UHP quartz-SilQ) for superior aerosol droplet filtration, delivering outstanding sensitivity and low RSDs. The spray chamber is equipped with an All Matrix Solution (AMS) port to perform > 200x *in-situ* aerosol dilution of the sample or the introduction of oxygen while analyzing organics to prevent carbon deposits on the cones (described in detail below).

NOTE: *Other compatible spray chambers are available on request. All spray chambers are compatible with the industry standard of 6 mm OD nebulizers. Please contact your PerkinElmer sales representative about available options.*

High Matrix Samples and Organic Solvent with All Matrix Solution (AMS)

The NexION's All Matrix Solution allows users to run samples with high TDS (such as seawater: > 3.5%; brine: > 25%) without the need for off-line dilution.

Also, oxygen can be introduced via the AMS port to allow the user to analyze organic solvents (IPA, NMP, etc.).

The AMS gas flow setup is optimizable via Syngistix™ for ICP-MS software to either use argon as a dilution gas or introduce oxygen gas to burn off excess carbon from the cones in organic solvents.

Optional Extras

Optional extras include Peltier cooler/heaters (-10 °C to 80 °C), which facilitates the analysis of organic solvents.

NOTE: *Versions compatible with either cyclonic or PFA spray chambers are available upon request. Please contact your PerkinElmer sales representative about available options.*

Torch

The sample introduction system comes standard with a SilQ one-piece torch and a fixed 2 mm injector, ensuring excellent performance in different matrices. This torch is easily interchangeable with demountable torches, where the injector can be chosen to fit the application.

NOTE: *A variety of different torch designs (fixed and demountable), which accommodate injectors with varying diameters (including 2.5 mm ID) and material compositions, are available on request. Please contact your PerkinElmer sales representative about available options.*

Torch Cassette

A variety of torch cassettes are available, whereby each torch cassette is color-coded according to the application, taking the guesswork out of the sample introduction component selection. Optional torch cassette and injector designs are available for:

- Organic solvents
- HF resistance
- Geological
- High TDS sample introduction/best BECs

The tool-free, ambidextrous design of the torch cassette allows the sample introduction system to be changed with minimal downtime. With fully-integrated gas and plasma ignition connections in the torch cassette and a one-piece torch, the torch cassette has fully software-controlled and automated X, Y, Z torch positioning (± 3 mm with 0.05 mm reproducibility), ensuring that maximum ion transmission is achieved, thereby enhancing sensitivity.

Inductively Coupled Plasma

The NexION 1000, 2000 and 5000 ICP-MS instruments offer the most robust plasma on the market, allowing for the rapid transition between aqueous and organic matrices, cold and hot plasma, delivering unmatched performance and stability.

RF Generator

The NexION line of ICP-MS instruments offers the only RF generator to be specifically designed for ICP-MS. The state-of-the-art 34-MHz free-running solid-state RF generator with PlasmaLok™ delivers the best of both plasma power range and stability. This generator provides accurate impedance matching and adjustable power with 1 watt increments from 400 to 1600 watts and a response time of 50 nanoseconds, quickly adapting to changing plasma loading. With no moving parts aside from the cooling fans, it electrically decouples the plasma from the ion optics, allowing independent adjustment of the ion optic parameters and the plasma conditions.

The RF generator is able to run in Cold Plasma mode (400-800 W) and Hot Plasma mode (1400-1600 W) in a single sample acquisition and can rapidly change between these modes without the need to create multiple methods.

LumiCoil RF Load Coil
The innovative design of the LumiCoil RF coil is unique in that it is air-cooled by the system exhaust and requires no additional infrastructure for water or gas cooling. This eliminates the need for maintenance or replacement of plasma load coils as is often needed with copper RF coils. This novel design ensures that the torch does not require any additional and costly consumables to prevent the secondary discharge of the plasma, such as torch shields, bonnets and screens.

PlasmaLok Interface
PlasmaLok stabilizes energy distribution, thus maintaining excellent spectral resolution and simplifying ion-optic tuning. This is achieved even when the sample matrix dramatically changes, such as going from a wet-sample aerosol (conventional nebulization) to a dry-sample aerosol (laser sampling), from hot plasma to cold plasma, and from aqueous solutions to organics.

Furthermore, PlasmaLok eliminates damage to the interface cones by preventing uncontrolled arcing between the plasma and cones without the need for a plasma shield.

And finally, PlasmaLok minimizes deposition on the cones and reduces double-charged signals, guaranteeing excellent signal precision and long-term stability. Due to the lower amount of deposition on the cones, this feature dramatically reduces the need for routine maintenance and cleaning of the cones.

Clear Plasma View
A true reflection, full-color plasma view window allows for careful, unobstructed and real-time visual inspection of the cones, torch, load coil, sampling depth, without needing to extinguish the plasma, as well as allowing visual cues based on the plasma color.

This feature simplifies the optimization of gases when running organic matrices and troubleshooting, allowing early diagnosis and quick response to issues via plasma observations.

Inert Tubing
Cleaned, high-purity stainless steel, low sulfur cell gas tubing is provided as the standard configuration for lower sulfur backgrounds. Low-sulfur argon tubing is available on request.

Interface

As with all NexION ICP-MS instruments, the NexION 5000 offers easy cone access at the touch of a button. The wide-aperture cones ensure less clogging and maintenance. The Quadrupole Ion Deflector (QID) replaces the traditional lens systems adopted in older ICP-MS designs and turns the ion beam 90 degrees to eliminate photons, unionized material and neutral species, cleaning the beam for outstanding BECs. With no lenses to clean or maintain after the cones, uptime is dramatically increased as routine maintenance decreases.

Triple Cone Interface with OmniRing Technology
The Triple Cone Interface is easy to remove and clean without opening the vacuum chamber. The second-generation wide-aperture Triple Cone Interface with OmniRing technology, produces the most tightly-defined ion beam in the industry while minimizing spa ce-charge effects, delivering outstanding sensitivity, low maintenance and a five-fold increase in analyte sensitivity. By applying a voltage to the cones, analysis can take place in extraction or focusing modes.

The details of the cones which come with the NexION 5000 ICP-MS are provided below:

Sampler Cone:
- Cleanroom model: Platinum-tipped;
- Non-cleanroom model: Nickel;
- Details: Grounded. 1.1 mm diameter orifice;
- Use: Samples ions from the plasma.

Skimmer Cone:
- Cleanroom model: Platinum-tipped;
- Non-cleanroom model: Nickel;
- Details: Grounded. 0.9 mm diameter orifice;
- Use: This large diameter offers a nearly 5x larger aperture than 0.4 mm cone orifices, delivering improved signal stability and less cone-maintenance during extended high TDS sample runs.

Hyper-skimmer Cone:
- Both models: Nickel;
- Details: Charged. 1.0 mm diameter orifice;
- Use: To produce a tightly focused ion beam that helps the QID to filter out neutrals and photons and ensures no maintenance beyond the cones.

OmniRing: The proprietary OmniRing technology applies a voltage behind the hyper-skimmer cone to optimize ion flow from the plasma, enhancing sensitivity and allowing analysis to take place in either extraction or focusing modes. The unique design of OmniRing guarantees no special cleaning of this component.

Cones are easily removed using two magnetic cone removal tools which ensure that the cones do not drop and are protected as they are being removed (***Note:*** *other NexION models use a single cone removal tool*).

Cold plasma is easily selected in the software without using any additional parts, delivering outstanding BECs and DLs. Ask your local PerkinElmer field application scientists about setting up Cold Plasma mode which can be easily selected in the software.

Cone and OmniRing voltages can be adjusted within the software to deliver the high sensitivity or the best BECs in hot or cold plasma. These cones are designed to offer both high sensitivity and high matrix tolerance without the need for any special

inserts or different base materials. Since there are no additional lens assemblies based on the cone configuration or application being run, downtime is significantly reduced.

NOTE: *Other cone materials and cones recommended for sulfur analysis are available on request. Please contact your local PerkinElmer sales representative about available options.*

Interface Gate Valve
The software-firmware-controlled interface gate valve defaults to the closed position when the plasma is off and when the instrument is not powered. The gate valve remains closed for a few seconds after plasma ignition which maintains the high vacuum in the ion optics housing. There is no need to exchange the gate valve for the analysis of 10% H_2SO_4, saving on the cost of components and instrument downtime.

General

A streamlined user experience is achieved via several product enhancements. The following features aim to create a simple and guided user experience as well as provide the best in detection limits:

Refined, User-Friendly Software
Syngistix for ICP-MS software (v. 3.0 or higher) enables users to quickly harness the powerful analytical capabilities of the NexION 5000 ICP-MS. The contemporary user interface addresses the complexity of the triple-quad and multi-quad ion optics into an easy-to-understand workflow. With just a few mouse clicks, the user can quickly access and complete a suite of automated optimizations which tune the instrument to reach optimal performance. Also included with the software are a number of tried and tested methods, allowing users to get up and running quickly.

Status Lighting
The NexION 5000 system has incorporated status lighting which provides visibility to the state of the instrument from afar and facilitates the quick response to and diagnosis of issues.

Regulatory and Safety Compliance
The NexION 5000 ICP-MS meets worldwide compliance requirements for safety, EMC and environmental regulations. All units have been developed and produced under a quality system certified to ISO 9001 and carry the European CE mark. Some of the safety and regulatory standards the NexION 5000 ICP-MS system meets are as follows:

- Safety: LVD (2014/35/EU), including nationally harmonized standards IEC/EN/UL/CSA 61010-1 and 2-81
- EMC (2014/30/EU): EN 61326-1; USA: FCC Part 18; Canada: ICES 003; Korea: KN RRA; AU/NZ: RCM
- RoHS 2 Directive (2011/65/EU) as amended by (EU) 2015/863 (also known as RoHS 3 compliance)
- WEEE Directive 2012/19/EU
- REACH (EC 1907/2006)
- SEMI S2/S8 (with upgrade kit)

SEMI S2/S8 Compliance and Protection Against Earthquakes
The NexION 5000 is the first multi-quadrupole ICP-MS in the industry which meets the strict regulatory requirements of SEMI S2/S8 standards (with the implementation of an optional upgrade kit). This kit ensures conformance to the stringent Environmental, Health and Safety (EHS) standards applicable to the semiconductor equipment manufacturing industries and semiconductor laboratories. An important part of S2/S8 standard compliance is the assurance that the NexION 5000 system is equipped with a number of unique features which help protect against collateral damage caused by earthquakes, such as a gas box to safeguard the gas connections, an emergency ON/OFF kit (EMO button), and a spill and restraint kit. Consequently, the NexION 5000 is the ideal ICP-MS solution for semiconductor laboratories located in active seismic zones.

SMARTintro Sample Introduction Modules
The SMARTintro sample introduction modules of the NexION 1000, 2000 and 5000 are interchangeable and color-coded to ensure that parts do not get mixed up in the laboratory. SMARTintro kits for specialized applications include options for HF resistance, organics and geological sample matrices.

Peripheral Equipment
The NexION family of instruments supports a wide range of PerkinElmer, ESI and CETAC autosamplers, autodilutors as well as laser ablation, field flow fractionation and speciation systems. PERSPEX® covers with extraction ports and easy-access doors are available for various autosampler models. A variety of bench options and pump noise enclosures are also available on request.

High Throughput Sampling Compatibility
The NexION family of instruments also supports a wide range of PerkinElmer and ESI high throughput and flow injection systems.

Difference Between Conventional Triple-Quadrupole Technology and Multi-Quadrupole ICP-MS Technology

The NexION platform of ICP-MS instruments delivers unsurpassed interference removal thanks to its Quadrupole Universal Cell, a true reaction cell with dynamic bandpass tuning allowing for customizable upper and lower mass cut-off in the cell. Unlike instruments with a collision cell designed for collision chemistry, the NexION Quadrupole Universal Cell is designed with reaction chemistry in mind, which is able to provide the most efficient removal of interferences and has the added advantage of being able to operate in Standard, Collision (with KED) and Reaction modes.

Since reaction gases in a collision-reaction cell are able to provide the most comprehensive interference removal, the example below outlines the differences between traditional triple-quadrupole instruments and a multi-quadrupole ICP-MS, where Cr is used to demonstrate these differences. In Figures 6 and 7, the ion-optic components that have control over the mass resolution are shown in green, and those which do not offer any mass resolution are shown in grey.

Conventional Triple-Quadrupole Technology

In conventional triple-quadrupole ICP-MS, analysis can take place in Single Quad or Triple Quad mode, where Single Quad mode typically only allows Q3 to be set as the analyzer quad. The ions of interest are focused and directed using an extraction lens. Despite being a useful approach for removing photons and neutral species, these components of the original ion beam become deposited on the extraction lens surface, which consequently requires regular cleaning. Furthermore, since the extraction lens does not have the ability to eject ions outside the mass range of interest, all of these ions go through to Q1 where some of the ions may be deposited on the first quadrupole and can lead to increased backgrounds over time. Moreover, since the kinetic energy spread of the ions is variable, this may cause highly accelerated ions to proceed through the lens to Q1, which can cause the sputtering of the Q1 material. In Q1, the nominal mass of interest is selected and all other masses not of interest are ejected from this quadrupole. The on-mass ions then enter Q2 and undergo collision/reaction in a passive multipole collision cell. Since there is no control over the ions in the cell, side reactions can take place between reaction by-products and/or gas impurities in the cell gases to form new interferences. In the following example of Cr, this can be seen as $NH_4(NH_3)_2^+$, which is an ion formed from the reaction by-product and the reaction gas and has the same nominal mass as the analyte (Cr) ion. Consequently the $NH_4(NH_3)_2^+$ ion will not be able to be separated from the analyte in Q3, resulting in a raised background and poorer detection limits for this analyte.

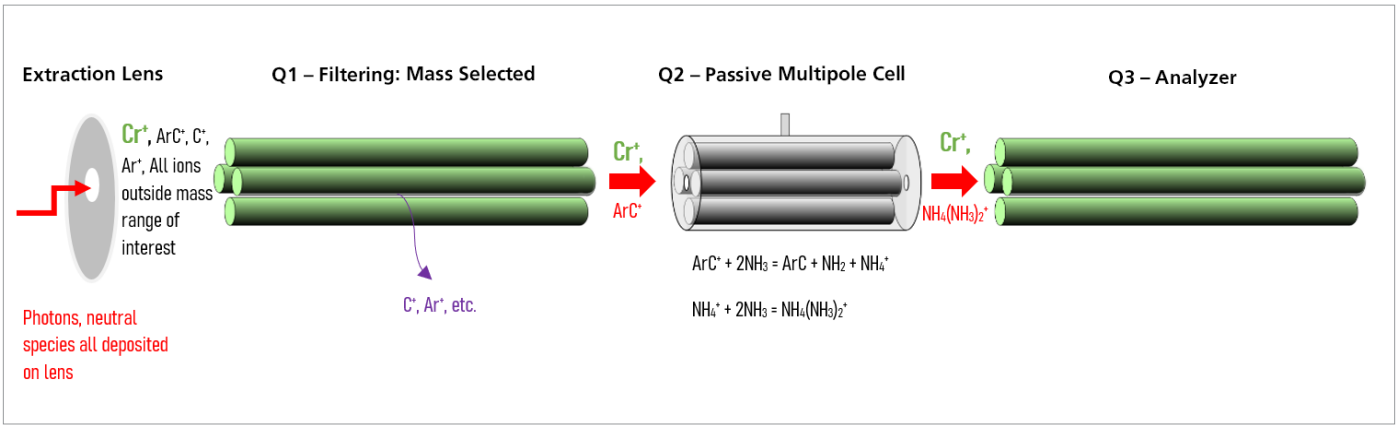

Figure 6. Diagram of a conventional triple quadrupole ICP-MS system demonstrating MS/MS analysis for Cr using ammonia gas and a passive collision cell as is standard with these systems. To improve readability, the ion beam path has been re-oriented to show the path of ions from left to right.

Multi-Quadrupole Technology

The NexION 5000 Multi-Quadrupole ICP-MS offers four stages of mass resolution and can operate in Single Quad, Triple Quad or Multi Quad modes. The key difference with this design is that the ions are controlled and have mass resolution at two additional areas in the system. The Quadrupole Ion Deflector (QID) acts as the first stage of mass resolution where it is possible to cut-off ions outside the mass range of interest which results in lower BECs for the analyte, no maintenance behind the cones, less downtime and long-term stability that you can trust. Moreover, the QID acts as an electrostatic analyzer, reducing the kinetic energy spread of the ions ensuring that there is no sputtering of Q1 which could increase the BECs of certain elements. In Single Quad mode, either Q1 or Q3 can be used as the analyzer quadrupole, each delivering phenomenal abundance sensitivity.

In Triple Quad mode, the ions follow the same process as discussed above for conventional triple-quadrupole technology, with the key difference that further control can be added in the QID, if desired. In Multi Quad mode, the ions enter the QID where ion beam cleanup takes place. If desired, masses outside the range of interest can be ejected, which reduces the number of ions entering Q1 for a cleaner system. The mass is selected in Q1 and passed on to the Universal Cell with dynamic bandpass tuning, which provides an additional mass filtering step. Here the Quadrupole Universal Cell quickly ejects reaction by-products before they have a chance to react and form new interferences. This ensures that a clean beam of analyte ions without interferences proceeds to Q3 and then on to detection.

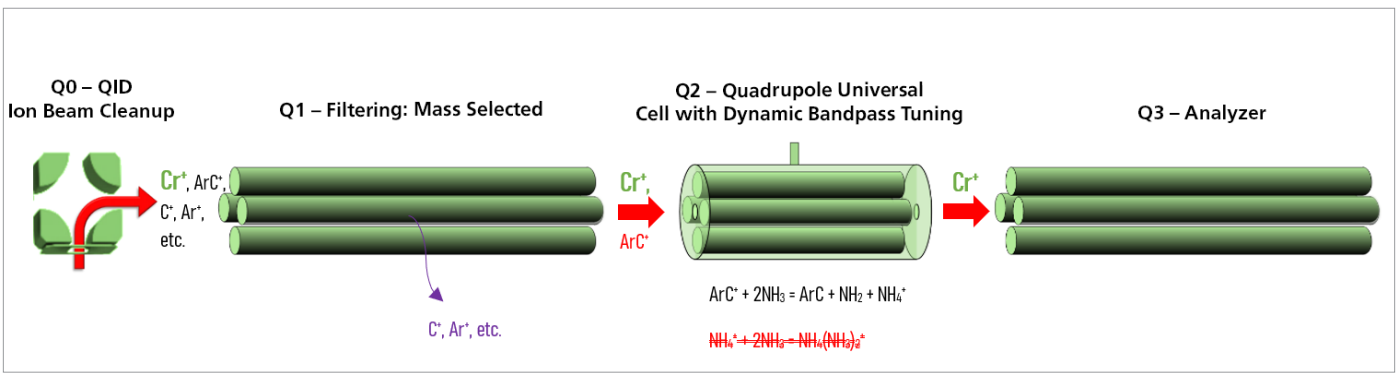

Figure 7. Diagram showing the ion path of the NexION 5000 Multi-Quadrupole ICP-MS with triple-quad capability. MS/MS analysis for Cr using ammonia gas and the active Quadrupole Universal Cell is demonstrated. To improve readability, the ion beam path has been re-oriented to show the path of ions from left to right.

SUMMARY TABLES

Standard Configuration

COMPONENT	STANDARD CONFIGURATION
Hyper-Skimmer Cone	Nickel
Plasma Gas Flow Controllers	Three (3)
Universal Cell Gas Channels	Four Mass Flow Controllers
Additional Plasma Gas Flow Controllers	One (plus 2 optional)
Argon Supply Lines	Polyethylene
Interface Pump	Standard, Rotary
Cooling Water Supply Fittings	Push-fit

Ambidextrous torch cassette for easy sample introduction exchange. Integrated gas coupling and self-aligning injector.

Hardware Specifications

SAMPLE INTRODUCTION	
Access	Eye-level height (based on unit being placed on an appropriate bench)
	Quick exchange torch access via SMARTintro sample introduction modules and torch cassette
Peristaltic Pump	Close-coupled, software-controlled 12-roller 4-channel peristaltic pump which is fully integrated with the ICP-MS system. Inert rollers, low pulsation and noise. Speeds 0-100 rpm
	2-stop flared tubing as standard
Spray Chamber	Non-cleanroom model: Glass baffle-type cyclonic spray chamber. Built-in AMS port for additional gases.
	Cleanroom model: SilQ baffle-type cyclonic spray chamber. Built-in AMS port for additional gases.
	Optional PFA cyclonic spray chamber and/or Peltier spray chamber cooler-heater available
Injector	Fixed, 2 mm ID. Optional self-aligning demountable torch injectors with various IDs and material compositions available
Service	O-ring free sample introduction system
PLASMA ION SOURCE	
Torch	Non-cleanroom model: screw-in, single piece, quartz; Cleanroom model: screw-in single piece, UHP quartz (SilQ) Variety of fixed and demountable torch injector designs available
	Automatic gas coupling
	Horizontal and vertical position: 3 to -3 mm, ±0.05 mm steps, ± 2 mm accuracy
	Sampling depth: 3 to -3 mm, ±0.5 mm step increments
Torch Mount	Ambidextrous cassette style torch mount, which supports single-hand removal of the torch and injector assembly
RF Generator	Solid-state RF generator specifically designed for ICP-MS, 34 MHz
	Accurate impedance matching
	RF power range: 400 W to 1600 W
	PlasmaLok ensures plasma stability
	No plasma shield/bonnet/screen required
	Most robust plasma on the market for easy switching between cold and hot plasma, aqueous and organic samples
Load Coil	Novel LumiCoil design, passively air-cooled via the extraction
	Lifetime guarantee*
	Aluminium load coil
Ar Gas Flow Controllers	Three channels: plasma/coolant, auxiliary, nebulizer
Additional Gas Flow Controllers	Integrated AMS (non-cleanroom model only). Mass flow controller (MFC) for single gas. Option to add up to two additional gases depending on model.
Clear Plasma View	True reflection full-color plasma view window. No cameras and/or supporting infrastructure to maintain or replace.
VACUUM SYSTEM	
Configuration	Four-stage differential pumping
Vacuum Pumps	Triple-inlet turbomolecular pump
	External backing rotary pump
Pump-Down Time	< 15 min after maintenance, which involves the breaking of vacuum and opening the vacuum chamber from atmospheric pressure (< 10^{-6} mbar)

Hardware Specifications *continued...*

INTERFACE	
Access	Eye-level height (assuming instrument has been placed on an appropriate bench). Cone access at the push of a button, instrument front panel drops down and slightly to the left for easy cone access.
Sampler Cone	Non-cleanroom model: Nickel, 1.1 mm ID; Cleanroom model: Pt-tipped 1.1 mm ID
Skimmer Cone	Non-cleanroom model: Nickel, 0.9 mm ID; Cleanroom model: Pt-tipped 0.9 mm ID
Charged Hyper-skimmer Cone and OmniRing Ensemble	Nickel cone, 1.0 mm ID, charged. OmniRing electrically isolated from hyper-skimmer cone
Interface Gate Valve	Software-firmware controlled, power failure, argon-depletion interlock
OPTICS	
Quadrupole Ion Deflector (Q0)	Quadrupole which actively turns ions 90 degrees while unionized materials, photons and neutrals are not deflected and carry on straight to be removed via vacuum.
	Replaces traditional lens system in older ICP-MS designs
	Optimizes the transmission for the mass of interest and broadly rejects other ions, therefore keeping the system cleaner than traditional linear lens systems
	No lenses to clean or maintain
	Ions exiting the QID have similar (< 10 ev) kinetic energies to prevent sputtering of the quad material
First Transmission Analyzer Quadrupole (Q1)	Mass range 1-285 amu
	2.5 MHz
	Full-length transmission analyzer quadrupole
	Resolution: typical operating resolution 0.7 amu, custom resolution to < 0.3 amu
	Quadrupole peak hop (slew) speed: 1.6 M amu/sec
	Quadrupole scan speed: 5000 amu/sec
	Peak hopping settling time: < 0.2 ms regardless of mass change
	Can be set as the main analyzer quadrupole
	Thermal coefficient of expansion: < 1.3 x 10^{-6}.K^{-1} at 25 °C for the best stability
Quadrupole Universal Cell (Q2)	Not a consumable, no maintenance
	Four gas channels, which can be mixed *in situ*
	User-defined low- and high-mass cut off window
	Can accommodate a wide variety of pure and mixed gases for extended periods of time
	Bandpass tuning of the cell is achieved by frequency modulation while keeping the RF amplitude constant to prevent unwanted chemical reactions occurring inside the cell
	Extended Dynamic Range (EDR) extends dynamic range up to 10^{12} by actively and selectively reducing ion signal on high concentration elements
	EDR does not affect the signal response of other elements or require the pressurization of the cell with a gas
	Axial field technology (AFT) controls the speed of the ions through the cell
Second Transmission Analyzer Quadrupole (Q3)	Mass range: 1-285 amu
	2.5 MHz
	Resolution: Typical operating resolution 0.7 amu, custom resolution to <0.3 amu
	Quadrupole peak hop (slew) speed: 1.6 M amu/sec
	Quadrupole scan speed: 5000 amu/sec
	Peak hopping settling time: < 0.2 ms regardless of mass change
	Mass stability for ^{7}Li, ^{24}Mg, ^{115}In and ^{238}U: < 0.05 amu over eight hrs of continuous operation
	Isotope ratio precision (^{107}Ag/^{109}Ag): < 0.08% RSD
	Thermal coefficient of expansion < 1.3 x 10^{-6}.K^{-1} at 25 °C for the best stability
Abundance Sensitivity	In Single Quad mode: 10^{-8} In Triple Quad/Multi Quad modes: Greater than detector dynamic range, therefore guaranteed to 10^{-10}

Hardware Specifications *continued...*

ION DETECTION	
Detector	Dual-stage discrete dynode detector
	Simultaneous pulse/analogue over two orders of magnitude
	Detector dead time of 35 ns
	< 0.2 ms switching between pulse and analogue
	Both pulse and analog signals are captured simultaneously
	Cradle design for easy exchange
	Transient data acquisition speed: > 3000 temporal data points/sec maximum
Minimum Dwell Time	10 µs
Dynamic Range	12 orders of magnitude with EDR, > 10 orders of magnitude without EDR
SOFTWARE	
System Operations	All analytical system operations (component optimization, methods development, calibration, analysis and reports) controlled using Syngistix for ICP-MS software
Automation	Syngistix software has automated system startup, shutdown, optimization and instrument tuning (including torch alignment)
Ease of Use	Scheduled user-defined alerts for routine maintenance
	Pre-set methods available
	Automated quality control checking
Analysis Options	Quantitative analysis: • External calibration • Additions (matrix matched) calibrations • Method of standard additions • Isotope ratios • Isotope dilutions Semi-quantitative analysis
Real-time Features	Real-time graphics with the ability to display transient and continuous signal profiles
	Real-time plotting of internal standard response in Results, plot exported with results
Graphing Feature	Ability to graphically overlay, add or subtract mass spectra and view composite signals
Method Setup	Computer-controlled automatic selection of cell gas when multiple gases or mixed mode are specified within a single method
	Computer-controlled cell gas flows and optimization
	Fast switching between cell gas modes (≥ 10 sec)
	Fast switching between Cold and Hot Plasma settings, allowing both modes to be run within a single analytical method
	Operation in a number of different modes and plasma conditions in a single method
	Pre-integrated correction equations with the option to delete and/or modify the equation being used
	Custom correction equations to accommodate for doubly-charged ions (half-mass correction) and other custom analytical needs
Auto-dilutors	Supports syringe-pump-based auto-dilution systems
	Supports auto-dilutions by both a global dilution factor and serial dilutions for samples out of range
Calibration Curve Fitting	The following curve-fitting options are available: • Linear least squares calibration fitting • Weighted linear least squares • Linear forced-through-zero least squares • Method of standard additions (matrix matched calibration) • Additions calibration
Quality Control	QC protocol limits on measured values: • Analyst to define when and how an action is taken • Ability to specify a second QC action
Data Reprocessing	Data reprocessing for: • Changes of calibration points • Internal standard points • Curve fit mode
	Reprocessing options: pulse, analog or dual detector modes

Hardware Specifications *continued...*

SOFTWARE	
Data Export	Single-click to export analytical data as a Microsoft® Excel® file
Data Integrity	All analytical raw data is retained and stored on the hard disk and encrypted
	Time and date printed on each sheet of data
	Mass calibration on six elements (Be, Co, In, Mg, Pb, U)
Support	Online help with quick steps to reference entire instrument user manual
Operating System	Microsoft® Windows® 10 64-bit operating system
Software Package Add-Ons	TIBCO Spotfire® Data Visualization Software
PERIPHERAL SYSTEM COMPATIBILITY	
Autosampler Capacity	Available autosamplers are capable of holding 150 or more 15 mL sample vessels
Autosampler Compatibility	PerkinElmer AS93/S10/S23/S25 autosamplers (fully integrated)
	CETAC ASX series autosamplers
	ESI SC, DX, and DXCi series autosamplers
	AIM autosamplers
High Throughput Sampling Compatibility	PerkinElmer HTS system
	ESI prepFAST systems
	ESI FAST system
	CETAC ASXpress system
	GE Niagara Plus CM system
Hyphenated Techniques	Compatible with a wide variety of hyphenated techniques. Please contact your local PerkinElmer sales representative for details.

** Assuming no misuse/damage caused by handling*

Site Description and Dimensions

ENVIRONMENTAL – LABORATORY			
Temperature	Optimal performance range		15 and 30 °C (59-86 °F)
	Rate of change		3 °C (5 °F)
Humidity	Range		20-80% (non-condensing)
UTILITIES			
Electrical	Consumption		Max 3200 VA (16 A max continuous current)
	Operating frequency		50/60 Hz
Cooling Water	Supply temperature		18 °C
	Supply rate		3.8 L/min (1.0 gpm) minimum 4.7 L/min (1.25 gpm) typical
	Pressure		@ 400-413 kPa (58-60 psig)
Argon Gas Supply	Purity requirements		≥ 99.996%
	Typical flow rate		15-20 L/min (typical)
	Pressure		@ 586-690 kPa (85-100 psig) min-max
Cell Gas Purity Requirements	Purity	Ammonia	≥ 99.999%
		Helium	≥ 99.9999%
		Methane	≥ 99.999%
		Oxygen	≥ 99.9999%
	Flow rate	Ammonia	0.6 mL/min (typical)
		Helium	5 mL/min (typical)
		Methane	0.5 mL/min (typical)
		Oxygen	0.5 mL/min (typical)
	Pressure		@ 69-103 kPa (10-15 psig)
System Exhaust Requirements	Port dimensions		9.2 cm (3.6 in.) ID
	Flow rate		110 to 150 CFM without instrument connected

Dimensions and Weight

No rear access required. All gas, exhaust, filter and electrical connections are on the front/side/top of the NexION 5000 ICP-MS. The instrument is designed to fit through all standard international door frames.

Parameter	Value
Width	115 cm (46 in.)
Height	74 cm (30 in.); with exhaust collar: 85 cm (33.5 in.)
Depth	74 cm (29.5 in.)
Weight	191 kg (420 lb.)

Typical Achievable Detection Limits (DLs) and Background Equivalent Concentrations (BECs) under Hot Plasma Conditions in a Class 1000 - 10 000 Cleanroom with NexION 5000 ICP-MS Cleanroom Model[1]

Element	BEC (ppt)	DL (ppt)
Li	0.018 (0.0001*)	0.028 (0.0004*)
Be	0.060	0.116
B	0.239	0.178
Na	0.108 (0.045*)	0.091 (0.033*)
Mg	0.026 (0.004*)	0.028 (0.008*)
Al	0.180 (0.005*)	0.049 (0.012*)
Si[c]	446.8	25.9
P[a]	1.39	2.86
S[a]	195.1	8.7
K	0.459 (0.021*)	0.158 (0.030*)
Ca	0.412 (0.050*)	0.085 (0.025*)
Sc[a]	0.008	0.022
Ti[a]	0.007	0.033
V[b]	0.004	0.009
Cr	0.340 (0.020*)	0.081 (0.011*)
Mn	0.015 (0.003*)	0.055 (0.006*
Fe	0.915 (0.052*)	0.173 (0.009*)
Co	0.026 (0.003*)	0.017 (0.008*)
Ni	0.433 (0.017*)	0.271 (0.029*)
Cu	0.081 (0.012*)	0.030 (0.010*)
Zn[b]	0.126	0.085
Ga	0.007	0.014
Ge[b]	0.294	0.071
As[a]	0.045	0.109
Se[a]	0.652	1.160

Element	BEC (ppt)	DL (ppt)
Sr	0.008	0.007
Mo[b]	0.033	0.038
Nb	0.012	0.015
Ru	0.097	0.040
Rh	0.073	0.162
Pd	0.033	0.055
Ag	0.064	0.107
Cd	0.027	0.058
In	0.008	0.014
Sn	0.012	0.075
Sb	0.077	0.050
Te	0.070	0.057
Ba	0.012	0.014
Hf	0.025	0.017
Ta	0.010	0.006
Re	0.017	0.045
Ir	0.587	0.047
Au	0.103	0.062
Tl	0.007	0.017
Bi	0.011	0.004
W	0.042	0.053
Pt	0.271	0.268
Pb	0.014	0.031
Th	0.016	0.028
U	0.019	0.016

* Data acquired under Cold Plasma conditions

[a] Reaction with oxygen

[b] Reaction with ammonia

[c] Reaction with hydrogen + ammonia

Specific Criteria Which Will Be Met During Installation

The summary below describes typical specifications which are guaranteed at installation. Please refer to Ref 2 for a comprehensive description.

Parameter	Element/Value	Guaranteed Specification at Installation	
		NexION 5000 ICP-MS Non-Cleanroom Model	NexION 5000 ICP-MS Cleanroom Model
Sensitivity	^{9}Be	> 15 Mcps/(mg/L)	> 15 Mcps/(mg/L)
	^{115}In	> 500 Mcps/(mg/L)	> 500 Mcps/(mg/L)
	^{238}U	> 300 Mcps/(mg/L)	> 300 Mcps/(mg/L)
	^{56}Fe	> 250 Mcps/(mg/L)[a]	> 250 Mcps/(mg/L)[a]
Detection Limit (ng.L^{-1})	^{9}Be	< 0.5	< 0.5
	^{31}P	< 20	< 20
	^{32}S*	–	< 50
	^{52}Cr	< 1.5 (Reaction mode, with ammonia)	< 0.7 (Reaction mode, with ammonia in a cleanroom)
	^{56}Fe[b]	< 1.5 (Reaction mode, with ammonia)	< 0.7 (Reaction mode, with ammonia in a cleanroom)
	^{115}In	< 0.1	< 0.1
	^{238}U	< 0.1	< 0.1
Oxides (%)	CeO/Ce	< 3	< 3
Background (cps)+	220.5	1.5 cps	1.5 cps
Short-term Precision	10 min	< 3 %	< 3 %
Long-term Stability	4 hrs	< 4 % (cycling between Standard and Reaction modes)	< 4 % (cycling between Standard and Reaction modes)

* Denotes measured in the factory only

[a] Reaction mode with ammonia

[b] Depends upon the cleanliness of the laboratory and the quality of the chemicals being used

+ Background signals are obtained under identical operating conditions with no changes to voltages during blank and Background signal acquisitions

References

1. Pruszkowski E., "Characterization of Ultrapure Water Using NexION 5000 ICP-MS", PerkinElmer Application Note, 2020.
2. NexION 5000 Multi-Quadrupole ICP-MS Installation Specifications, PerkinElmer, 2021.

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