The Performance Characteristics of Axial and Radial View in ICP-OES Analysis

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ABSTRACT

ICP-OES is a well-established technique for the analysis of trace elements in a variety of matrices. However, one of the greatest challenges when analyzing samples by ICP-OES is achieving a balance between matrix tolerance, sensitivity and dynamic range.

Typically, for samples that require high sensitivity an axially viewed plasma is used for analysis. The limitations of this are low matrix tolerance and dynamic range resulting from physical effects and the configuration of the plasma torch and interface. Conversely, for high matrix tolerance a radially viewed plasma is used; in this configuration the sensitivity is reduced but matrix tolerance and dynamic range can be improved.

There has been great success in combining both axial and radial views in dual view instruments. This enables both axial and radial measurements to be made during a sample analysis. However, dual plasma interface and torch configurations tend to be based on axial systems and therefore can have the inherent drawbacks associated with axially configured ICP-OES instruments.

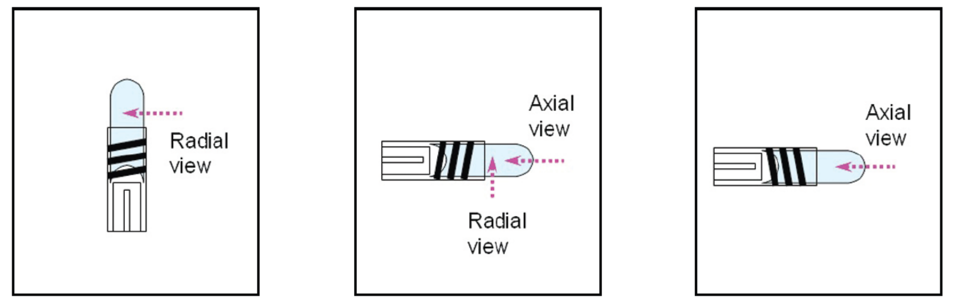
This poster will investigate recent advances in instrument design and plasma interface configurations and examples of key figures of merit such as sensitivity, dynamic range, matrix tolerance and interference reduction will be used to make the assessment.

INTRODUCTION

ICP-OES instruments can be configured as radial, axial or dual view. In the radial configuration, the plasma is viewed from the side, while in the axial configuration; the plasma is viewed end-on (along the length of the plasma) and in the dual view configuration, the plasma can be viewed in either the radial or axial orientation (see Figure 1).

The dedicated radial plasma view is accepted as the configuration with the highest tolerance for high dissolved solids and other complex matrices. This is due to lower levels of matrix interferences in the region of the plasma that is viewed and that the plasma does not deposit material on an interface. The radial plasma view offers less sensitivity than the axial view, however, it is preferable for analyzing difficult samples such as organics or very high dissolved solid matrices, as the plasma viewing position can be optimized to reduce background emissions. The axially viewed plasma configuration offers greater sensitivity, than radial configuration, but has higher susceptibility to matrix interferences, as the entire plasma is viewed, increasing the quantity of light observed from both analyte and background emissions.

However, combining an axial plasma view with an automatically switchable radial plasma view in the dual plasma view configuration produces a sensitive, versatile instrument with the ability to handle a wide range of samples with complex matrices. The switching between the two plasma views is carried out by the fore-optics.



a) Radial torch b) Dual view (Duo) torch c) Axial only torch

Figure 1. Plasma viewing options in ICP-OES instruments.

Optical purge design

Gases common in air, such as oxygen and carbon dioxide, can absorb much of the intensity of UV radiation (< 190 nm) therefore in order to enable the sensitive analysis of analytes in this wavelength region, the use of a purge system in the polychromator, fore-optics and the plasma interface is critical.

The Thermo Scientific™ iCAP™ 7000 Plus Series ICP-OES Analyzer uses a unique distributed gas purge system which purges the polychromator uniformly and is integral to the design of the fore-optics and plasma interface. The purge system can be configured to use either argon or nitrogen gas and was developed using Computational Fluid Dynamics (CFD) techniques, in order to examine and optimize the purge gas flow, thermal distribution, gradients and stability. The compact design and low volume optical tank ensures quick and efficient purging using minimum gas flows.

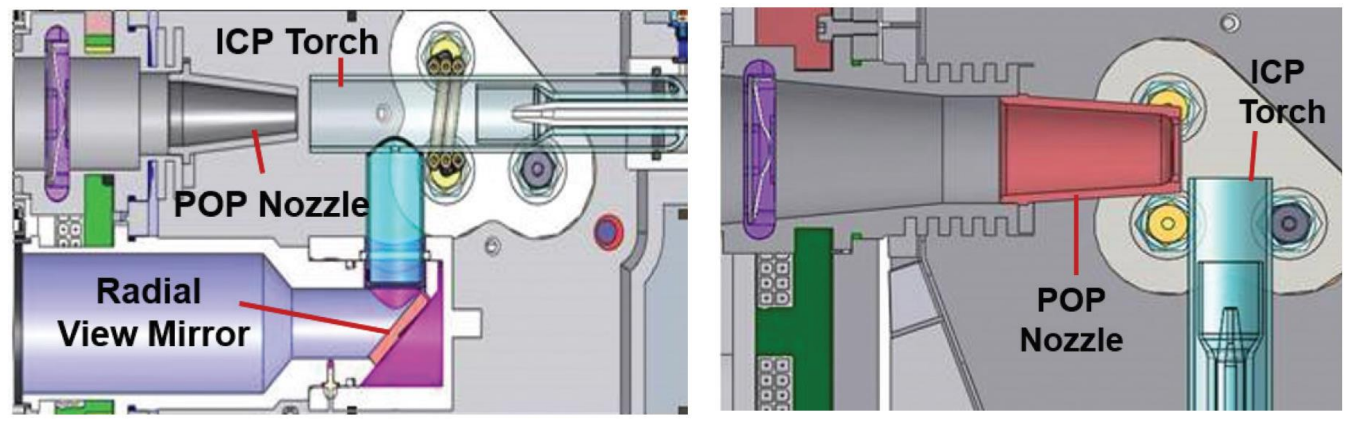


Figure 2. Schematic of the POP tubes for Duo (above) and Radial (below) instruments.

The purge gas exits the optical system through the POP tube, and in doing so removes constituents in the plasma interface that may otherwise absorb the UV light intensity, this is shown in Figure 3. Additionally, the POP tube purge gas flow provides a counter flow of argon to occlude environmental factors, such as dust and soot, removing the interferences they cause. Some other ICP-OES designs are required to use additional gas flows such as a shear gas, to optimize their plasma interface. This can increase instrument running costs, interfere with light transmission or requires expensive accessories such as air compressors to be purchased with the instrument.

An alternative radial POP interface for the dual view iCAP 7000 Plus Series ICP-OES Analyzer has been developed. This replaces a simple quartz window with a ceramic interface (Figure 3). The radial POP interface has a light channel which only allows direct light from the plasma to pass through to the polychromator. This improves long term stability of the analysis. Due to the purge gas directed through the POP interface UV light transmission is improved (Figure 4).

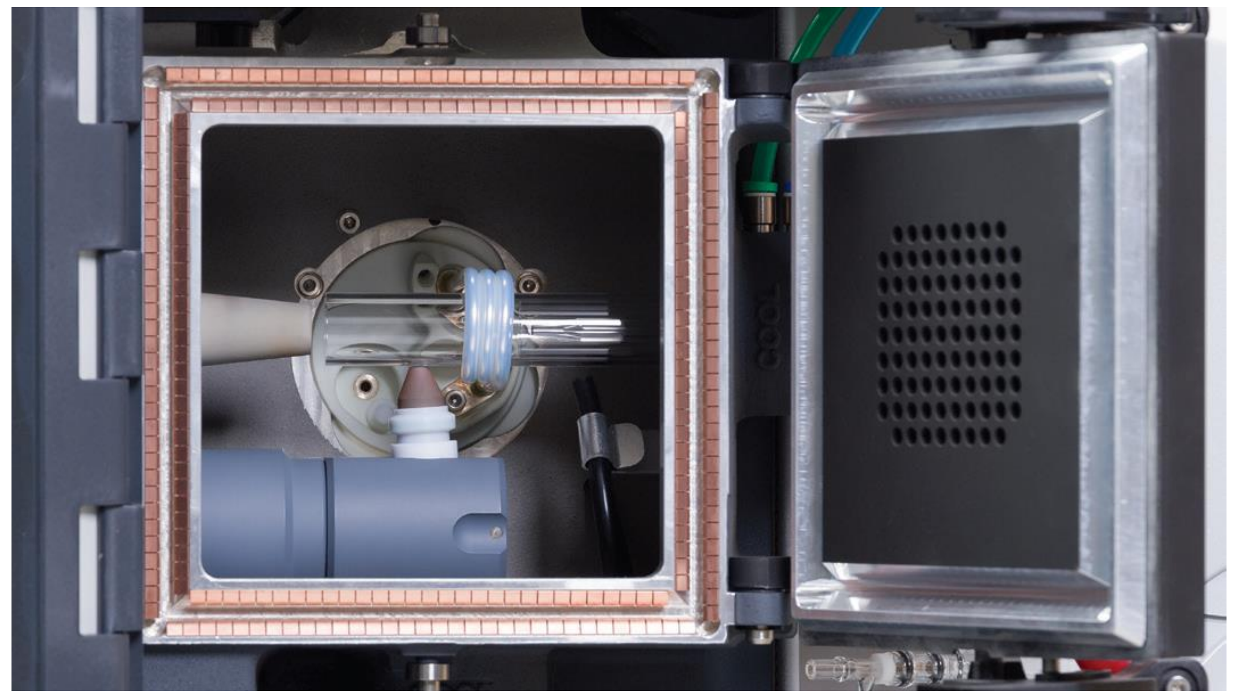


Figure 3. The torch box of a dual view iCAP 7000 Plus Series ICP-OES, showing the two POP plasma interfaces .

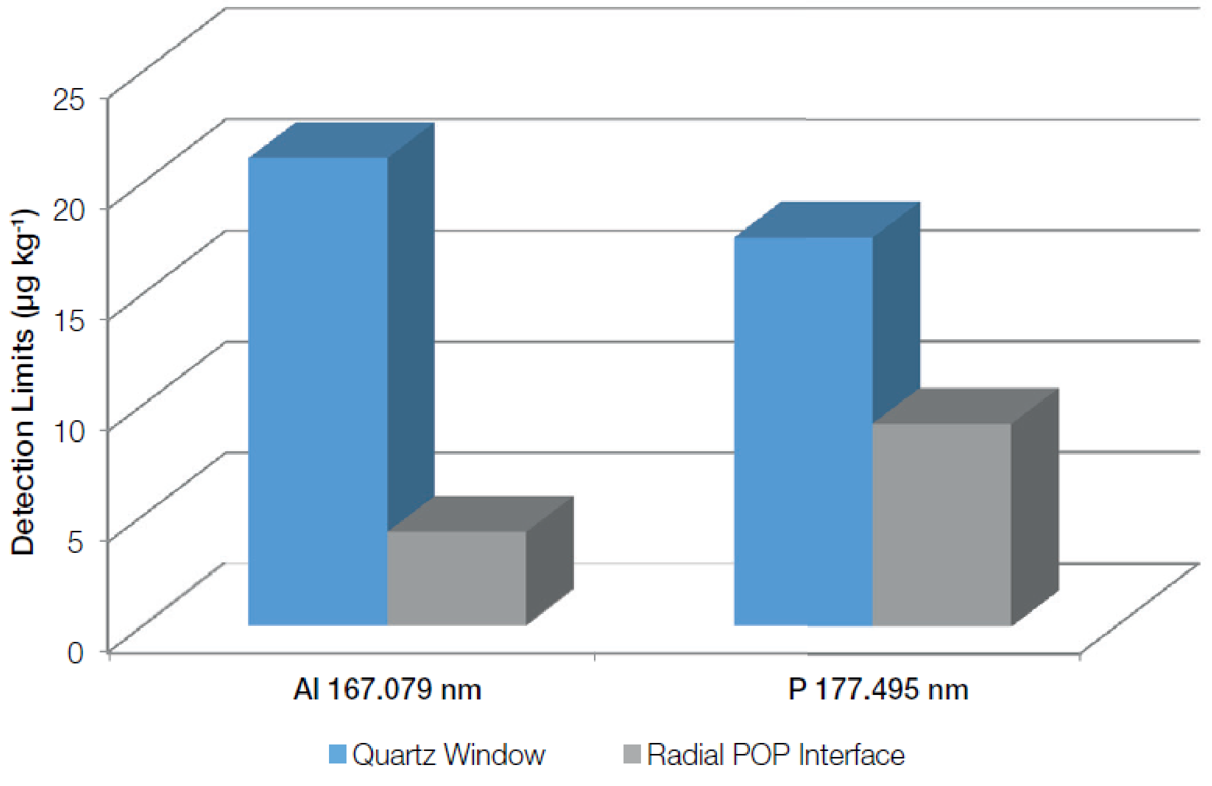


Figure 4. Improved detection limits of Al 167.079 nm and P 177.495 nm in the radial view of a dual view iCAP 7000 Plus Series ICP-OES Analyzer.

ICP-OES analysis of high sample matrices

To demonstrate its suitability for a wide range of applications, the Thermo Scientific™ iCAP™ 7400 ICP-OES Radial instrument was selected to analyze a simple aqueous, an organic (oil) and a more challenging high dissolved solids (salt) sample over a typical workday's time span of 12 hours. Different sample introduction set ups were used for the analyses of the differing sample types, including the use of an ESI pergo Argon Nebulizer Gas Humidifier for the analysis of the salt solution. Method parameters and instrumentation can be found in Table 1. The iCAP 7400 ICP-OES Radial was used in conjunction with a Teledyne CETAC ASX-560 Autosampler for all analyses.

Three different multi-element solutions were prepared for this analysis:
The aqueous stability test solution (50 µg·kg-1 of Be, Cd, Mn and 5 mg·kg-1 of Al, Ba, Cu, Fe, K, P and Zn) was prepared from single element standards (1000 mg·kg-1, SPEX CertiPrep Group, Metuchen, US) in an acidic matrix (2% HNO3, Fisher Chemical, Loughborough, UK),

The organics stability test solution (1 mg·kg-1 of all elements) was prepared from Conostan® S-21+K oil standard (100 mg·kg-1, SCP SCIENCE, Baie-D'Urfé, Canada) in Conostan® PremiSolv™ ICP Solvent and,

The salt stability test solution was prepared with the same elements and the same concentrations as the aqueous stability test solution, but in a different matrix (2% HNO3 and 8% Na, prepared from NaCl 99.99 Suprapur®, Merck KGaA, Darmstadt, Germany).

Parameter	Setting		
	Aqueous Matrix	Organic Matrix	Salt Matrix
Pump Tubing (Standard Pump)	Sample Tygon® orange/white Drain Tygon® white/white	Sample SolventFlex orange/white Drain SolventFlex white/white	Sample Tygon® orange/white Drain Tygon® white/white
Pump Speed	40 rpm	40 rpm	50 rpm
Nebulizer	Concentric glass	V-groove	PEEK Mira Mist®
Nebulizer Gas Flow	0.55 $L{\cdot}min^{-1}$	0.4 $L{\cdot}min^{-1}$	0.55 $L{\cdot}min^{-1}$
Spray Chamber	Cyclonic	Baffled cyclonic	Baffled cyclonic
Auxiliary Gas Flow	0.5 $L{\cdot}min^{-1}$	1.5 $L{\cdot}min^{-1}$	0.6 $L{\cdot}min^{-1}$
Coolant Gas Flow	12 $L{\cdot}min^{-1}$	12 $L{\cdot}min^{-1}$	14 $L{\cdot}min^{-1}$
Center Tube	2 mm	1 mm	2 mm
RF Power	1150 W	1150 W	1250 W
Exposure Time	UV 15 s, Vis 5 s	UV 15 s, Vis 5 s	UV 15 s, Vis 5 s

Table 1. Method parameters for the three different matrices.

All results were normalized to the intensity of the first sample and are referred to as the recovery in percentage. No drift corrections via an internal standard were performed. Highly stable performance of the measurement is demonstrated, with excellent long term stability was achieved over a time span of 12 hours with all elements having recoveries within ±10%, and most of the analytes, especially for the aqueous and the salt sample, showing recoveries even better than ±5%. The average RSD of the replicates is ≤1% for most of the analytes, only a few element lines show slightly higher values of up to 1.3% (Table 2).

Element and wavelength (nm)	Aqueous matrix		Organic matrix		Salt matrix	
	Average replicates RSD (%)	Recovery range (%)	Average replicates RSD (%)	Recovery range (%)	Average replicates RSD (%)	Recovery range (%)
Ag 338.289	-	-	0.6	93.0 - 100.0	-	-
Al 396.152	0.5	96.2 - 110.3	0.5	94.4 - 100.0	0.7	95.2 - 101.2
Ba 455.403	1.0	94.7 - 100.0	0.4	93.0 - 100.3	0.5	98.2 - 103.9
Be 313.042	0.6	96.4 - 100.5	-	-	0.5	96.0 - 102.4
Ca 396.847	-	-	0.3	94.2 - 100.0	-	-
Cd 226.502	1.1	95.3 - 100.2	0.1	95.7 - 100.6	0.8	97.3 - 103.2
Cu 223.008	0.2	95.5 - 100.0	0.3	95.8 - 100.0	0.4	95.9 - 101.7
Fe 238.204	0.5	95.5 - 100.2	0.3	94.1 - 100.0	0.5	96.4 - 103.0
K 766.490	0.6	96.0 - 100.0	1.3	92.5 - 100.0	1.3	96.9 - 102.9
Mg 280.270	-	-	0.3	93.2 - 100.0	-	-
Mn 257.610	1.2	93.4 - 100.0	0.3	92.8 - 100.4	0.9	97.3 - 104.2
Mo 202.030	-	-	0.2	97.1 - 100.4	-	-
Ni 221.647	-	-	0.2	95.6 - 100.5	-	-
P 177.495	0.2	98.3 - 100.0	0.3	98.0 - 100.0	0.4	96.6 - 101.9
Si 212.412	-	-	0.4	98.9 - 101.6	-	-
Sn 189.989	-	-	0.5	95.8 - 100.6	-	-
Ti 334.941	-	-	0.3	93.0 - 100.0	-	-
V 311.071	-	-	0.3	93.8 - 100.0	-	-
Zn 213.856	0.2	96.0 - 100.0	0.1	96.0 - 100.0	0.3	95.8 - 101.5

Table 2. Average RSDs of replicates and recovery range for stated element wavelengths in %. As described in sample preparation, the different matrices contained different sets of elements.

CONCLUSIONS

The Thermo Scientific iCAP 7000 Plus Series ICP-OES Analyzer has a range of different torch and interface configurations. Recent optimization of these configurations have enabled greater sensitivity in the UV region for the radial view of a dual view system. In addition the radial view system demonstrates excellent stability of the analytical signal over the period of a typical analytical run (240 samples), similar stability can also be achieved on a dual view system. With the need for regular recalibration minimized and sample re-analysis decreased, a higher sample throughput is achieved. This results in a reduced cost per analysis.

REFERENCES

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SP43438 Thermo Scientific iCAP 7000 Plus Series ICP-OES Purged optical path plasma interfaces for improved sensitivity and stability
TN43259 Highly stable performance of the Thermo Scientific iCAP 7000 Plus Series ICP-OES Radial for aqueous, organic and high dissolved solids sample matrices

TRADEMARKS/LICENSING

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