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Technical Bulletin

ICP-MS (Inductively Coupled Plasma – Mass Spectrometry) and ICP-AES (Inductively Coupled Plasma – Atomic Emission Spectroscopy): What is the difference and which one to use?

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Introduction

Lakehead University Instrument Laboratory recently acquired a new ICP-MS. The instrument is used for determining trace element concentrations in a sample. The ICP-MS can measure most of the elements in the periodic table; some to even parts per trillion range.

Although the technology for ICP-MS has been around for over 20 years, it is not as common as ICP-AES. The system itself is more expensive and complex to operate than the ICP-AES, although depending on the nature of your research the features may outweigh the costs. The instrument has the stigma of being difficult to use and requires a skilled person to operate it (Thomas, 2001). While the technology is constantly improving, Lakehead University does have skilled operators on site for the ICP-MS, making it an important inorganic analytical tool for both research and industry.

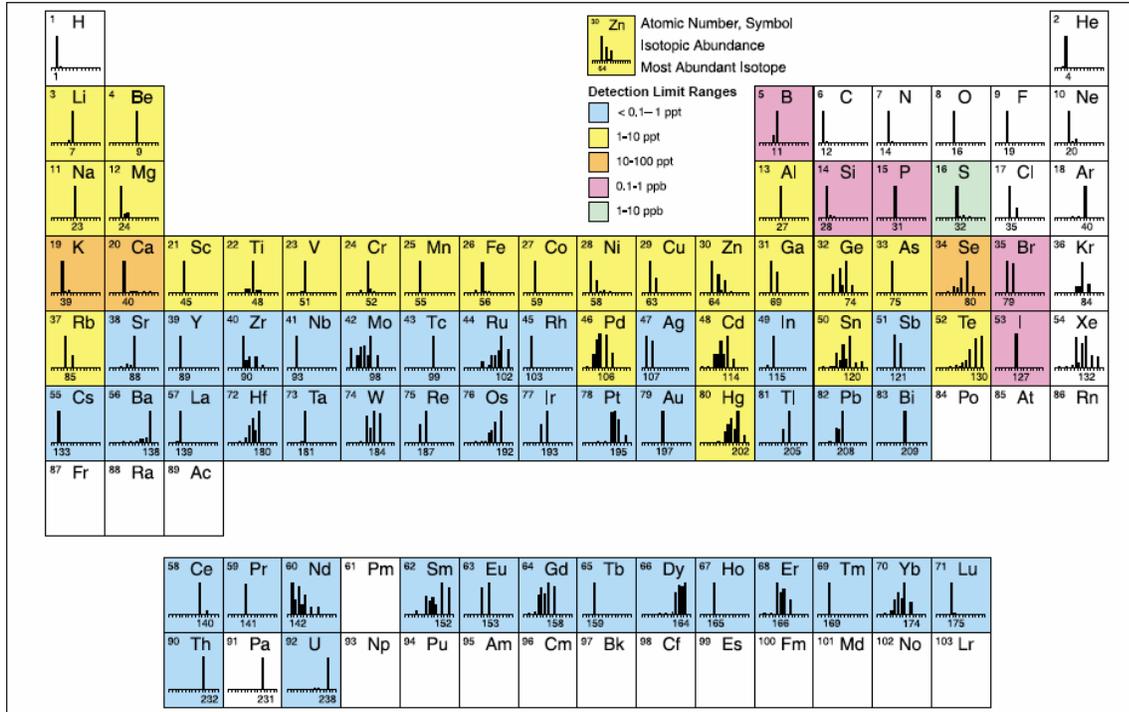


Figure 1: shows the detection limits for elements that can be measured by ICP-MS (Photo from Wolf, 2005 courtesy of Perkin Elmer Inc., 2001)

Uses of ICP

- Geological: major, minor and trace element concentrations for prospecting, determining origins of rocks, marine geochemistry
- Environmental: soil and sediment geochemistry, trace elements in water samples
- Biological and clinical: trace elements in animal tissues, Al in blood, Cu in brain tissue
- Agricultural: trace metals in soils, fertilizers, feed, body fluids and animal tissues (Boss and Fredeen, n.d.)

Basic Introduction to ICP-MS

Samples are digested in acid and introduced to the instrument through a nebulizer which functions to convert the liquid sample to an aerosol. The aerosol is introduced into a very hot, RF generated argon plasma which serves as an ionization source. The plasma's function is to heat the molecules until they are broken apart into elements. These elements continue to absorb heat and eventually release an electron, forming a charged ion. The ions are then pumped through a vacuum system and are consequently focused by an electric field into the quadrupole mass spectrometer. Ions are separated from each other by mass to charge ratio by the quadrupole mass selective detector.

The quadrupole will only allow one particular mass to charge ratio past it at a time because a voltage is set which causes unfit ions to be ejected from it. The quadrupole changes its voltage very quickly and therefore is able to have a quick scan speed (Perkin Elmer, 2010). The ions which are separated by the quadrupole then move to the detector and, through the use of standards, are quantified (Wolf, 2005).

The ICP-MS is also able to distinguish between isotopes of the same element. It is due to these ratios that several analytical parameters can be determined, including useful ones such as provenance.

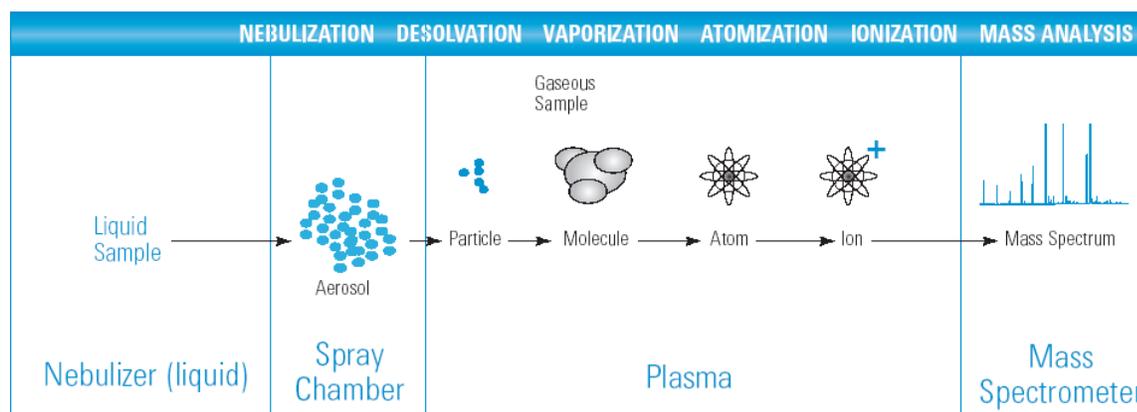


Figure 2: Schematic diagram of what occurs to your sample with ICP-MS (Photo from Agilent Technologies, 2005).

Differences between ICP-MS and ICP-AES

The main difference between the two systems lies in how they measure elemental concentrations. In ICP-AES, high temperatures of the plasma excite elemental or ionic species to a higher energy level. When these elements return to their original ground state, they emit a characteristic radiation.

Light emitted from this process has a specific wavelength which is used to determine elemental concentrations and are quantified using the help of standards. Since all the elements are being excited by the heat source at the same time, they can also emit light at the same time. Significant overlap may occur if there are many elements that are emitting light with similar wavelengths (Boss and Fredeen, n.d.).

This method of detection is different than the ICP-MS which measures the mass to charge ratio of ions from the plasma by the quadrupole.

ICP-MS also suffers from interferences, although many can be corrected mathematically and more easily than the ICP-AES. Polyatomic ions such as oxides are one of the most common

types of interferences associated with ICP-MS. An example of this occurs when argon from the plasma and chlorine from either the sample itself or the sample matrix ($40\text{Ar}35\text{Cl}$) overlaps with arsenic (75As) which is an important element requiring measurement in environmental samples. A high plasma temperature can help reduce this impact, as well as the use of the CeO^+/Ce^+ ratio as cerium has one of the highest oxide formation rates. If the ratio is low, at around 2-3%, then one can gather that most of the oxides did dissociate (Agilent, 2005). Lakehead University's ELAN DRC-e is designed with specialized equipment using reaction gas to remove these interferences and prevent them from reforming before reaching the detector.

Both systems can perform semi-quantitative or quantitative results. In general, ICP-AES is better suited for use with samples that have many ions with a lower atomic weight, such as the major elements and the lighter metals. ICP-MS is better suited for use with samples that have many ions with a higher atomic weight, such as trace metals and rare earth elements but not for major elements (Lui, 2002).

ICP-MS has lower and better detection limits than ICP-AES and so should be used when trying to determine trace element concentrations in your sample (Exova, n.d.). It is also useful in isotopic studies as it can be used to determine concentrations of individual isotopes of an element (Perkin Elmer, 2010). ICP-MS also has an upper limit for Total Dissolved Solids (TDS) at 2000 ppm whereas ICP-AES has a higher TDS tolerance. This fact should be taken into account before sample submittal (Agilent Technologies, 2005).

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- Wolf, R. 2005. What is ICP-MS? ... and more importantly, what can it do? <http://minerals.cr.usgs.gov/icpms/intro.html>

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