A Hyphenated Technique On Inductively Coupled Plasma Mass Spectrometry

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Abstract: **Accurate determination of elements in various kinds of samples is essential for many areas, including environmental science, medicine, as well as industry. Inductively coupled plasma mass spectrometry that is highly sensitive and capable of the determination of a range of metals. In trace elemental analysis, the method has advantages of high speed, precision, and sensitivity compared to other elemental analytical techniques. The next generation of ICP-MS is Next ION 300 ICP-MS instrument are 3 modes of operations (standard, collision, & reaction) various calibration approaches can be used to perform accurate quantitative measurements by ICP-MS. It is important to give an overview of the most common applications currently being carried out by ICP-MS and its sampling accessories, to give a flavour of the different industries and markets that are benefiting from the techniques enormous potential.**

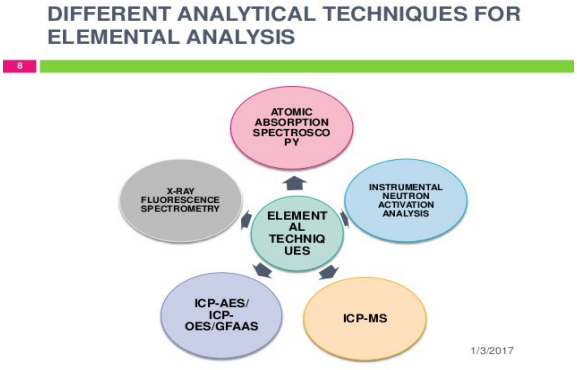
Keywords: **ICP-MS, Quantitative, Sensitive, Analytical techniques, Elemental Mass Spectrometry.**

I. INTRODUCTION

Since its commercial introduction in 1983, inductively coupled plasma-mass spectrometry (ICP-MS) evolved as one of the techniques in the field of elemental (ultra) trace analysis of metals & metalloids in numerous matrices. Give its unique properties such as,

1. High Sensitivity
2. Multi-element capabilities
3. A wide linear range and
4. The possibility to obtain isotopic information

The purpose of elemental analysis is to determine quantity of particular element within a molecule or material.



Inductively coupled plasma mass spectrometry is a powerful tool enabling multi-elemental analysis of numerous matrices with sensitivity and good precision.

Today, ICP-MS is routinely developed in diverse fields such as geochemistry, environmental, and life sciences, industries, forensic science & archaeology.

For nearly, 30 years ICP-MS has been gaining favour with laboratories around the world as the instrument of choice for performing trace metal analysis.

ICP-MS is an efficient and highly sensitive tool for target element oriented discoveries of relevant and unknown compounds.

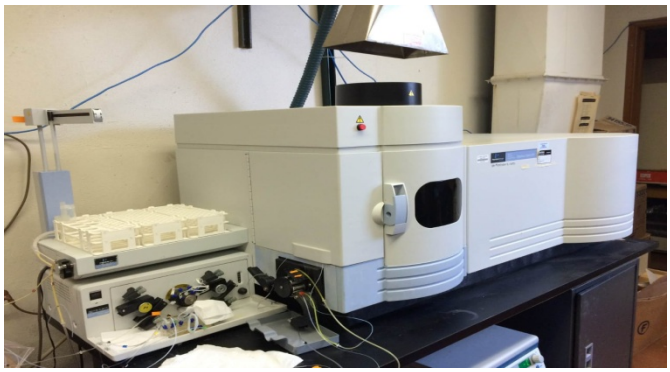
ICP-MS is a hyphenated to separation techniques for species – specific detection & identification.

It is important to emphasize that because of the enormous interest in the technique, Most of the ICP-MS instrument companies have very active R&D programs in place, in order to get an edge in a very competitive place.

Inductively coupled plasma mass spectrometry (ICP-MS) not only offers extremely low detection limits in the sub parts per trillion (ppt) ranges, but also enables quantification at the high parts per million (ppm) level.

This technique capability makes the technique very alternative compared to other price material technique electro thermal atomization (ETA) which is limited to determination at the trace level, or flame atomic absorption (FAA) and inductively coupled plasma mass optical emission spectroscopy (ICP-OES), which are traditionally used for the detection higher concentrations.

ICP-MS is undoubtedly the fast growing trace element technique available today. Since its commercialization in 1983, approximately 5000 systems have been installed world-wide carrying out many varied & diverse applications.



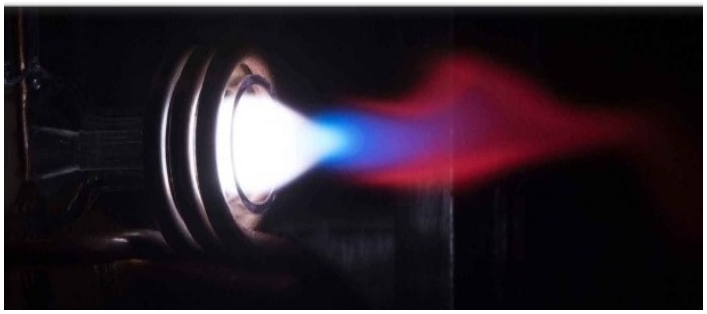
ICP-MS systems are powerful analytical instrument to obtained the best quality of data for this instruments, sample preparations and introduction must be performed with care and also data acquisition and processing should be thoroughly scrutinized.

Compared to atomic absorption spectrometry, ICP-MS has a greater speed, precision and sensitivity. However, compared with types of mass spectrometry such as thermal ionization mass spectrometry, (TIMS) and glow discharge mass spectrometry (GD-MS), ICP-MS many interfering species argon from the plasma, compounded gases of air that leak through the cone orifices from the glass ware contamination and the cones.

It can perform qualitative, semi-quantitative and quantitative analysis.

What is inductively coupled plasma?

Inductively coupled plasma is plasma that contains a sufficient concentration of ions and electrons to make the gas electrically conductive. The plasmas used in spectrochemical analysis are essentially electrically neutral, with each positive charge on an ion balanced by a free electron. In these plasmas the positive ions are almost all singly charged and there are few negative ions, so there are nearly equal amounts of ions and electrons in each unit volume of plasma. Inductively coupled plasma (ICP) for spectrometry is sustained in a torch that consists of three concentric tubes, usually made of quartz. The end of this torch is placed inside an induction coil supplied with a radiofrequency electric current [5]. A flow of argon gas (usually 14 to 18 liters per minute) is introduced between the two outermost tubes of the torch and an electric spark is applied for a short time to introduce free electrons into the gas stream. These electrons interact with the radio-frequency magnetic field of the induction coil and are accelerated first in one direction, then the other, as the field changes at high frequency. The accelerated electrons collide with argon atoms, and sometimes a collision causes an argon atom to part with one of its electrons. The released electron is in turn accelerated by the rapidly changing magnetic field. The process continues until the rate of release of new electrons in collisions is balanced by the rate of recombination of electrons with argon ions (atoms that have lost an electron). This produces a 'fireball' that consists mostly of argon atoms with a rather small fraction of free electrons and argon ions. The temperature of the plasma is very high, of the order of 10,000 K5. The ICP can be retained in the quartz torch because the flow of gas between the two outermost tubes keeps the plasma away from the walls of the torch. A second flow of argon (around 1 liter per minute) is usually introduced between the central tube and the intermediate tube to keep the plasma away from the end of the central tube. A third flow (again usually around 1 liter per minute) of gas is introduced into the central tube of the torch. This gas flow passes through the centre of the plasma, where it forms a channel that is cooler than the surrounding plasma but still much hotter than a chemical flame. Samples to be analyzed are introduced into this central channel, usually as a mist of liquid formed by passing the liquid sample into a nebulizer6. As a droplet of nebulised sample enters the central channel of the ICP, it evaporates and any solids that were dissolved in the liquid vaporize and then break down into atoms. At the temperatures prevailing in the plasma a significant proportion of the atoms of many chemical elements are ionized, each atom losing its most loosely bound electron to form as singly charged ion.

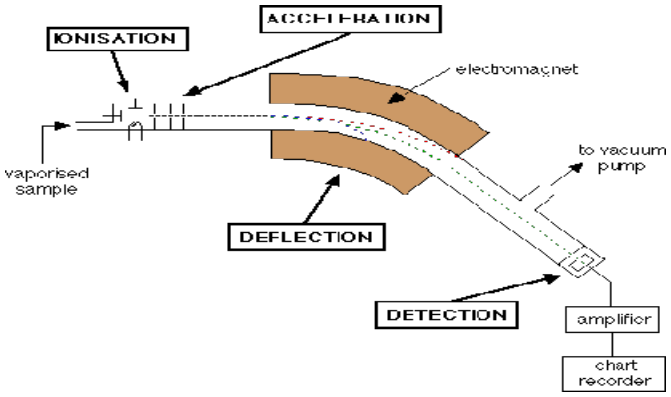


What is Mass Spectrometry?

- It is the most accurate method for determination of molecular mass of a compound and its elemental composition.
- It can provide concurring that molecular of an organic and inorganic compounds.
- The mass spectrometer is an instrument in which substance in gaseous or vapour state is bombarded with beam of electrons(70 ev) to form a positively charged ions(cations) which are sorted to mass to charge ratio to record their masses and relative abundance.
- All mass spectrometers consists of three parts.
  - ✓ Ion Source
  - ✓ Mass Analyser
  - ✓ Detector System

Stages within the mass Spectrometry:-

1. Producing ions from the sample.
2. Separating ions of differing masses.
3. Detecting the number ions of each mass produced.
4. Collecting the data and generating the mass spectrum.

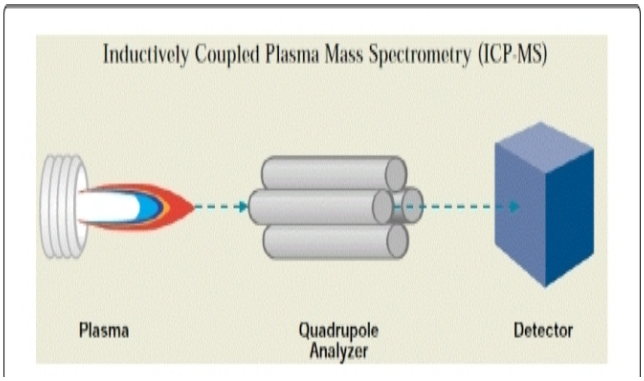


FEATURES OF THE MAIN QUALIFICATION APPROACHES USED IN ICP-MS

Qualification mode	Advantages	Limitations
semi-quantitative	1) rapid for screening purposes 2) provides semi-quantitative data 3) provides information on spectral interferences	— poor accuracy — high uncertainty — does not provide traceability of results
external calibration	1) assures high accuracy 2) lowest possible detection limits 3) possibility to use multi-elements standards 4) traceability to high purity standards vulnerable to matrix effects	— vulnerable to matrix effects
external calibration with internal standard (IS)	a) assure high accuracy b) lowest possible detection limits c) possible to use multi-elements standards d) traceability to high purity standards e) robust for instrumental fluctuations f) the ratio of analyte signal intensity to that of IS is measured	— limited to the selection of IS for given element: mass of isotope, primary ionization potential and chemical 'behaviour' as close as possible to the ionization potential of the analyte.
isotopic ratio measurements	a. robust for instrument fluctuation and matrix effect b. robust for the poor recovery of analytical procedure	— requires the high isotopic resolutions of instrument — not useful for monoisotopic elements — isotopic equilibrium is required — at least two isotopes should be free of spectral interferences
isotopic dilution	1) high accuracy; lowest uncertainty 2) interferences free; the analyte acts as its own IS 3) useful in trace elements determination and in speciation	

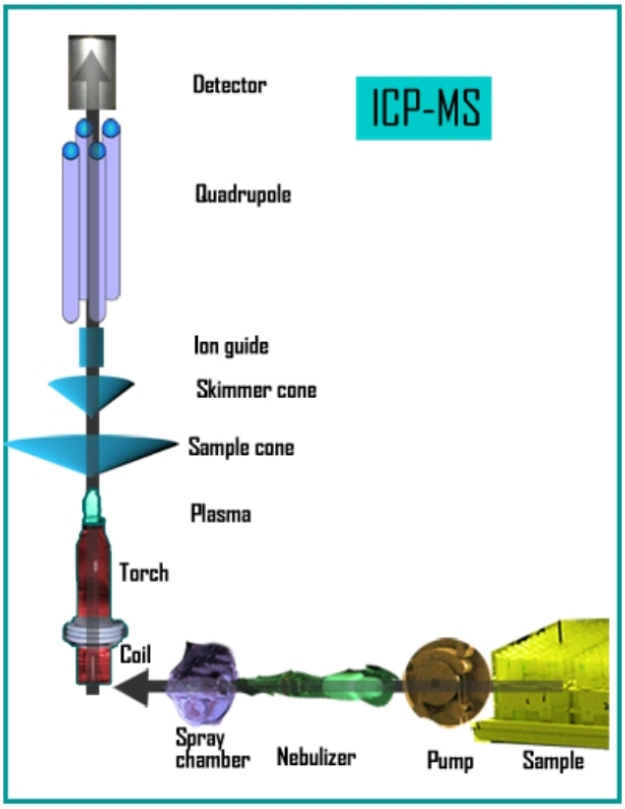
II. PRINCIPLE OF ICP-MS

- Liquid samples to form aerosol in nebuliser.
- Introduction of argon to the IP torch, which located of a radio frequency coil for energy supply.
- Radio frequency field causes collisions of argon atoms, generating a high energy plasma
- Sample aerosol decomposes in plasma (6000 – 10000k) to form analyse atoms which are spontaneously ionised.
- Ions extracted from the plasma into mass spectrometry region.



III. INSTRUMENTATION OF ICP-MS

INSTRUMENT DESCRIPTION AND THEORY ICP technology was built upon the same principles used in atomic emission spectrometry. Samples are decomposed to neutral elements in high temperature argon plasma and analyzed based on their mass to charge ratios.



IV. INSTRUMENTATION AND WORKING OF ICP-MS

Sample Introduction The first step in analysis is the introduction of the sample. This has been achieved in ICPMS through a variety of means. ICP-MS spectrometers can accept solid as well as liquid samples. Solid samples are introduced into the ICP by way of a laser ablation system which can usually be purchased as an accessory. Aqueous samples are introduced by way of a nebulizer which aspirates the sample with high velocity argon, forming a fine mist. The aerosol then passes into a spray chamber where larger droplets are removed via a drain (fig 2). The most common method is the use of a nebulizer. This is a device which converts liquids into an aerosol, and that aerosol can then be swept into the plasma to create the ions. Nebulizers work best with simple liquid samples (i.e. solutions). However, there have been instances of their use with more complex materials like slurry. Many varieties of nebulizers have been coupled to ICP-MS, which includes pneumatic, cross-flow, Babington, ultrasonic, and desolating types. The aerosol generated is often treated to limit it to only smallest droplets, commonly by means of a double pass or cyclonic spray chamber. Use of auto samplers makes this easier and faster. Less commonly, the laser ablation has been used as a means of sample introduction. In this method, a laser is focused on the sample and creates a plume of ablated material which can be swept into the plasma. This is particularly useful for solid samples, though can be difficult to create standards for leading the challenges in quantitative analysis. Other methods of sample introduction are also utilized. Electro thermal vaporization (ETV) and in torch vaporization (ITV) hot surfaces (graphite or metal, generally) are used to vaporize samples for introduction. These can use very small amounts of liquids, solids, or slurries. Other methods like vapour generation are also known.

Figure 1:- Generation of aerosol by nebulizer.

Liquid is converted into a fine aerosol by pneumatic action of a flow of argon gas (~1L/min) smashing the liquid into tiny droplets.

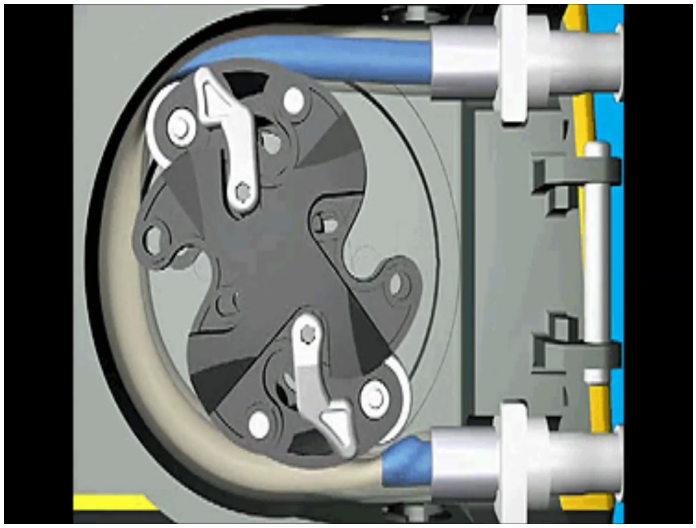
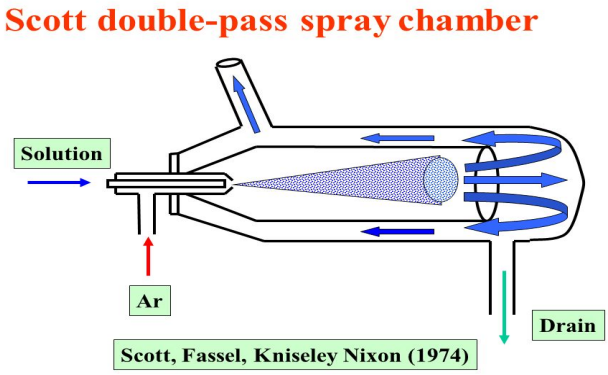


Figure 2:- Peristaltic Pump

Peristaltic Pump: Ensures constant flow of liquid irrespective of differences in viscosity between samples, standards and blanks. Sample pumped at 1ml/min.

Scott double-pass spray chamber:-

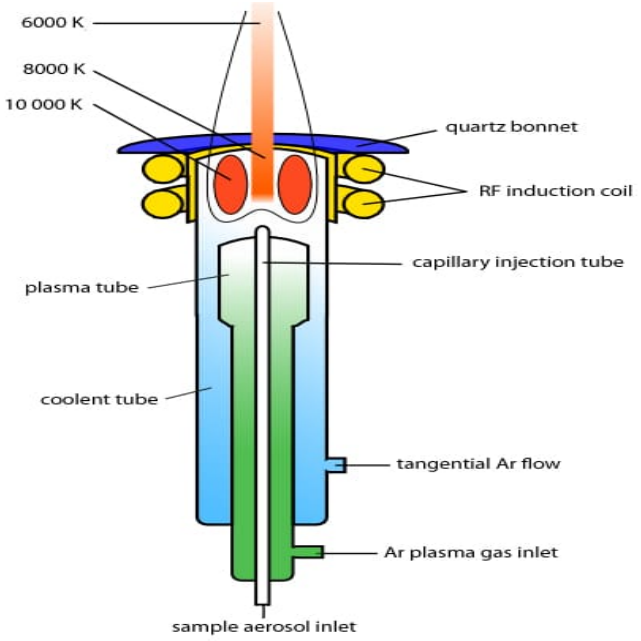
Spray chamber only allows small droplets (<10µm) to enter the plasma. Large droplets having higher momentum collide with wall of spray chamber, get condensed and eventually fall out by gravity through the drain.



Argon Plasma/Sample Ionization:-

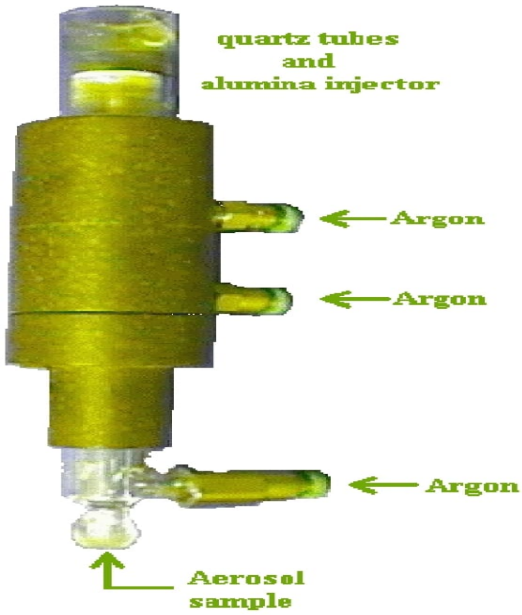
Once the sample passes through the nebulizer and is partially de solvated, the aerosol moves into the torch body and is mixed with more argon gas. A coupling coil is used to transmit radio frequency to the heated argon gas, producing an argon plasma "flame" located at the torch. The hot plasma removes any remaining solvent and causes sample atomization followed by ionization. In addition to being ionized, sample atoms are excited in the hot plasma, a phenomenon which is used in ICP-atomic emission spectroscopy. Shown to the right is an ICP torch. The aerosol

moves into the bottom of the torch body. The green ports on the right side of the body are where more argon is introduced to the flow. At the top are two high quality quartz tubes and an inner alumina injector tube (fig 3). ICP-MS Interface Because atomization/ionization occurs at atmospheric pressure, the interface between the ICP and MS components becomes crucial in creating a vacuum environment for the MS system. Ions flow through a small orifice, approximately 1 millimetre in diameter, into a pumped vacuum system. Here a supersonic jet forms and the sample ions are passed into the MS system at high speeds, expanding in the vacuum system. The entire mass spectrometer must be kept in a vacuum so that the ions are free to move without collisions with air molecules. Since the ICP is maintained at atmospheric pressure, a pumping system is needed to continuously pull a vacuum inside the spectrometer. In order to most efficiently reduce the pressure several pumps are typically used to gradually reduce pressure to 10-5 mbar before the ion stream reaches the quadruple. If only one pump were used, its size would be excessive to reduce the pressure immediately upon entering the mass spectrometer.



Plasma Torch:-

The plasma used in an ICP-MS is made by partially ionizing argon gas (Ar → Ar+ + e−). The energy required for this reaction is obtained by pulsing an electrical current in wires that surround the argon gas. After the sample is injected, the plasma's extreme temperature causes the sample to separate into individual atoms (atomization). Next, the plasma ionizes these atoms (M → M + + e−) so that they can be detected by the mass spectrometer (fig 4). Inductively coupled plasma (ICP) for spectrometry is sustained in a torch that consists of three concentric tubes, usually made of quartz. The end of this torch is placed inside an induction coil supplied with a radiofrequency electric current. A flow of argon gas (usually 14 to 18 litres per minute) is introduced between the two outermost tubes of the torch and an electrical spark is applied for a short time to introduce free electrons into the gas stream. These electrons interact with the radio-frequency magnetic field of the induction coil and are accelerated first in one direction, then the other, as the field changes at high frequency (usually 27.12 MHz). The accelerated electrons collide with argon atoms, and sometimes a collision causes an argon atom to part fraction of free electrons and argon ions. An ICP-MS combines a high-temperature ICP (Inductively Coupled Plasma) source with a mass spectrometer. The ICP source converts the atoms of the elements in the sample to ions. These ions are then separated and detected by the mass spectrometer. Figure 5 shows a schematic representation of an ICP source in an ICP-MS. Argon gas flows inside the concentric channels of the ICP torch. The RF load coil is connected to a radiofrequency (RF) generator. As power is supplied to the load coil from the generator, oscillating electric and magnetic fields are established at the end of the torch (fig 5). The sample is typically introduced into the ICP plasma as an aerosol, either by aspirating a liquid or dissolved solid sample into a nebulizer or using a laser to directly convert solid samples into an aerosol. Once the sample aerosol is introduced into the ICP torch, it is completely desolvated and the elements in the aerosol are converted first into gaseous atoms and then ionized towards the end of the plasma.



The interface – sampling ions:-

Placing a plasma, operating at 6000 °C, near an ion focusing device operating near room temperature is a bit like placing the earth about a half-mile away from the sun. In addition to a large temperature difference, the plasma operates at a pressure that is much higher than the vacuum required by the ion lens and mass spectrometer portions of the instrument. The

interface allows the plasma and the ion lens system to coexist and the ions generated by the plasma to pass into the ion lens region. The interface consists of two or three inverted funnel-like devices called cones. Until recently, all commercially available ICP-MS systems used the two-cone design. Such a design requires downstream focusing of the beam that exits the interface region. This focusing has been achieved through the use of a single or a series of charged devices called ion lenses. The need for these ion lenses can be explained in Figure 2. As mentioned earlier, the plasma (located to the left of the sampler cone) operates at atmospheric pressure, while the filtering quadrupole (located to the right of the skimmer cone) operates at a very low pressure. With a two-cone design, there can only be a two-step reduction in the pressure between the plasma and filtering quadrupole. With a two-step pressure reduction, the ion beam undergoes substantial divergence as it exits the second cone, thus requiring additional focusing if the ion beam is to properly enter the filtering quadrupole.

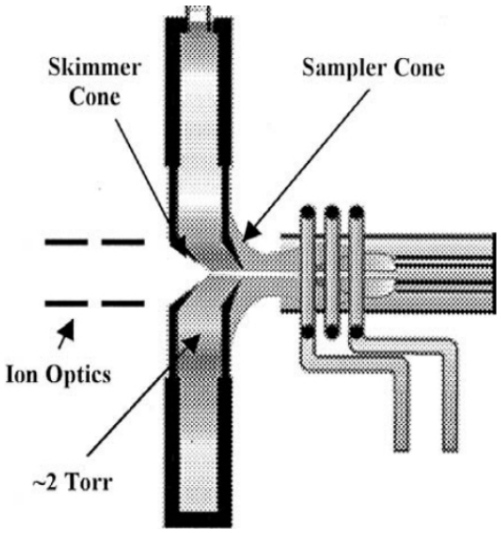
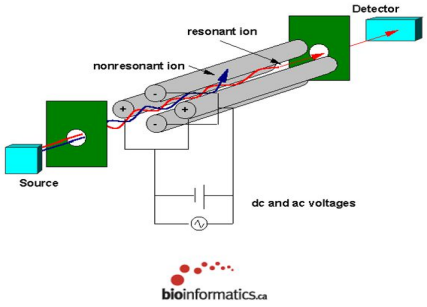


FIGURE 5.2 Detailed view of the interface region.

Mass Spectrometer:-

In the first stage of the mass spectrometer ions are removed from the plasma by a pumped extraction system. An ion beam is produced and focused further into the actual unit. There are several different types of mass analyzers which can be employed to separate isotopes based on their mass to charge ratio. Quadrupole analyzers are compact and easy to use but offer lower resolution when dealing with ions of the same mass to charge (m/z) ratio. Double focusing sector analyzers offer better resolution but are larger and have higher capital cost. The quadrupole mass filter is made up of four metal rods aligned in a parallel diamond pattern. A combined DC and AC electrical potential is applied to the rods with opposite rods having a net negative or positive potential. Ions enter into the path between all of the rods. When the DC and AC voltages are set to certain values only one particular ion is able to continue on a path between the rods and the others are forced out of this path. This ion will have a specific m/z ratio. Many combinations of voltages are chosen which allows an array of different m/z ratio ions to be detected. Shown below is animation of this process. Three mass fragments enter into the quadrupole vacuum chamber. The voltage of the rods is set so that only the pink mass fragment passes completely through the quadrupole rod array and into the detector. The green and blue fragments are unstable at this voltage combination and their path eventually brings them into contact with the rods so that they never reach the detector (fig 6). Quadrupole rods require periodic maintenance and cleaning due to the build-up of ions which are removed during the mass discrimination process. These ions form a film which eventually builds up and dulls the metallic surface. To remove this film the vacuum chamber must be repressurized and disassembled. This process can be time consuming and very delicate but is essential to keep a mass spectrometer performing well (fig 7). Once the ions enter the mass spectrometer, they are separated by their mass-to-charge ratio. The most commonly used type of mass spectrometer is the quadrupole mass filter. In this type, 4 rods (approximately 1 cm in diameter and 15-20 cm long) are arranged as in (Fig 8). In a quadrupole mass filter, alternating AC and DC voltages are applied to opposite pairs of the rods. These voltages are then rapidly switched along with an RF-field. The result is that an electrostatic filter is established that only allows ions of a single mass-to-charge ratio (m/e) pass through the rods to the detector at a given instant in time. So, the quadrupole mass filter is really a sequential filter, with the settings being change for each specific m/e at a time. However, the voltages on the rods can be switched at a very rapid rate. The result is that the quadrupole mass filter can separate up to 2400 amu(atomic mass units) per second.

Quadrupole Mass Analyzer



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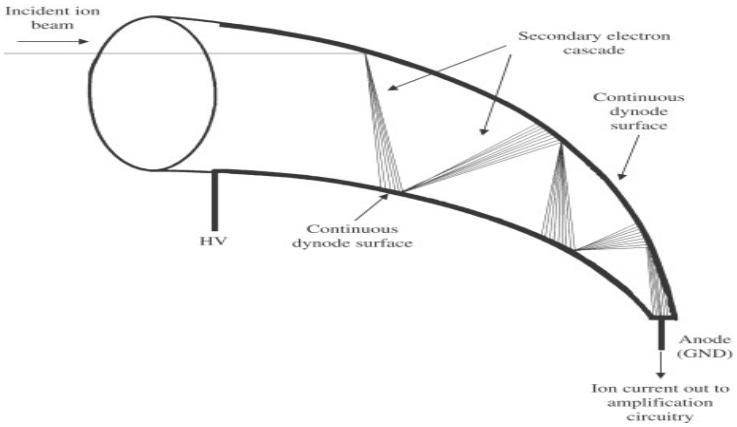
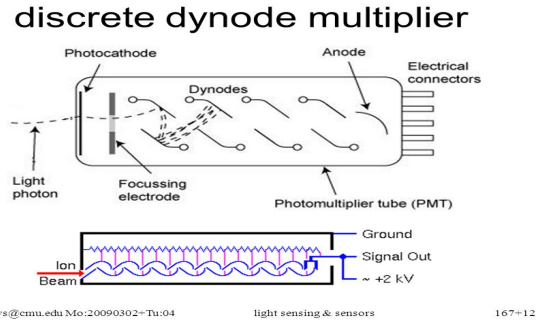
A recent innovation has introduced a third cone into the interface which greatly reduces the divergence of the ion beam as it exits the interface region. The third cone, called the hyper-skimmer, provides a three-step reduction in pressure between the plasma and the filtering quadrupole, resulting in a substantial reduction in the divergence of the emerging ion beam. With the three-cone design, conventional ion lenses can be completely eliminated from the instrument, resulting in greater ion transmission, improved long-term stability, and reduced instrument maintenance. In the three-cone design, none of the cones has a voltage applied such as may exist on an extraction lens. Since the cones are electrically neutral, any build-up of material on their surfaces will not significantly impact their function. In addition, experience has shown that the three-cone design requires no more maintenance than a conventional two cone design. Cones are most often produced from nickel or platinum. While nickel cones have a lower purchase price, platinum cones provide longer life, are more resistant to some acids, and provide a small improvement in instrument performance. The orifice openings of the cones should be large enough to allow for the passage of the ion beam while, at the same time, not allow so much gas to enter the instrument that the instrument's vacuum system is taxed. Experience has shown that orifice openings of approximately 1 mm are ideal.

Detector:-

The most common detector used for ICP-MS is an electron multiplier (EM). Positively-charged analyte ions strike the first dynode of the detector which is held at a high negative voltage. The impact of the ion on the detector causes the emission of several electrons from the surface, which, in turn, strike the next dynode releasing more electrons. This process (called secondary emission) continues, generating an amplification cascade that culminates in a signal large enough to be measured reliably as an ion 'count'. In this way, an EM can generate a measurable signal pulse from the impact of a single ion on the detector, conferring very high analytical sensitivity. In fact, detection limits in ICP-MS are far superior to flame atomic absorption, and are comparable (or superior) to graphite furnace atomic absorption (Figure 3). Typical limits of detection in ICP-MS are in the nmol/L range for most elements; the exact value being dependent on the element, the type of biological matrix, the dilution factor employed during sample preparation, the design of the sample introduction system, instrument operating conditions (including plasma temperature) and background signals (reagent purity etc.). Most detectors are able to operate in both a pulse (digital) and analogue mode. These so-called dual detectors automatically switch from pulse to analogue mode when the signal intensity exceeds a certain threshold, allowing the linear dynamic range of the detector to be extended to approximately 8–12 orders of magnitude. These two detector modes require cross-calibration to ensure optimum linear response across this range.





Detection Limits:-

One of the great advantages to ICP-MS is extremely low detection limits for a wide variety of elements. Some elements can be measured down to part per quadrillion range while most can be detected at part per trillion levels. The table below shows some common detection limits by element.

V. MAINTENANCE OF INSTRUMENT

There are many aspects of maintenance that need to be encompassed by daily, weekly and annual procedures. The frequency of maintenance is typically determined by the sample volume and cumulative run time that the instrument is subjected to. One of the most frequent forms of routine maintenance is replacing sample and waste tubing on the peristaltic pump, as these tubes can get worn fairly quickly resulting in holes and clogs in the sample line, resulting in skewed results. Other parts that will need regular cleaning and/or replacing are sample tips, nebulizer tips, sample cones, skimmer cones, injector tubes, torches and lenses. It may also be necessary to change the oil in the interface roughing pump as well as the vacuum backing pump, depending on the workload put on the instrument.

VI. NEXT GENERATION OF ICP-MS

The NextION 300 offers:

- 3 mades of operation(Standard, Collision, and Reaction) and can be quickly switched from 1 mode to another.
- So, every analysis can be performed on the same instrument.
- It's the only ICP-MS that lets you maximize productivity without compromising sensitivity or performance.
- A single ICP-MS instrument offers both the simplicity and convenience of a collision cell and the exceptional detection limits of a true reaction cell.
- Stability is optimized by incorporating a unique triple cone interface and Quadrupole Ion Deflector. Designed to remove an unprecedented level of unionized material(and preventing it from entering the universal cell), this innovative ion path keeps the instrument clean, minimizing drift and eliminating the need for cell cleaning.

Applications of New Generation of ICP-MS:-

- **Gold Nanoparticles** reference materials using the NextION 300 ICP-MS in Single Particle Mode.
- Coupling flow field flow fractionation to ICP-MS for the **detection and characterization of Silver Nanoparticles.**
- The **determination of lead in calcium – based Antacid and Dietary Supplements.**
- The determination of **Metals in Cosmetics.**
- Assuring safety of **traditional Chinese herbal medicines** by monitoring **inorganic impurities** using ICP-MS.

VII. COMPARISON OF ICP-MS & OTHER TECHNIQUES

	ICP-MS	ICP-AES	GFAAS	FAAS
Detection Limits	Excellent	Good	Excellent	Good
Productivity	Excellent	Excellent	Low	Good
Precision	1-3%	0.3-2%	1-5%	0.1-1%
Chemical Interference	Moderate	Few	Many	Many
Dissolved solids	0.1-0.4%	2-25%	Up to 20%	0.5-3%
# Elements	75	73	50	68
Sample Usage	Low	Medium	Very Low	High
Isotope Analysis	Yes	No	No	No
Method Development	Skill required	Skill required	Skill required	Easy
Running Costs	High	High	Medium	Low
Capital Costs	Very high	High	Medium	Low

VIII. PHARMACEUTICAL APPLICATIONS

1. One of the largest volume uses for ICPMS is in the medical and forensic field, specifically, toxicology. A physician may order a metal assay for a number of reasons, such as suspicion of heavy metal poisoning, metabolic concerns, and even hepatological issues. Depending on the specific parameters unique to each patient's diagnostic plan, samples collected for analysis can range from whole blood, urine, plasma, serum, to even packed red blood cells.
2. Another primary use for this instrument lies in the environmental field. Such applications include water testing for municipalities or private individuals all the way to soil, water and other material analysis for industrial purposes.
3. This technique is also widely used the field of radiometric dating, in which it is used to analyze relative abundance of different isotopes. ICP-MS is more suitable for this application than the previously used Thermal Ionization Mass Spectrometry, as species with high ionization energy such as Osmium (Os) and Tungsten (Hf-W) can be easily ionized.

4. In the field of flow cytometry, a new technique uses ICP-MS to replace the traditional fluorochromes. Briefly, instead of labeling antibodies (or other biological probes) with fluorochromes, each antibody is labeled with a distinct combination of lanthanides.
5. Regardless of the sample type, blood, water, etc., it is important that it be free of clots or other particulate matter, as even the smallest clot can disrupt sample flow and block or clog the sample tips within the spray chamber. Very high concentrations of salts, e.g. sodium chloride in sea water, can eventually lead to blockages as some of the ions reunite after leaving the torch and build up around the orifice of the skimmer cone. This can be avoided by diluting samples whenever high salt concentrations are suspected, though at a cost to detection limits.
6. Quantification of proteins and bio molecules by icp-ms: There is an increasing trend of using ICP-MS as a tool in speciation analysis normally involves a front end chromatograph separation and an elemental selective detector such as AAS and ICP-MS. For example, ICP-MS may be combined with size exclusion chromatography and quantitative preparative native continuous polyacrylamide gel electrophoresis for identifying and quantifying native metal in bio fluids. Also the phosphorylation status of proteins can be analyzed.
7. A new type of protein tagging reagents called metal coded affinity tags (Me CAT) were introduced to label proteins quantitatively with metals, especially lanthanides. The Me CAT labeling allows relative and absolute quantification of all kind of proteins or other biomolecules like peptides. My CAT comprises a site specific biomolecule tagging group with at least a strong chelate group which binds metals.
8. The Me CAT labeled proteins can be accurately quantified by ICP-MS down to low attomol amount of analyte which is at least 2–3 orders of magnitude more sensitive than other mass spectrometry based quantification methods.
9. By introducing several Me CAT labels to a biomolecule and further optimization of LC-ICP-MS detection limits in the zeptomol range are within the realms of possibility. By using different lanthanides Me CAT multiplexing can be used for pharmacokinetics of proteins and peptides or the analysis of the differential expression of proteins e.g. in biological fluids.

IX. CONCLUSION

ICP-MS is a highly sensitive analytical technique for the determination of trace elements of clinical interest in biological fluids. ICP-MS offers numerous features which make it particularly attractive for the clinical laboratory. These include: high sensitivity, wide linear dynamic range, wide elemental coverage, multi-element capability, high sample throughput and simple sample preparation.

It is here by concluded that this technique is superior to other technique giving the results up to a level.

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