

HUMAN HEALTH

ENVIRONMENTAL HEALTH

WORLD LEADER IN
AA, ICP-OES
AND ICP-MS

Atomic Spectroscopy

A Guide to Selecting the
Appropriate Technique and System





WHAT IS ATOMIC SPECTROSCOPY?

PRIMARY INDUSTRIES

Many industries require a variety of elemental determinations on a diverse array of samples. Key markets include:

- Environmental
- Chemical/Industrial
- Geochemical/Mining
- Biomonitoring
- Food
- Agriculture
- Hydrocarbon Processing
- Semiconductor
- Nuclear
- Renewable Energy
- Pharmaceutical

For more details, see Page 10.

Atomic spectroscopy is the technique for determining the elemental composition of an analyte by its electromagnetic or mass spectrum. Several analytical techniques are available, and selecting the most appropriate one is the key to achieving accurate, reliable, real-world results.

Proper selection requires a basic understanding of each technique since each has its individual strengths and limitations. It also requires a clear understanding of your laboratory's analytical requirements.

The following pages will give you a basic overview of the most commonly used techniques and provide the information necessary to help you select the one that best suits your specific needs and applications.

COMMONLY USED ATOMIC SPECTROSCOPY TECHNIQUES

There are three widely accepted analytical methods – atomic absorption, atomic emission and mass spectrometry – which will form the focus of our discussion, allowing us to go into greater depth on the most common techniques in use today:

- Flame Atomic Absorption Spectroscopy
- Graphite Furnace Atomic Absorption Spectroscopy
- Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES)
- Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Flame Atomic Absorption Spectroscopy

Atomic Absorption (AA) occurs when a ground state atom absorbs energy in the form of light of a specific wavelength and is elevated to an excited state. The amount of light energy absorbed at this wavelength will increase as the number of atoms of the selected element in the light path increases. The relationship between the amount of light absorbed and the concentration of analytes present in known standards can be used to determine unknown sample concentrations by measuring the amount of light they absorb.

Performing atomic absorption spectroscopy requires a primary light source, an atom source, a monochromator to isolate the specific wavelength of light to be measured, a detector to measure the light accurately, electronics to process the data signal and a data display or reporting system to show the results. (See Figure 1.) The light source normally used is a hollow cathode lamp (HCL) or an electrode-less discharge lamp (EDL). In general, a different lamp is used for each element to be determined, although in some cases, a few elements may be combined in a multi-element lamp.

In the past, photomultiplier tubes have been used as the detector. However, in most modern instruments, solid-state detectors are now used. Flow Injection Mercury Systems (FIMS) are specialized, easy-to-operate atomic absorption spectrometers for the determination of mercury. These instruments use a high-performance single-beam optical system with a low-pressure mercury lamp and solar-blind detector for maximum performance.

Whatever the system, the atom source used must produce free analyte atoms from the sample. The source of energy for free-atom production is heat, most commonly in the form of an air/acetylene or nitrous-oxide/acetylene flame. The sample is introduced as an aerosol into the flame by the sample introduction system consisting of a nebulizer and spray chamber. The burner head is aligned so that the light beam passes through the flame, where the light is absorbed.

The major limitation of Flame AA is that the burner-nebulizer system is a relatively inefficient sampling device. Only a small fraction of the sample reaches the flame, and the atomized sample passes quickly through the light path. An improved sampling device would atomize the entire sample and retain the atomized sample in the light path for an extended period of time, enhancing the sensitivity of the technique. Which leads us to the next option – electrothermal vaporization using a graphite furnace.

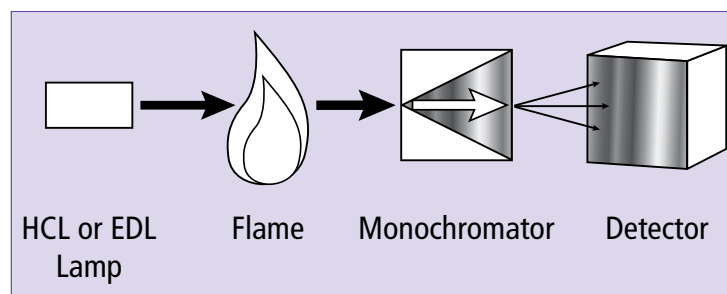
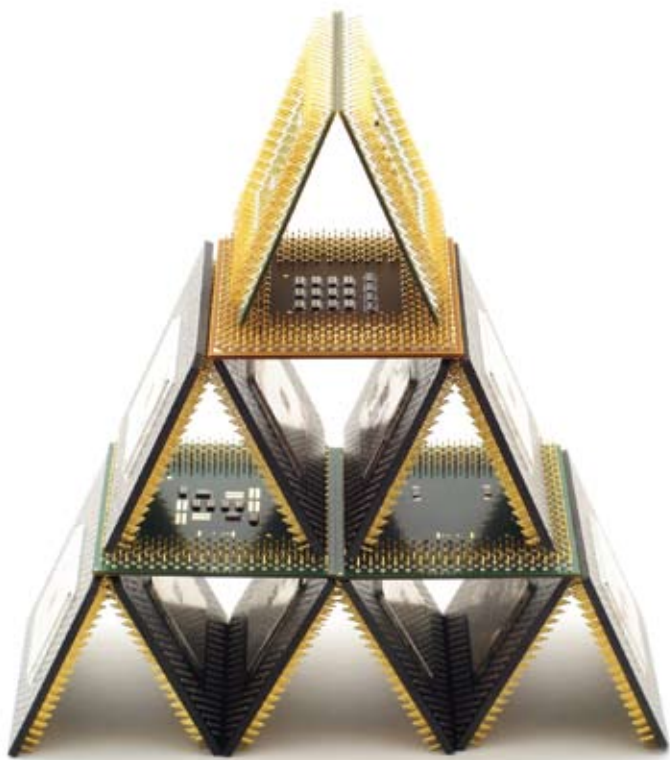


Figure 1. Simplified drawing of a Flame AA system.





Graphite Furnace Atomic Absorption Spectroscopy

With Graphite Furnace Atomic Absorption (GFAA), the sample is introduced directly into a graphite tube, which is then heated in a programmed series of steps to remove the solvent and major matrix components and to atomize the remaining sample. All of the analyte is atomized, and the atoms are retained within the tube (and the light path, which passes through the tube) for an extended period of time. As a result, sensitivity and detection limits are significantly improved over Flame AA.

Graphite Furnace analysis times are longer than those for Flame sampling, and fewer elements can be determined using GFAA. However, the enhanced sensitivity of GFAA, and its ability to analyze very small samples, significantly expands the capabilities of atomic absorption.

GFAA allows the determination of over 40 elements in microliter sample volumes with detection limits typically 100 to 1000 times better than those of Flame AA systems.

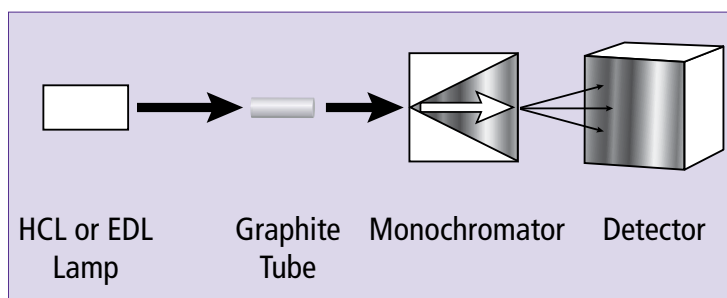


Figure 2. Simplified drawing of a Graphite Furnace AA system.

The Periodic Table of the Elements

1 H Hydrogen 1.00794																	2 He Helium 4.003				
3 Li Lithium 6.941	4 Be Beryllium 9.012182															5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050															13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80				
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29				
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)				
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (269)	111 Rg Roentgenium (272)											
58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967								
90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)								

The Periodic Table of Elements – See page 12 for a listing of detection limits for all elements using the different atomic spectroscopy methods.

Commonly Used Atomic Spectroscopy Techniques

Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) is the measurement of the light emitted by the elements in a sample introduced into an ICP source. The measured emission intensities are then compared to the intensities of standards of known concentration to obtain the elemental concentrations in the unknown sample.

There are two ways of viewing the light emitted from an ICP. In the classical ICP-OES configuration, the light across the plasma is viewed radially (Figure 3a), resulting in the highest upper linear ranges. By viewing the light emitted by the sample looking down the center of the torch (Figure 3b) or axially, the continuum background from the ICP itself is reduced and the sample path is maximized. Axial viewing provides better detection limits than those obtained via radial viewing by as much as a factor of 10. The most effective systems allow the plasma to be viewed in either orientation in a single analysis, providing the best detection capabilities and widest working ranges.

The optical system used for ICP-OES consists of a spectrometer that is used to separate the individual wavelengths of light and focus the desired wavelengths onto the detector (Figure 4). Older, "direct reader" types of ICP-OES systems used a series of photomultiplier tubes to determine pre-selected wavelengths. This limited the number of elements that could be determined as the wavelengths were generally fixed once the instrument was manufactured. Sequential-type systems can select any wavelength and focus it on a single detector. However, this is done one element at a time, which can lead to much longer analysis times.

In today's modern ICP-OES systems, solid-state detectors based on charge-coupled devices (CCD) are used, providing very flexible systems and eliminating the need for large numbers of single photomultiplier detectors.

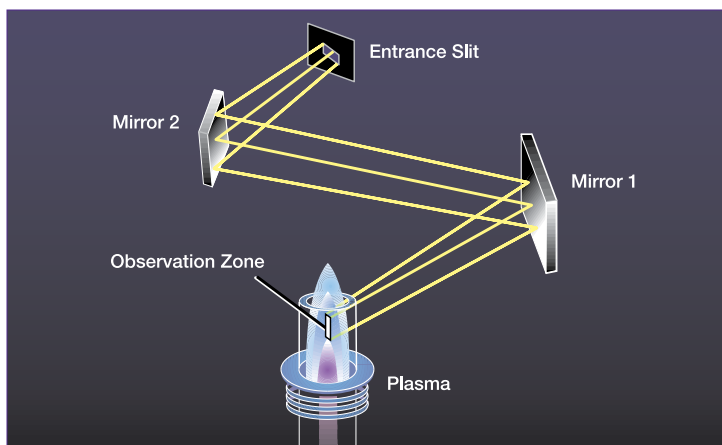


Figure 3a. Radially viewed plasma with a vertical slit image in the plasma.

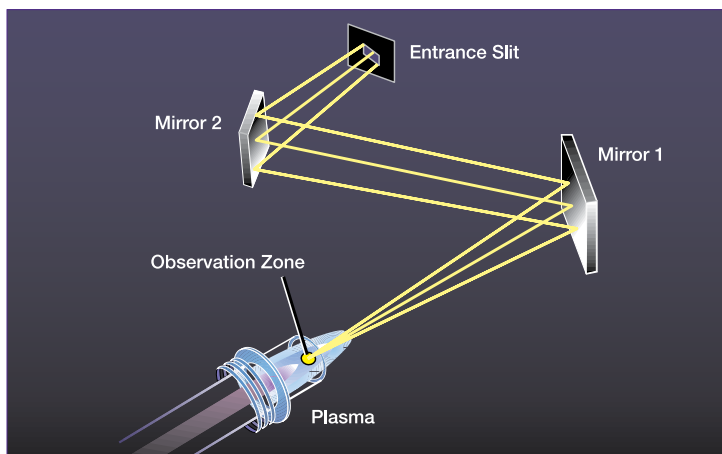


Figure 3b. Axially viewed plasma with an axial slit image in the plasma.

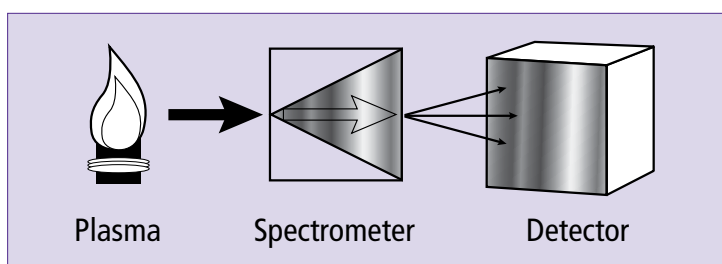


Figure 4. Simplified drawing of a basic ICP system.

INDUCTIVELY COUPLED PLASMA (ICP)

ICP is an argon plasma maintained by the interaction of an RF field and ionized argon gas. The plasma can reach temperatures as high as 10,000 °K, allowing the complete atomization of the elements in a sample and minimizing potential chemical interferences.

Inductively Coupled Plasma – Mass Spectrometry

With Inductively Coupled Plasma Mass Spectrometry (ICP-MS), the argon ICP generates singly charged ions from the elemental species within a sample that are directed into a mass spectrometer and separated according to their mass-to-charge ratio. Ions of the selected mass-to-charge ratio are then directed to a detector that determines the number of ions present (Figure 5). Typically, a quadrupole mass spectrometer is used for its ease-of-use, robustness and speed. Due to the similarity of the sample-introduction and data-handling techniques, using an ICP-MS is very much like using an ICP-OES system.

ICP-MS combines the multi-element capabilities of ICP techniques with exceptional detection limits equivalent to or below those of GFAA. It is also one of the few analytical techniques that allows the quantification of elemental isotopic concentrations and ratios, as well as precise speciation capabilities when used in conjunction with HPLC or GC interfaces. This feature enables the analytical chemist to determine the exact form of a species present – not just the total concentration.

However, due to the fact that the sample components are actually introduced into the instrument, there are some limitations as to how much sample matrix can be introduced into the ICP-MS. In addition, there are also increased maintenance requirements as compared to ICP-OES systems. Generally, ICP-MS systems require that the total dissolved solids content of a sample be below 0.2% for routine operation and maximum stability. There are several items, such as the interface cones and ion lens, located between the ICP torch and the mass spectrometer, that need to be cleaned on a periodic basis to maintain acceptable instrument performance.



Recent developments in ICP-MS have led to new technologies that can remove even the most difficult-to-avoid interferences (such as those coming from plasma species or if an element only has one isotope) without limiting the detection capabilities of the system. Dynamic Reaction Cell (DRC™) technology, for example, allows most interferences to be removed before they reach the mass spectrometer by using controlled gas-phase reaction chemistry inside an enclosed cell containing a second quadrupole mass filter (Figure 6). The result is a dramatically improved detection capability into the sub parts-per-trillion range for most elements.

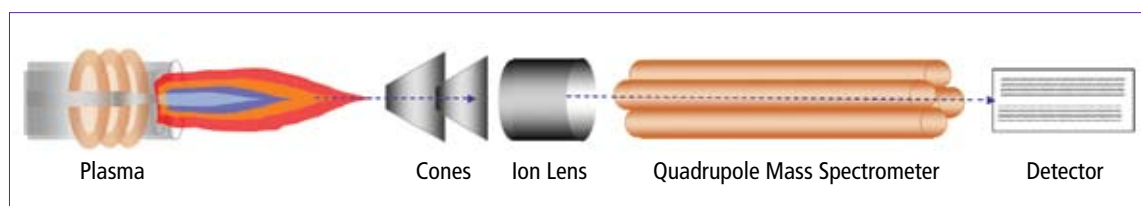


Figure 5. Simplified drawing of a basic ICP-MS system.

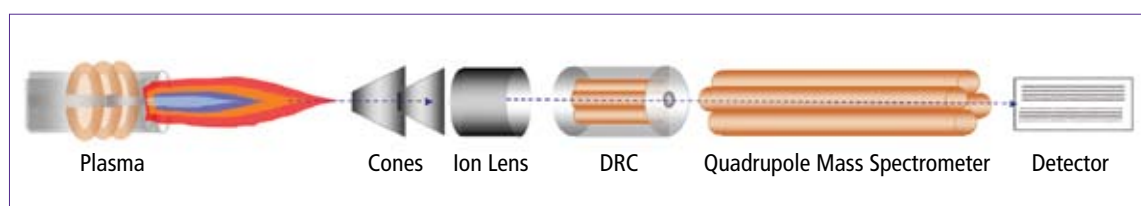


Figure 6. Simplified drawing of a Dynamic Reaction Cell (DRC) ICP-MS system.

SELECTING A TECHNIQUE FOR YOUR ANALYSIS

With the availability of a variety of atomic spectroscopy techniques, laboratory managers must decide which of them is best suited to their particular analytical requirements. Unfortunately, because the techniques complement each other so well, it may not always be clear which is the optimum solution for a particular application.

Selecting a technique requires the consideration of a variety of important criteria, including:

- Detection limits
- Analytical working range
- Sample throughput
- Data quality
- Cost
- Interferences
- Ease-of-use
- Availability of proven methodology



In order to help you narrow your selection, many of these criteria are discussed below for Flame AA, Graphite Furnace AA, ICP-OES and ICP-MS. In simple terms, your choice can be guided by answering the four questions in the following table:

Table 1. Technique decision matrix.

	Flame AA	GFAA	ICP-OES	ICP-MS
How Many Elements				
Single	■			
Few		■		
Many			■	■
What Levels?				
High ppb	■		■	
Sub ppb		■	■	■
Sub ppb-ppm				■
Sub ppt				■
How Many Samples?				
Very few	■	■		
Few	■	■	■	■
Many			■	■
How Much Sample?				
> 5 mL	■	■	■	■
< 1-2 mL		■		

Detection limits

The detection limits achievable for individual elements are important in determining the usefulness of an analytical technique for a given analytical problem. Without adequate detection limit capabilities, lengthy analyte concentration procedures may be required prior to analysis.

Typical detection limit ranges for the major atomic spectroscopy techniques are shown in Figure 7. For a complete listing of detection limits by element for Flame AA, GFAA, ICP-OES (with radial and axial torch configurations) and ICP-MS, see the table on page 12.

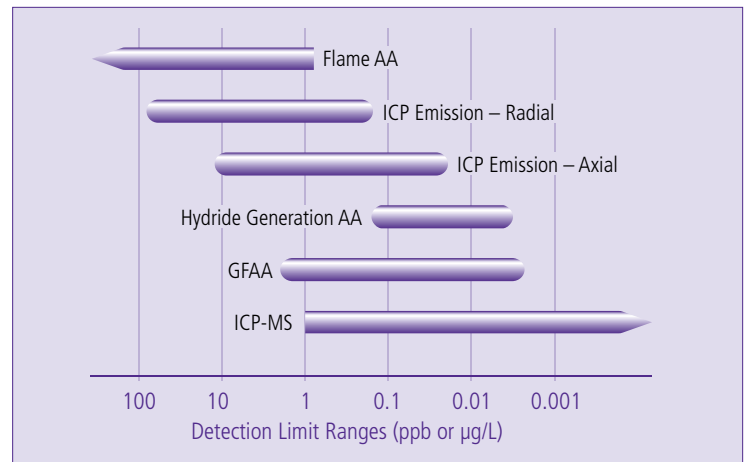


Figure 7. Typical detection limit ranges for the major atomic spectroscopy techniques.

Analytical working range

The analytical working range can be viewed as the concentration range over which quantitative results can be obtained without having to recalibrate the system. Selecting a technique with an analytical working range (and detection limits) based on the expected analyte concentrations minimizes analysis times by allowing samples with varying analyte concentrations to be analyzed together. A wide analytical working range can also reduce sample-handling requirements, minimizing potential errors.

Sample throughput

Sample throughput is the number of samples that can be analyzed or elements that can be determined per unit of time. For most techniques, analyses performed at the limits of detection or where the best precision is required will be more time-consuming than less demanding analyses. Where these factors are not limiting, the number of elements to be determined per sample and the analytical technique will determine the sample throughput.

- **Flame AA** – Provides relatively high sample throughput when analyzing a large number of samples for a limited number of elements. A typical determination of a single element requires only 3-10 seconds. However, Flame AA requires specific light sources and optical parameters for each element to be determined and may require different flame gases for different elements. As a result, even though it is frequently used for multi-element analysis, Flame AA is generally considered to be a single-element technique.
- **Graphite Furnace AA** – As with Flame AA, GFAA is basically a single-element technique. Because of the need to thermally program the system to remove solvent and matrix components prior to atomization, GFAA has a relatively low sample throughput. A typical graphite furnace determination normally requires 2-3 minutes per element for each sample.
- **ICP-OES** – A true multi-element technique with exceptional sample throughput. ICP-OES systems typically can determine more than 73 elements per minute in individual samples. Where only a few elements are to be determined, however, ICP is limited by the time required for equilibration of the plasma with each new sample, typically about 15-30 seconds.
- **ICP-MS** – Also a true multi-element technique with the same advantages and limitations of ICP-OES. ICP-MS can typically determine more than 73 elements per minute in an individual sample, depending on such factors as the concentration levels and required precision. Although ICP-MS has a wide working range, the upper linear concentration range is generally less than that of ICP-OES systems and may require that some samples be diluted.



Costs

As they are less complex systems, instrumentation for single-element atomic spectroscopy (Flame AA and GFAA) is generally less costly than that for the multi-element techniques (ICP-OES and ICP-MS). There can also be a considerable variation in cost among instrumentation for the same technique. Instruments offering only basic features are generally less expensive than more versatile systems, which frequently also offer a greater degree of automation. Figure 9 provides a comparison of typical instrument price ranges for the major atomic spectroscopy techniques.

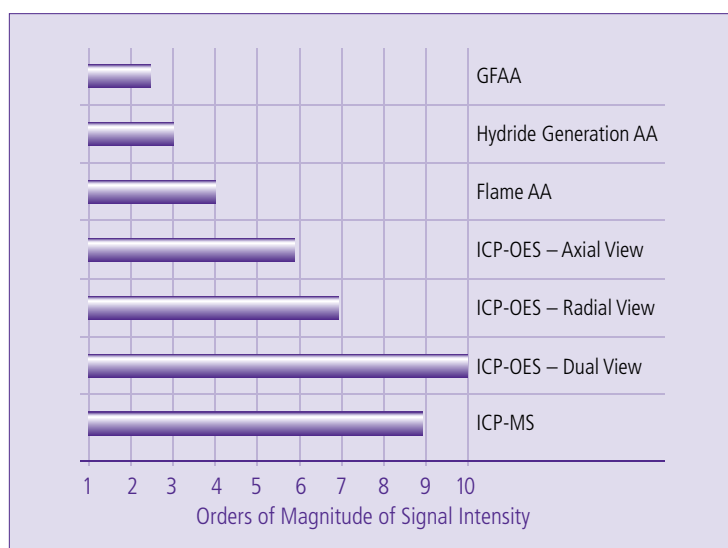


Figure 8. Typical analytical working ranges for the major atomic spectroscopy techniques.

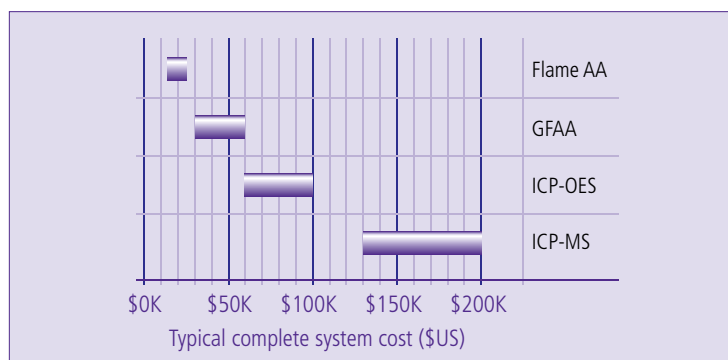






Figure 9. Typical relative purchase prices for atomic spectroscopy systems.

SELECTING A SYSTEM FOR YOUR ANALYSIS

TECHNIQUE	STRENGTHS	LIMITATIONS	APPLICATIONS	SYSTEM
Flame AA – Flame Atomic Absorption Spectroscopy	<ul style="list-style-type: none"> • Very easy-to-use • Widely accepted • Extensive application information available • Relatively inexpensive 	<ul style="list-style-type: none"> • Low sensitivity • Single element analytical capability • Cannot be left unattended (flammable gas) 	Ideal for laboratories analyzing large numbers of samples for a limited number of elements and for the determination of major constituents and higher concentration analytes.	AAAnalyst – Atomic Absorption Spectrometers 
GFAA – Graphite Furnace Atomic Absorption Spectroscopy	<ul style="list-style-type: none"> • Exceptional detection limits • Well-documented applications • May be left unattended 	<ul style="list-style-type: none"> • Limited analytical working range • Sample throughput somewhat less than other techniques 	Ideal for laboratories analyzing a limited number of elements and requiring excellent detection limits.	AAAnalyst – Atomic Absorption Spectrometers 
ICP-OES – Inductively Coupled Plasma Optical Emission Spectroscopy	<ul style="list-style-type: none"> • Best overall multi-element atomic spectroscopy technique • Excellent sample throughput • Very wide analytical range • Good documentation available for applications • May be left unattended • Easy-to-use 	<ul style="list-style-type: none"> • Higher initial investment 	Ideal for laboratories analyzing multiple elements in a moderate or large number of samples.	Optima – ICP-OES Systems 
ICP-MS – Inductively Coupled Plasma Mass Spectrometry	<ul style="list-style-type: none"> • Exceptional multi-element capabilities • Ability to perform isotopic analyses • Well-documented interferences and compensation methods • Rapidly growing application information • Detection limits equal to or better than GFAA with much higher productivity • May be left unattended 	<ul style="list-style-type: none"> • Highest initial investment • Method development more difficult than other techniques • Limited solids in sample 	Ideal for laboratories analyzing multiple elements in a large number of samples and requiring a system capable of determining trace and ultratrace analyte concentrations.	ELAN – ICP-MS Systems 

Once you have identified the best solution for your particular application, read on for more in-depth product details.

AAAnalyst – Atomic Absorption Spectrometers

This advanced line of atomic absorption (AA) spectrometers maximizes AA performance for even the most difficult samples. Engineered to generate superior results and provide faster, more accurate analyses, the AAAnalyst™ series offers a range of capabilities from simple Flame AA systems to fully integrated benchtop units providing the best in both Flame and Graphite Furnace.

PerkinElmer's high-efficiency double-beam optical system and solid-state detector provide outstanding signal-to-noise ratios and our transversely heated graphite atomizer (THGA) tube design eliminates most interferences.

Each AAAnalyst system can be equipped with flexible, intuitive WinLab32™ software which features all the tools to analyze samples, report and archive data and ensure regulatory compliance. (See inset for more details.)



Optima – ICP-OES Systems

Optima™ systems have the optimized design required to ensure accuracy, improve method development and consistently deliver the correct answer faster. Available with a range of performance capabilities, this line of ICP-OES instruments offers an ideal solution for laboratories with moderate to heavy sample loads.

The family includes systems for research and quality assurance laboratories that have a wide variety of samples and lower frequency of analysis, as well as models designed for laboratories with heavier loads of difficult samples.

With a custom, patented solid-state detector, third generation solid-state RF power supply and purged optical system, Optima ICP-OES solutions provide superior performance and enhanced reliability, reducing operating costs and ensuring that your instrument is available when needed. Models offered include both radial or dual viewing of the plasma. Dual-view allows the widest working range possible.

Optima systems also come equipped with flexible, intuitive WinLab32 software that features all the tools to analyze samples, report and archive data and ensure regulatory compliance. (See inset for more details.)

WinLab32 CONTROL SOFTWARE

- Common look and feel ensures consistent cross-platform use
- Wizards, localization and tool tips make WinLab32 easy to learn and use
- Extensive QC options ensure data quality
- Automatic start-up and shut-down improves productivity
- QC charting option allows efficient preparation of quality control charts
- Optional 21 CFR Part 11 software to help meet regulatory requirements
- Integrated control of accessories extends capabilities of each system
- Robust platform



ELAN – ICP-MS Systems

Designed for routine, high-productivity, trace-elemental analysis, the ELAN® series of ICP-MS instruments provides excellent detection limits, especially with PerkinElmer’s patented Dynamic Reaction Cell (DRC™) technology to preserve detection limits in complex samples.

The preferred choice for many laboratories, ELAN systems are free-standing and mobile for added installation and application flexibility. The instruments feature a variety of sample introduction systems, including specialized options ranging from cooled and desolvating spray chambers, to ultrasonic and parallel-path or cross-flow nebulizers.

ELAN software gives each system the power to perform qualitative, semi-quantitative, quantitative or specialized analyses such as isotope-ratio, isotope-dilution or even speciation analyses. Features include priority samples, flexible quality control checks, transient signal handling, run-list build and customizable reporting. The software also includes PathFinder™ (an HTML-based Help function) and Enhanced Security™ to ensure regulatory compliance.



Atomic Spectroscopy Applications by Market				
MARKET	TYPICAL APPLICATIONS	COMMONLY USED TECHNIQUES		
		AA	ICP-OES	ICP-MS
Environmental	Water	□	■	■
	Soil	□	■	■
	Air	■	□	■
Chemical/Industrial	Quality control/Product testing	■	■	■
Geochemical/Mining	Exploration	■	■	■
	Research	□	■	■
Biomonitoring	Biological fluids	■	□	■
Food	Food safety	■	■	■
	Nutritional labeling	■	■	□
Agriculture	Soils	■	■	□
Semiconductor	Wafers	□	□	■
	High chemical purity	■	□	■
Nuclear	Low-level waste	□	■	■
	Process water	□	■	■
Renewable Energy	Biofuels	□	■	■
	Solar panels	□	■	■
Hydrocarbon Processing	Petroleum refining	■	■	■
	Lubricants and oils	□	■	□
Pharmaceutical	Drug development	□	□	■
	Quality control	□	■	□

Frequency of Technique Used



IMPORTANCE OF ATOMIC SPECTROSCOPY TO SPECIFIC MARKETS

Environmental

In the environment we live in, understanding heavy metal contamination is critical. The accurate measurement of concentrations of these metals is imperative to maintain clean air, water and soil for a safer world.

Chemical/Industrial

From the analysis of raw materials and components to finished product testing and quality control, industrial and chemical manufacturers require accurate analytical techniques to ensure the safety and performance of their products.

Geochemical/Mining

With myriad applications from date stamping to precious metals testing, atomic spectroscopy offers a fast, accurate solution for broad geological surveys as well as an invaluable means of testing potential mining areas before incurring the high costs associated with digging.

Biomonitoring

Instrumentation for accurate measurements of metals in biological matrices is vital when assessing human exposures to natural and synthetic chemicals. Speciation is also becoming increasingly important due to its ability to provide additional information on element valence state or molecular form.

Food

Accurate analysis of food for nutritional content, contamination or authenticity – the exact geographic source of the product – is critical for regulatory and quality assurance.

Agriculture

Trace metals are essential for plant growth. Atomic spectroscopy also facilitates precise soil analysis to ensure that metals are not at levels that could unduly affect the food source (livestock and/or crops).

Hydrocarbon Processing

From petroleum refining to a broad spectrum of applications using lubricants and oils, many industries require the determination of metals – particularly analytes that can lead to degradation and contamination – to ensure conformity and monitor and control processes.

Semiconductor

Determining lower and lower values in a variety of materials – rapidly and affordably – has become necessary in the increasingly competitive semiconductor industry.

Nuclear

Operating under constant scrutiny, the nuclear field is required to monitor and measure the levels of a variety of elements to an exacting degree. Atomic spectroscopy is commonly used to determine trace elements in everything from process water to low-level waste.

Renewable Energy

As the world continues to move toward eco-friendly technologies and energy sources, there's an ever-increasing need for accurate elemental analysis. Applications include testing biofuels for batch consistency and quality control, and trace elemental analysis on solar panels to ensure optimum performance.

Pharmaceutical

Drug research, development and production is dependent on elemental analysis, starting with the testing of individual ingredients and continuing through production to final quality control, as impurities can affect drug efficacy and metabolism.

ATOMIC SPECTROSCOPY DETECTION LIMITS

Element	Flame AA	Hg/Hydride	GFAA	ICP-OES	ICP-MS	Element	Flame AA	Hg/Hydride	GFAA	ICP-OES	ICP-MS
Ag	1.5		0.005	0.6	0.002	Mo	45		0.03	0.5	0.001
Al	45		0.1	1	0.005 ^a	Na	0.3		0.005	0.5	0.0003 ^c
As	150	0.03	0.05	2	0.0006 ^b	Nb	1500			1	0.0006
Au	9		0.15	1	0.0009	Nd	1500			2	0.0004
B	1000		20	1	0.003 ^c	Ni	6		0.07	0.5	0.0004 ^c
Ba	15		0.35	0.03	0.0002 ^d	Os				6	
Be	1.5		0.008	0.09	0.003	P	75000		130	4	0.1 ^a
Bi	30	0.03	0.05	1	0.0006	Pb	15		0.05	1	0.00004 ^d
Br					0.2	Pd	30		0.09	2	0.0005
C					0.8 ^e	Pr	7500			2	0.00009
Ca	1.5		0.01	0.05	0.0002 ^d	Pt	60		2.0	1	0.002
Cd	0.8		0.002	0.1	0.00009 ^d	Rb	3		0.03	5	0.0004
Ce				1.5	0.0002	Re	750			0.5	0.0003
Cl					12	Rh	6			5	0.0002
Co	9		0.15	0.2	0.0009	Ru	100		1.0	1	0.0002
Cr	3		0.004	0.2	0.0002 ^d	S				10	28 ^j
Cs	15				0.0003	Sb	45	0.15	0.05	2	0.0009
Cu	1.5		0.014	0.4	0.0002 ^c	Sc	30			0.1	0.004
Dy	50			0.5	0.0001 ^f	Se	100	0.03	0.05	3	0.0007 ^b
Er	60			0.5	0.0001	Si	90		1.0	10	0.03 ^a
Eu	30			0.2	0.00009	Sm	3000			2	0.0002
F					372	Sn	150		0.1	2	0.0005 ^a
Fe	5		0.06	0.1	0.0003 ^d	Sr	3		0.025	0.05	0.00002 ^d
Ga	75			1.5	0.0002	Ta	1500			1	0.0005
Gd	1800			0.9	0.0008 ^g	Tb	900			2	0.00004
Ge	300			1	0.001 ^h	Te	30	0.03	0.1	2	0.0008 ^k
Hf	300			0.5	0.0008	Th				2	0.0004
Hg	300	0.009	0.6	1	0.016 ⁱ	Ti	75		0.35	0.4	0.003 ^l
Ho	60			0.4	0.00006	Tl	15		0.1	2	0.0002
I					0.002	Tm	15			0.6	0.00006
In	30			1	0.0007	U	15000			10	0.0001
Ir	900		3.0	1	0.001	V	60		0.1	0.5	0.0005
K	3		0.005	1	0.0002 ^d	W	1500			1	0.005
La	3000			0.4	0.0009	Y	75			0.2	0.0002
Li	0.8		0.06	0.3	0.001 ^c	Yb	8			0.1	0.0002 ^m
Lu	1000			0.1	0.00005	Zn	1.5		0.02	0.2	0.0003 ^d
Mg	0.15		0.004	0.04	0.0003 ^c	Zr	450			0.5	0.0003
Mn	1.5		0.005	0.1	0.00007 ^d						

All detection limits are given in micrograms per liter and were determined using elemental standards in dilute aqueous solution. All detection limits are based on a 98% confidence level (3 standard deviations).

All atomic absorption detection limits were determined using instrumental parameters optimized for the individual element, including the use of System 2 electrodeless discharge lamps where available. Data shown were determined on an AAnalyst™ 800.

All ICP-OES (Optima 7000/7300) detection limits were obtained under simultaneous multi-element conditions with the axial view of a dual-view plasma using a cyclonic spray chamber and a concentric nebulizer.

Cold-vapor mercury detection limits were determined with a FIAS-100 or FIAS-400 flow injection system with amalgamation accessory.





















The detection limit without an amalgamation accessory is 0.2 µg/L with a hollow cathode lamp, 0.05 µg/L with a System 2 electrodeless discharge lamp. (The Hg detection limit with the dedicated FIMS-100 or FIMS-400 mercury analyzers is < 0.005 µg/L without an amalgamation accessory and < 0.0002 µg/L with an amalgamation accessory.) Hydride detection limits shown were determined using an MHS-15 Mercury/Hydride system.

GFAA detection limits were determined on an AAnalyst 800 using 50 µL sample volumes, an integrated platform and full STPF conditions. Graphite furnace detection limits can be further enhanced by the use of replicate injections.

Unless otherwise noted, ICP-MS detection limits were determined using an ELAN 9000 equipped with Ryton™ spray chamber, Type II Cross-Flow nebulizer and nickel cones. All detection limits were determined using 3-second integration times and a minimum of 8 measurements.

Letters following an ICP-MS detection limit value refer to the use of specialized conditions or a different model instrument as follows: ^a Run on ELAN DRC in standard mode using Pt cones and quartz sample introduction system. ^b Run on ELAN DRC in DRC mode using Pt cones and quartz sample introduction system. ^c Run on ELAN DRC in standard mode in Class-100 Clean Room using Pt cones and quartz sample introduction system. ^d Run on ELAN DRC in DRC mode in Class-100 Clean Room using Pt cones and quartz sample introduction system. ^e Using C-13. ^f Using Dy-163. ^g Using Gd-157. ^h Using Ge-74. ⁱ Using Hg-202. ^j Using S-34. ^k Using Te-125. ^l Using Ti-49. ^m Using Yb-173.

Atomic Spectroscopy Accessories

<p>Multiwave 3000</p> <p>   AAnalyst Optima ELAN</p> <p>Microwave sample digestion system</p> <ul style="list-style-type: none"> • Build-in cooling system to reduce total cycle time, improving productivity • Ideal for drying, evaporation, acid digestion and solvent extraction 	<p>FIAS</p> <p>   AAnalyst Optima ELAN</p> <p>Fully automated flow-injection system</p> <ul style="list-style-type: none"> • Simplifies and speeds up analyses requiring complex sample preparation such as Mercury and other hydride-forming elements 	<p>Specialized Software</p> <p>   AAnalyst Optima ELAN</p> <ul style="list-style-type: none"> • QC charting • Tools for 21 CFR compliance • Speciation software
<p>Autosamplers</p> <p>   AAnalyst Optima ELAN</p> <ul style="list-style-type: none"> • Flexible rack configurations • Fast, accurate random access • Corrosion-resistant samplign components • Flow-through rinse station to minimize sample-to-sample contamination 	<p>High-Throughput Sample-Introduction System</p> <p>  Optima ELAN</p> <ul style="list-style-type: none"> • Minimizes sample uptake and washout time • Throughput increased up to 2-3 fold • Eliminates sample contact with peristaltic pump tubing 	<p>AA Consumables</p> <p> AAnalyst</p> <ul style="list-style-type: none"> • HCL and EDL lamps • Graphite tubes • Standards
<p>Mercury Hydride System</p> <p>  AAnalyst Optima</p> <ul style="list-style-type: none"> • Highly sensitive determination of Mercury or hydride-forming elements 	<p>Graphite Furnace (for AAnalyst 400)</p> <p> AAnalyst</p> <ul style="list-style-type: none"> • Quick, easy interchange between flame and furnace • Low sample consumption (as low as a few μL) • Exceptional detection limits, down to the pg range 	<p>ICP-OES and ICP-MS Consumables</p> <p>  Optima ELAN</p> <ul style="list-style-type: none"> • Cones • Torches • Nebulizers • Standards

For more information on any of the products shown here, or for a complete listing of all atomic spectroscopy accessories available, please visit www.perkinelmer.com



PerkinElmer has been at the forefront of inorganic analytical technology for over 40 years. With a comprehensive product line that includes Flame AA systems, high-performance Graphite Furnace AA systems, flexible ICP-OES systems and the most powerful ICP-MS systems, we can provide the ideal solution no matter what the specifics of your application.

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