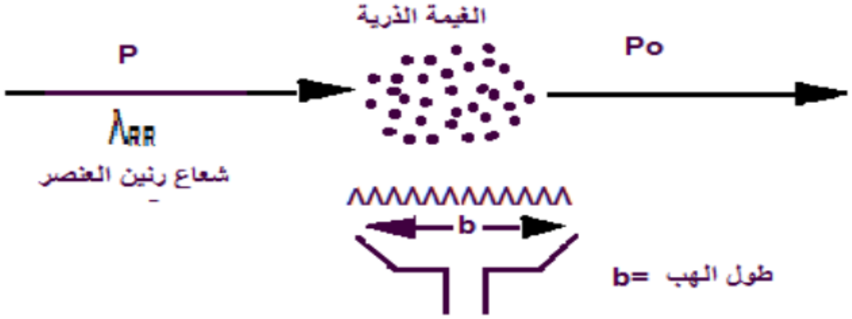
Atomic Absorption Spectrophotometry

Atomic absorption spectroscopy (AAS) is a spectroanalytical procedure for the quantitative measurement of chemical elements. AAS is based on the absorption of light by free ions that have been atomized from a sample. An alternative technique is atomic emission spectroscopy (AES).

In analytical chemistry the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analyzed. AAS can be used to determine over 70 different elements in solution, or directly in solid samples via electro thermal vaporization and is used in pharmacology, biophysics, archaeology and toxicology research.

The amount of absorption A is directly proportional to the concentration or number of free atoms of the element in the atomic cloud.



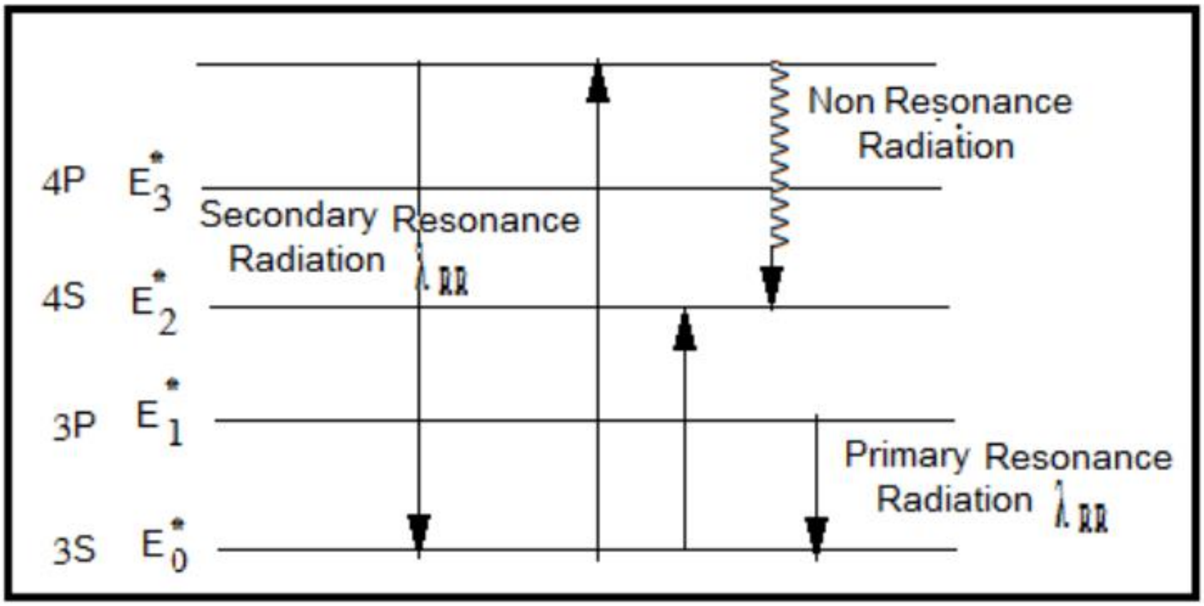
$$\log \frac{P^o}{P} = A = abC$$

Atomic absorption spectrometry has many uses in different areas of chemistry such as clinical analysis of metals in biological fluids and tissues such as whole blood, plasma, urine, saliva, brain tissue, liver, hair, muscle tissue. Atomic absorption spectrometry can be used in qualitative and quantitative analysis.

In atomic absorption analysis, the formation of an atomic cloud of metal-containing free atoms with a neutral charge is required. These atoms can only absorb the resonance beam emitted by the **Hallow cathode lamp, HCL**, and measure the absorbance.

What is the primary resonance beam, the secondary resonance beam, and the non-resonance beam?

When the molecule or atom gains energy, the electrons are excited and move to higher electronic orbits, when the electron returns to the ground state, it emits energy in the form of a light beam or photons, and it is a resonance beam because it has returned to the original orbit °E (ground state) , and it is a primary resonance beam if it returns from the first excited orbit, *E1, which is the highest intensity, and a secondary resonance beam if it returns from any other electronic orbit, and it is less intense than the first, and the beam is non-resonant if the electron returns to a non-basic electronic orbit and is not useful in spectral analysis



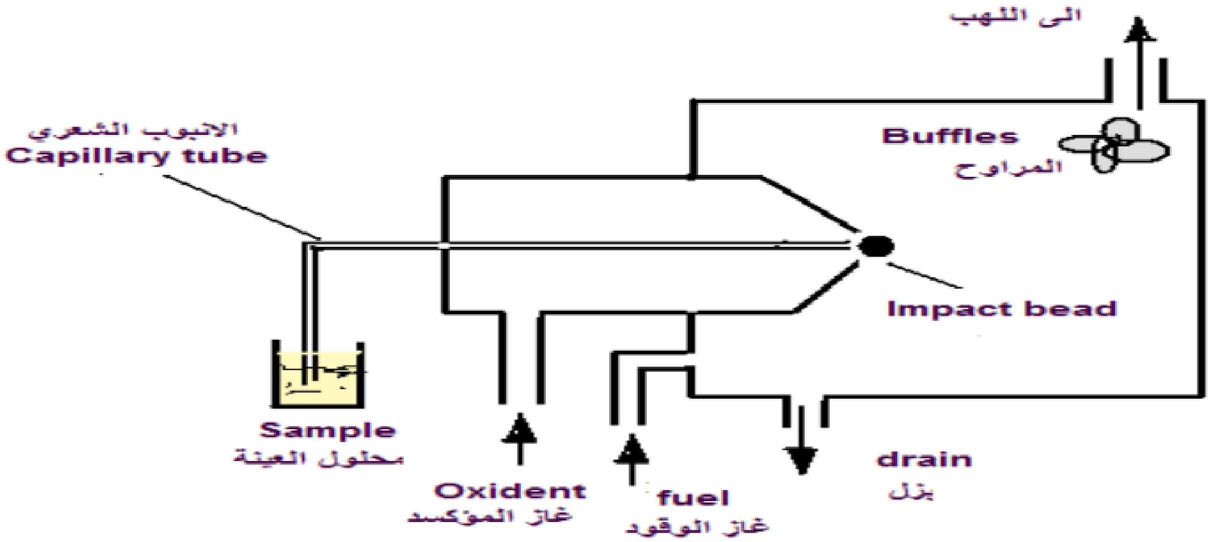
Nebulization

It is the process of converting the solution of the element into a spray or very small droplets using a nebulizer device by mixing the solution with fuel gas and oxidizer gas. The sample solution turns into a spray that reaches the flame, forming the atomic cloud of the element. The spray formed from the sample solution, fuel gas and oxidizer is called **Aerosol** or sometimes called **Mist**. There are two types of nebulizers.

1- Pneumatic Nebulizer

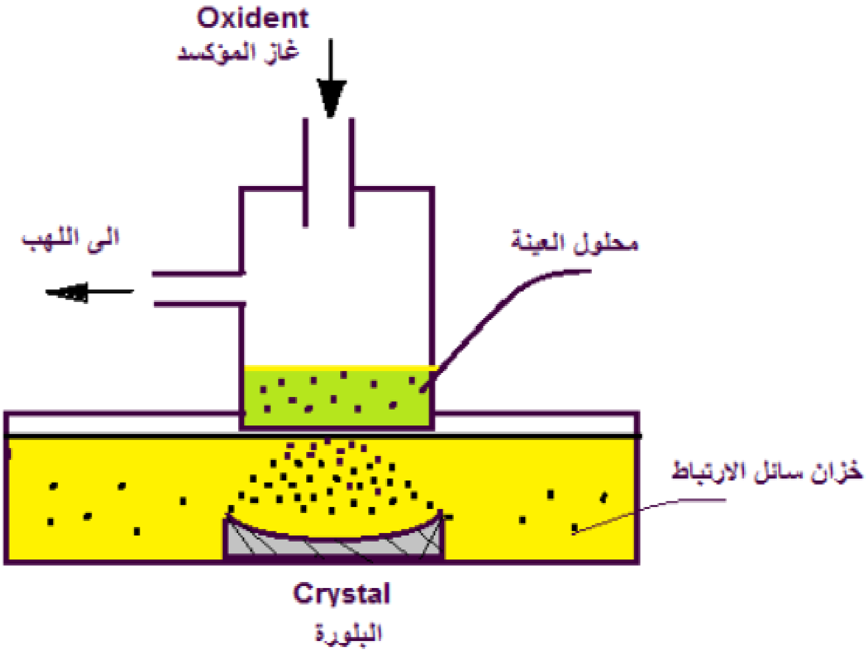
A tool made of plastic and there is a capillary tube to draw the sample solution. There is a vacuum around the capillary tube through which the oxidizing gas passes, which causes a pressure drop, so the sample solution is pushed out and enters the capillary tube. The efficiency of the nebulizer can be increased by placing a bead called an impact bead where the fast droplets collide and disintegrate as a result of the collision.

These small droplets are swept into the flame by fans, Baffles. The efficiency of this nebulizer is low and ranges between 10-20%, as 90% of the sample solution is expelled to the outside at a flow rate of 3-5 ml/min. It is neglected because the size of the droplets is large. This nebulizer is suitable for daily routine analysis and is inexpensive.



2-Ultrasonic Nebulizer

The ultrasonic nebulizer is efficient, around 40-50%, which is better than the air nebulizer. However, it is expensive due to the high cost of the crystal (the quartz crystal that makes it up). The ultrasonic nebulizer is not preferred for daily routine analysis because it requires changing the sample solution, which requires time and effort.



What are the factors that determine the diameter of the droplets?

1- Type of solvent used : Aqueous solvents are more difficult to nebulize than organic solvents, because the surface tension of organic solvents is lower, and the solution breaks into smaller droplets and reaches the flame in the form of smaller droplets, and the number of atoms released is greater and the sensitivity is higher.

2- Rate - or speed of spraying the solution.

3- Speed of the oxidizing gas and fuel gas

There is an equation of these factors, **Sakuyama equation**, which helps in calculating the diameter of the droplet, which is called the **Sauter mean** and is measured in micrometers µm

$$d^{o} = \frac{565}{v}\left(\frac{\gamma}{\rho}\right)^{0.5} + 597\left[\frac{\eta}{(\gamma\rho)^{0.5}}\right]^{0.45}\left(\frac{1000\,Q_{liq}}{Q_{gas}}\right)^{1.5}$$

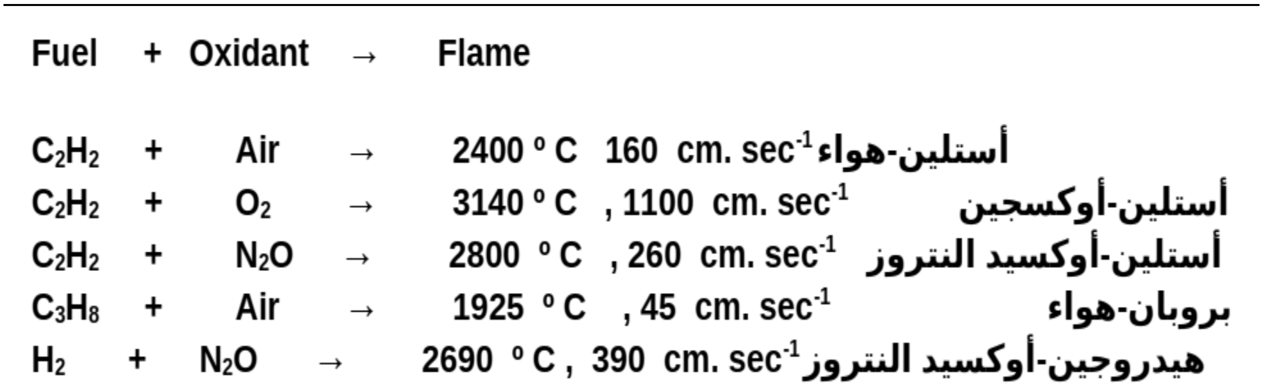
Where: v = represents the velocity of the oxidizing gas , η = viscosity of the solution , ρ = density of the solution , γ = surface tension , Q Liq, Q gas the flow rate of the solution and gas

Atomization

1- Flame Atomization

2- Non- Flame Atomization

1- Flame Atomization: It is the process of converting an element into free, neutral atoms using a flame, which results from mixing and reacting fuel gas and oxidizer gas. Acetylene gas is often used as a fuel, and air or nitrous oxide N2O is the oxidizing gas. Types of flames



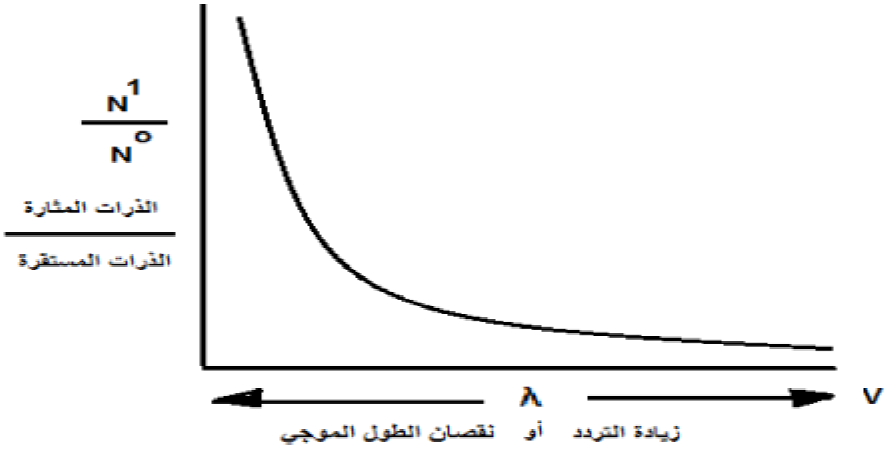
Fuel	+	Oxidant	→	Flame		
C_2H_2	+	Air	→	2400 °C	160 cm. sec^{-1}	أستلين-هواء
C_2H_2	+	O_2	→	3140 °C	, 1100 cm. sec^{-1}	أستلين-أوكسجين
C_2H_2	+	N_2O	→	2800 °C	, 260 cm. sec^{-1}	أستلين-أوكسيد النتروز
C_3H_8	+	Air	→	1925 °C	, 45 cm. sec^{-1}	بروبان-هواء
H_2	+	N_2O	→	2690 °C ,	390 cm. sec^{-1}	هيدروجين-أوكسيد النتروز

- The acetylene-air flame is used to analyze and estimate 30 elements that are not refractory oxides non-molten, such as: Mn, Fe, Pb, Mg, Cd, Cr, Co, Cu, Zn.
- **Refractory Elements** are the elements that form refractory oxides that resist melting when heated in a conventional flame, and therefore oxygen or nitrous oxide is used as an oxidizing gas to analyze them. , The acetylene-nitrous oxide flame is used to analyze refractory elements that are refractory oxides non-molten using a conventional flame, i.e. it requires a very high temperature, such as: Al, Ta ., Ti, V, Si, P, Ge, B, W, Be.
- The hydrogen nitrous oxide flame - N_2O is used to analyze organic samples that give a smoky flame such as benzene, xylene and oil because the ratio of carbon to oxygen is high

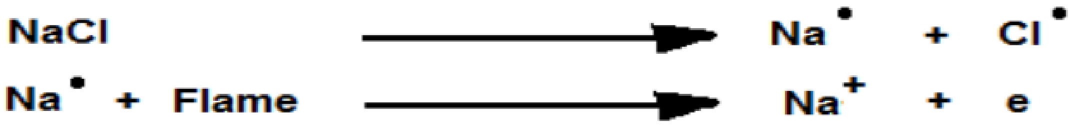
The flame temperature depends on the type of fuel gas and oxidizer gas and their ratio, i.e. the ratio of oxygen to carbon, and on the size of the sample sprayed into the flame. The temperature determines the ratio of excited atoms N1 to stable, neutral atoms No. In atomic absorption, the ratio of excited atoms N1 to stable, neutral atoms No of the element must be small and is calculated using the Boltzman Equation.

$$\frac{N_1}{N_\circ} = \frac{g_1}{g_\circ} e^{-\Delta E/KT} = \frac{g_1}{g_\circ} e^{-hv/KT}$$

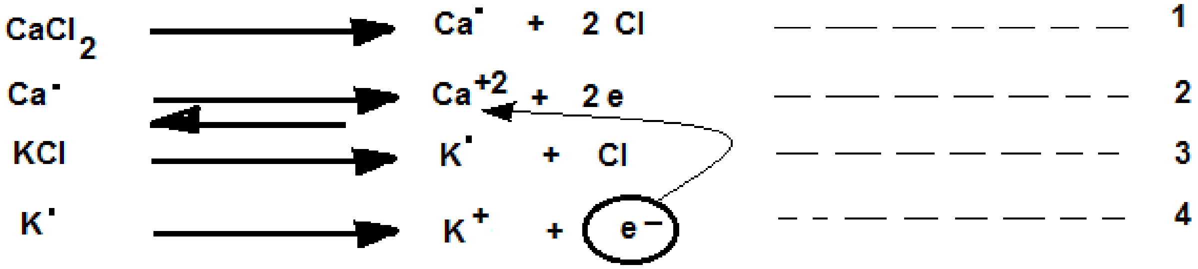
In atomic absorption, the smaller the value of the fraction N1/ No is, meaning that the percentage of excited atoms is small compared to the stable neutral atoms that absorb the element's resonance beam, the better and more accurate the analysis is the atomic absorption method is preferred, to analyze these elements that emit atomic spectra at short wavelengths, i.e. high frequencies, because the value of the fraction is small such as S, P, Te, As, Ce, Ca, and Zn. As for the elements that emit their spectra at long wavelengths, i.e. low frequencies, the value of the fraction N1/ No is high, i.e. the percentage of excited atoms is high, and for this reason, the atomic emission method is preferred for their analysis.



The flame temperature must be maintained to obtain neutral atoms. If the temperature is high, the element may ionize and we will have ions instead of free atoms.



Because it is not possible to obtain a flame with a constant temperature, the ionization process of atoms is stopped by adding an ionization buffer: Ionization Buffer, which is a salt of a substance or metal with an ionization potential lower than the ionization potential of the metal to be analyzed, such as when analyzing calcium chloride, $CaCl_2$, we obtain free and neutral Ca and Cl atoms, and part of the Ca atoms may ionize into Ca^{+2} ions. The ionization of calcium Ca into Ca^{+2} is undesirable because it does not absorb the resonance beam, so an ionization buffer is added, such as potassium chloride, KCl, where the ionization potential of potassium K is lower than the ionization potential of calcium



The ionization of potassium atoms K into K^+ ions gives an increase in the number of electrons, which leads to stopping the ionization process of calcium atoms. The amount of ionization buffer that must be added to the sample solution to stop the ionization of the metal required for analysis, can be calculated by using the Saha Equation:

$$\text{Log } K_i = -\frac{5040\ E_i}{T} + \frac{5}{2}\ \text{Log } T - 6.49 + \text{Log}\left(\frac{g_{m+} + g_{e-}}{gm}\right)$$

Where, Ki = ionization constant of a buffer metal, Ei = ionization potential of a buffer metal, -gm+, gm, ge= Statistical weights of the metal ion, metal atom and electron, T = absolute temperature.

The concentration of the buffer ionization is calculated from the following equation

$$K_M\, C_M = K_M\, C_M$$

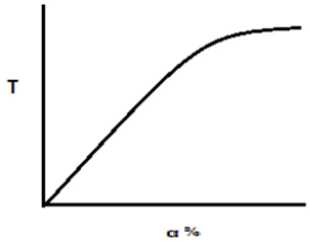
الفلز داري التاين

metal ionization buffer

When finding the value of the ionization buffer concentration C, concentration is multiplied by 100 to prevent ionization completely, and the weight is added to the solution of the metal sample to be analyzed. The value of KM can be used to calculate the ionization degree of the metal α to choose the best temperature that gives the highest percentage of neutral atoms in the stable state, i.e. the lowest ionization of the metal.

$$\alpha\,\% = \left(\sqrt{\frac{K_i}{P}}\right) X\ 100$$

P = التركيز الكلي للبخار الذري في اللهب وهو الضغط الذي تولده الذرات.

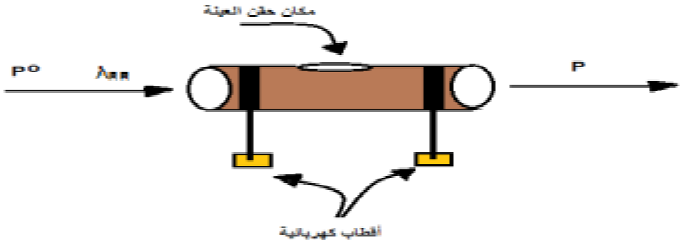


2- Non- Flame Atomization

a) **Electro thermal Atomization (ETA)**
b) **Cold Atomization**
c) **Hydride Generation Method**

a) Electro thermal Atomization (ETA)

The element is atomized using an electric current and using a graphite furnace, which is a small cylindrical tube open at both ends. The sample is injected with a small volume of 10 microliters using a micro syringe through an opening or hole at the top of the tube. An inert gas such as nitrogen or argon is passed to prevent oxidation of the tube (furnace) during heating. The furnace is heated electrically by two electrodes, where the sample is heated in three steps:



1-Dry Step

The solvent is evaporated and the temperature may reach 100 ° C, especially if water is the solvent.

2-Ash Step

In which the largest possible part of the sample components is removed from the organic or inorganic source material and the temperature depends on the nature of the sample source and ranges between 150 - 1500°C.

3- Atomies Step

The temperature of the graphite furnace is regulated to atomize the element and the degree varies depending on whether the element is easy or difficult to volatilize and the temperature ranges between 1100-3000 °C and sometimes higher. The sample turns into atomic vapor, an atomic cloud and the element's resonance beam λRR passes with a Po intensity inside This atomic cloud, which is inside the graphite furnace, where part of the radiation is absorbed and then comes out with an intensity of P.

Graphite is chosen for the manufacture of furnaces for the following reasons:

1- It has a high melting point of up to 3500°C

2- It has a high electrical conductivity.

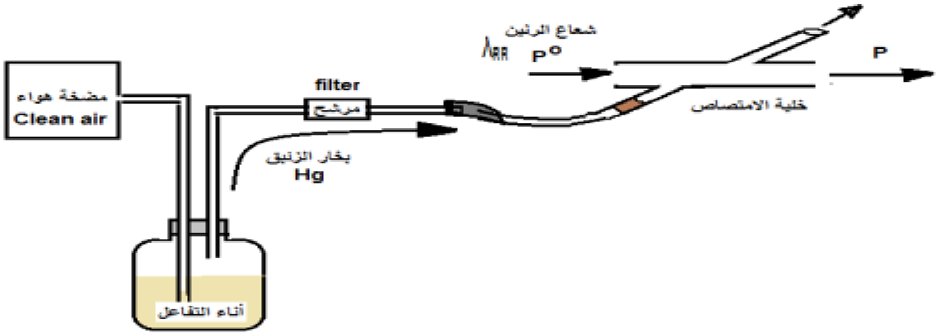
3- It has a high thermal conductivity.

Disadvantages: It oxidizes and burns in air, so it is surrounded by an inert gas such as nitrogen or argon.

Flame Atomization	Electro thermal Atomization
1-Less sensitivity because atomization is done in an open atmosphere pmm	1-High sensitivity because atomization takes place inside the oven ppb
2- Operating the flame may cause some hazards..	2- Graphite oven is safer
3- The sample size required for analysis is high	3- The sample size is very small and this is useful in analyzing biological, forensic and environmental samples.
4- . The components must be removed from the sample and separated before analysis.	4- The components can be removed from the sample during the Ash step
5- Recovery or repeatability is very good	5- Recovery or repeatability is low especially if the samples are heterogeneous

b) Cold Atomization,

also called the cold vapor method, is used only to estimate organic and inorganic mercury. It is more accurate, sensitive and easier than other methods for estimating mercury, as the sensitivity reaches 0.2 nanograms.

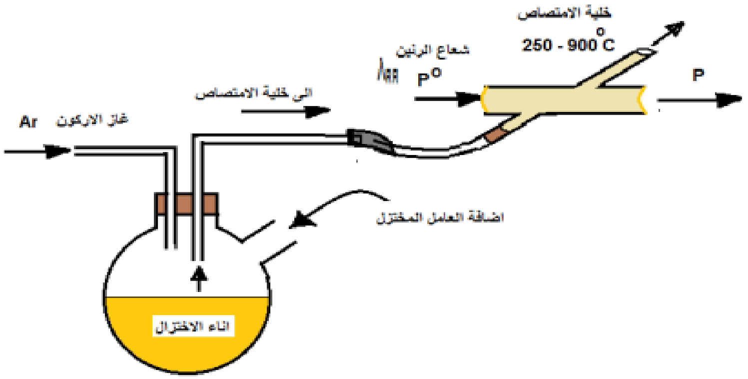


The method includes the oxidation of the organic material where mercury is converted to mercury(II) ion Hg^{+2} Using a mixture of potassium permanganate, $KMnO_4$ and dilute sulfuric acid, the sample is heated for an hour at a temperature of 70°C, where we obtain the mercury(II) ion, Hg^{+2}. To reduce the mercury(II) ion Hg^{+2} to mercury Hg, a solution of $SnCl_2$ is used in an acidic environment where the mercury ion is converted to free mercury atoms Hg° and a stream of air or argon is passed to pull mercury atoms into the absorption cell, through which the element resonance beam λRR passes, which is absorbed by the atoms and the absorbance is measured

C) Hydride Generation Method

There are several elements, including Sb, As, Bi, Ge, Sn, Te, Se, Pb that can be converted into volatile hydrides using reducing agents such as sodium boronate $NaBH_4$ in an acidic medium of 1 M hydrochloric acid HCl. These hydrides are separated from the sample and are swept away using an inert gas such as chlorine into an absorption cell heated to a temperature of 250-900 °C, where the element's λ RR resonance beam is passed and the absorption is measured.

$$As^{+3} + 3H^{-} \longrightarrow AsH_3\uparrow$$
$$Sn^{+2} + 2H^{-} \longrightarrow SnH_2\uparrow$$

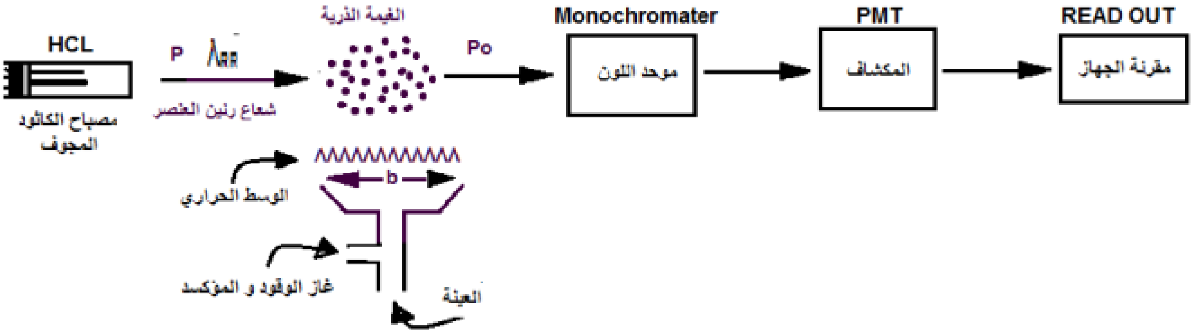


In the absorption cell, due to the presence of a high temperature, the positive ions of these hydrides are transformed into free, neutral atoms that have the ability to absorb their resonance beam that passes through the absorption cell.

$$\mathrm{2\,AsH_3\uparrow \longrightarrow 2\,As^{o} + 3H_2}$$

$$\mathrm{SnH_2\uparrow \longrightarrow Sn^{o} + H_2}$$

Atomic Absorption Spectrophotometer



1- Resonance Radiation Source

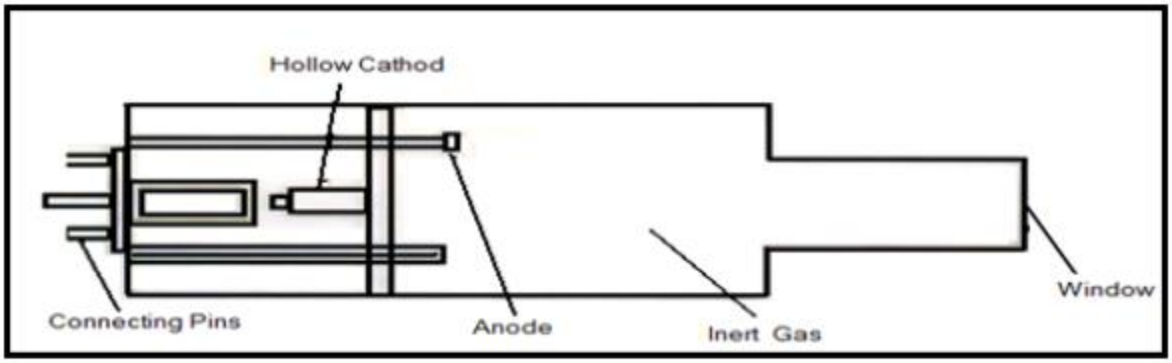
a) Hollow Cathod Lamp HCL

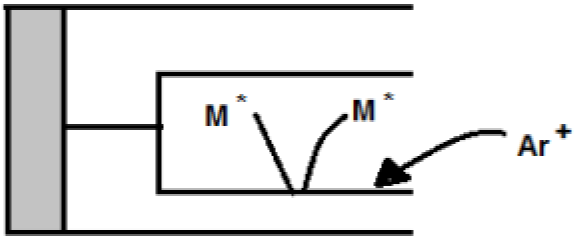
It gives linear spectra of the elements, and consists of a transparent glass bulb cylinder evacuated from air and contains an inert gas such as argon Ar or neon Ne and sometimes xenon Xe at a low pressure of 10 torr. Inside it is the cathode pole, which is in the form of a small cylinder with a diameter of 2 mm and a length of 0.5 cm so that the discharge is focused on a narrow area and to increase the intensity of the resonance beam. It is made of the metal required to obtain or emit its resonance beam. As for the positive pole, the anode, it is a piece of tungsten metal, w near the cathode. Both poles are based on a base connected to the electric current, where an electric discharge occurs inside the cathode. How?

When the electrons exit the cathode, they collide with the atoms of the inert gas argon Ar and give a positive argon ion Ar+, and this accelerates towards the negative pole with high energy and collides with the surface of the cathode because it is negatively charged, and the excited metal atoms *M exit or are released from the surface of the cathode

$$\mathrm{Ar + e^{-} \rightarrow Ar^{*} + 2\,e^{-}}$$

$$\mathrm{Ar^{*} + M \rightarrow M^{*}}\ \text{Excited state}$$





The process of metal atoms leaving the surface of the cathode is called spatter and these atoms give the element's resonance beam when they lose the energy that they acquired in the form of a photon or spectrum symbolized by RRλ, which is Resonance Radiation, which passes through the atomic cloud of the element and the absorbance is measured. The lamp life is about 1000 hours and it is preferable to use new lamps because they give a linear relationship between absorbance A and concentration C. After all, the old lamp gives a non-linear relationship. HCL lamps are made of two types:

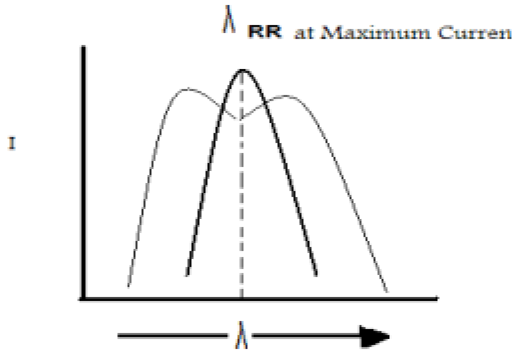
1- Single metal, i.e. the cathode is made of a single metal

2- Multi-metal, i.e. the cathode is made of a mixture or an alloy containing a mixture of metals and the metals must be chosen so that they do not interfere with each other spectrally, i.e. their wavelengths do not interfere, such as zinc, Zn, 213 nm sodium, Na 589 nm nickel, Ni 232 nm

The choice of the inert gas inside the lamp depends on:

1- The gas ionization potential should be equal to the metal ionization potential for which the resonance beam is to be obtained.

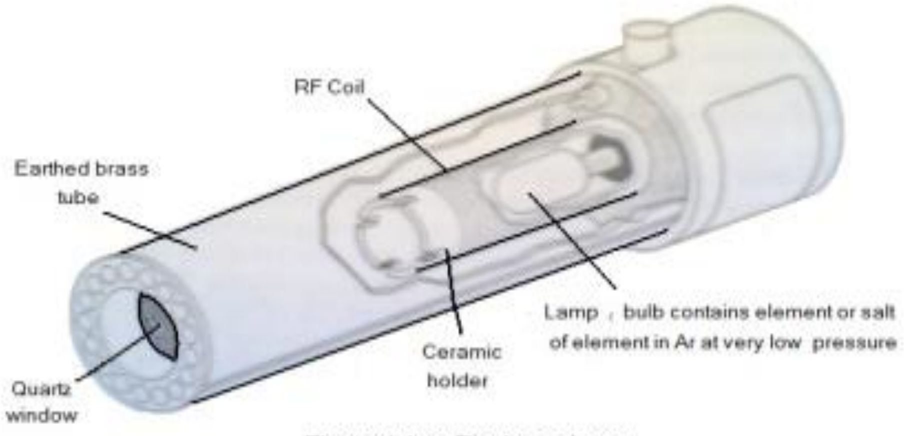
2- The wavelength of the metal resonance beam should be spaced and different from the inert gas. We have elements such as Lead, Pb, Iron, Fe, Nickel, Ni. Ne gas is preferred over argon Ar because it gives RRλ close to its resonance beam. As for the elements of arsenic As and aluminum Al, it is preferable to use argon Ar gas. Each element has a maximum current that must be determined and passed through the lamp. Zinc Zn must pass a current of no more than 10 mA, while copper Cu has a maximum current of 25 mA, i.e. no more than that. Why?



If a current greater than this maximum current is passed, what is known as reverse self-atomic absorption occurs, i.e. large quantities of metal atoms will be emitted from the surface of the cathode and these large quantities will absorb the resonance beam emitted by the atoms of the element, i.e. the same element absorbs the spectrum emitted by its atoms, and for this reason the peak is exposed and bulged, so it is recommended to use 65-75% of its maximum current in the analysis because it gives the best result and increases the absorbance by more than 60%, and the maximum current is used in the analysis of elements that give weak resonance radiation such as arsenic, As, selenium, Se, tellurium Te, germanium Ge, cesium Cs.

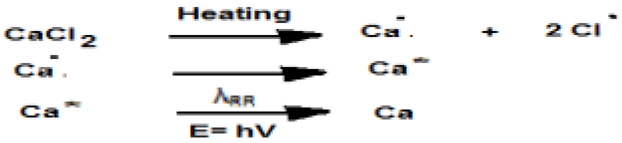
b) Electrode less Discharge Lamp

It is a ceramic cylinder surrounded by an induction coil or a copper wire with a radio frequency of 245 MHz and a power of 200 watts. It is connected to a radio frequency electric current source. The ceramic cylinder contains a quartz bulb with a length ranging between 8-3 cm and a diameter of 1 cm, containing a small amount of powdered metal of the element required to obtain a resonance beam or one of its salts. The bulb contains an inert gas such as Ar or Ne at a pressure of 10 torr to obtain a line spectrum.



Electrodeless Discharge Lamp

How does an EDL lamp work? When the ceramic cylinder is heated, the bulb containing the metal salt is heated and the metal is heated as a result of heating the ceramic container and the salt CaCl2 decomposes into Ca and Cl and excited atoms emerge after absorbing energy. The calcium atom Ca absorbs energy and is excited into *Ca and when it returns to its original state, i.e. losing energy, it emits a RRλ



The bulb contains a small weight of mercury 1 mg with the metal powder and its benefit is that the mercury vapor prevents the precipitate of metal atoms on the wall of the glass bulb and thus increases the efficiency and life of the lamp. It is preferable to use the EDL lamp over the HCL lamp to analyze elements with a weak resonance beam such as P, Se, Te, As, S or that give a resonance beam in the vacuum region Far UV.

The reason is that the EDL lamp gives a more intense and sensitive resonance beam than the HCL lamp and the reason is that the excitation occurs in a small glass bulb.

The HCL lamp is distinguished from the EDL lamps by the following:

1- The EDL lamp gives a more intense and sensitive resonance beam than the HCL lamp because the process occurs inside a small glass bulb and not a cylinder

2- The EDL lamp has a longer life than the HCL lamp because the atoms of the element are confined inside the bulb

3- In the case of the EDL lamp, we need a special source of electrical energy, so the HCL lamp is preferred

4- The EDL lamp is manufactured for a limited number of elements 17 elements while the HCL lamp is manufactured for a number of 36 elements or more.

5- Elements that give resonant radiation in the vacuum region of UV, Vacuum UV, i.e. have a wavelength less than 200 nm. It is preferable to use an EDL lamp over an HCL lamp when analyzing them. 6- The EDL lamp is more expensive than the HCL lamp.

2-Monochromator

It is located after the absorption cell, where it isolates other foreign spectra and passes only the resonance beam of the element to be analyzed (RRλ), which weakens after passing through the atomic cloud.

3-Detector

It is the photomultiplier tube (PMT) and the beam falls on it after it exits the monochromator It converts the light energy into electrical energy that is transferred to the device's reader.

Calibration or Standardization:

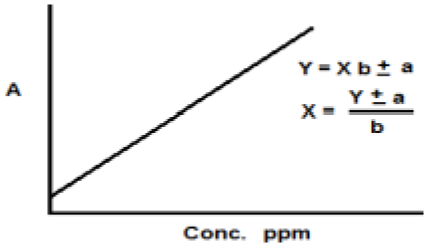
There are two methods or methods of calibration or standardization used in flame and non-flame atomization, which are:

1- Direct calibration

2- Indirect calibration (standard addition method)

Direct Calibration

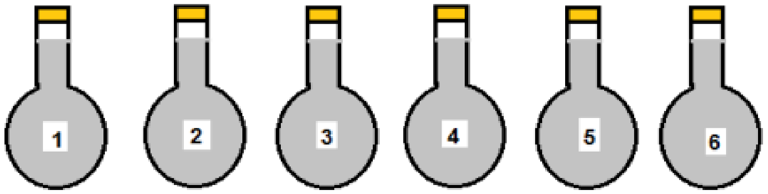
A calibration curve can be prepared from the same element in a sample of unknown concentration using standard solutions with different concentrations of one of the element's salts. For example, when analyzing lead in a sample of lead nitrate, $Pb(NO_3)_2$, aqueous calibration solutions of lead nitrate containing known concentrations of Pb^{2+} are prepared. The absorbance of these solutions is measured, a calibration curve is drawn between the concentration values and the corresponding absorbance, and the concentration of the unknown is calculated from the equation of the straight line.



This method is used when the element to be analyzed is present in an uncomplicated sample, which does not contain many elements because the complex sample gives a curved calibration curve line, i.e., a non-linear relationship, and the calibration line is straight within a certain range of concentration. It is prepared using 4 or 5 standard solutions and requires zeroing the device using the solvent (Blank) , where the value of the blank absorbance is subtracted from the values of the sample absorbance readings. As for the electrothermal method, the sample is re-injected several times.

Standard Addition Method

When the sample is very complex and contains a large number of elements and it is difficult to remove the effect of the sample matrix, which causes chemical interference with the sample that affects the analysis result, such as when estimating calcium in a cement sample containing: Al_2O_3, SiO_2, Na_2O, Fe_2O_3, CaO, MgO, SO_4^{-2}. A reaction occurs between calcium and silica, forming $CaSiO_3$, which is a substance that is difficult to atomize. Therefore, the standard additions method is used because it eliminates the interference of elements with the sample and removes chemical interferences and makes calcium in the same experimental conditions in the standard and unknown solution. Therefore, the analysis result is accurate. This method is summarized in adding different volumes of a standard solution of the ion of the element required to be analyzed to all volumetric flasks that contain a fixed volume of the unknown sample solution. For example, 5 volumetric flasks are prepared and a fixed volume of 5 ml of the cement sample solution is added to them, and different volumes, i.e. different concentrations of the standard calcium solution are added to them, and the volume is completed to the mark with distilled water, as shown in the following example

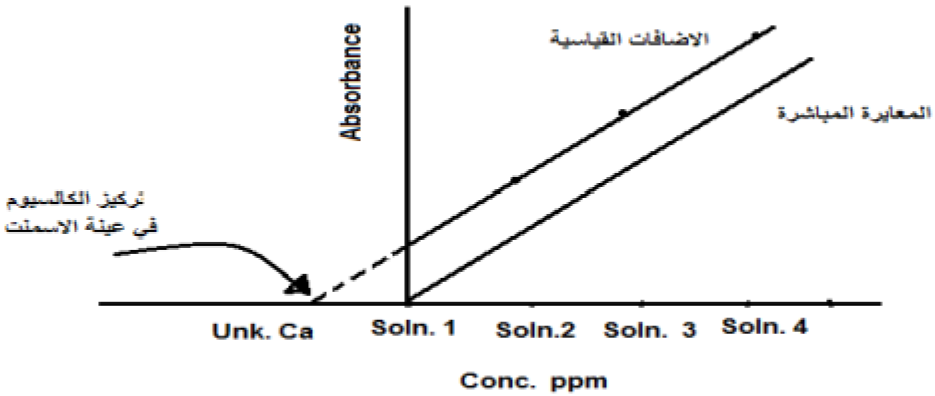


عينة الاسمنت	مللتر	0	5	5	5	5	5
محلول Ca القياسي	مللتر	0	0	0.5	1.0	1.5	2
حامض	مللتر	1	1	1	1	1	1
ماء مقطر لاايوني	مللتر	9	4.0	3.5	3.0	2.5	2

وبعد ترزيذ العينات وقياس الامتصاصية نحصل على القراءات الآتية :

رقم المحلول	الامتصاصية	الامتصاصية المصححة
1	--------	--------
2	0.05	--------
3	0.2	0.15
4	0.49	o.44
5	0.80	0.75
6	1.12	1.07

If the two lines are parallel, i.e. the slope of the lines is equal as in the figure below, we conclude that the interferences are few and negligible, and calcium can be analyzed by either method because there are no chemical interferences and the behavior of calcium is similar in both methods. If the two lines are not parallel, i.e. the slope of the lines is not equal, i.e. the behavior and conduct of calcium are not similar, so the standard addition method must be followed to make the calibration curve and calculate the concentration



Atomic Absorption Interferences

1- Chemical Interferences

These are the interferences that hinder the transformation or formation of neutral free atoms due to the interaction of other elements present in the sample with the element to be analyzed, which leads to the formation of heat-resistant, refractory compounds with the element to be estimated, for example, to estimate calcium in the presence of phosphate, which reacts with the calcium ion to give calcium pyrophosphate $Ca_2P_2O_7$, or when estimating magnesium, Mg, in the presence of aluminum, a thermally stable compound is formed, which is the aluminum magnesium compound. These interferences can be eliminated either by raising the flame temperature or adding a releasing agent called a releasing agent. This reagent reacts with the interfering materials, phosphate and aluminum. Among the releasing reagents are lanthanum chloride $LaCl_3$ or strontium chloride $SrCl_2$, which react and give a stable complex with phosphate and prevent its reaction with calcium.

$$LaCl_3 + Ca^{+2} + PO_4^{-3} \longrightarrow LaPO_4 + Ca^{+2}$$

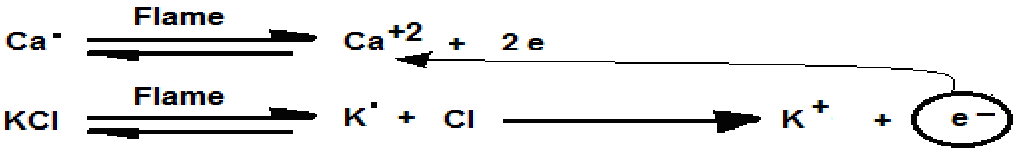
2-Physical Interferences

These interferences occur due to the difference in the physical properties of standard solutions and solutions of unknown samples such as the difference in viscosity, type of solvent, acid concentration, etc. which leads to a change in the rate and efficiency of atomization and dispersion as the organic solvent increases the rate of atomization and dispersion such as the alcoholic solution of silver and the aqueous solution of silver. Alcohol dispersion is better than water because the van der Waals forces are less than in water, in addition to the ease of combustion of the organic solvent compared to the aqueous solution which reduces the flame temperature. There is another interference or effect that arises due to the spectra called spectral interference which occurs due to the presence of molecules or other elements that absorb the beam at the wavelength of the analyzed element and is eliminated and its effect is removed by background correction methods

3- Ionization Interferences

Some metals give ions in the flame instead of free neutral atoms that have the ability to absorb the element's resonance beam. This leads to a decrease in the sensitivity of the analysis. To prevent ionization, an electrolytic solution of an easily ionized metal, such as KCl Ionization buffer, is added to the sample.

The required KCl ionization buffer concentration is calculated using Saha's equation. To obtain electrons from the ionization buffer, an ionization buffer with an ionization potential lower than the ionization potential of the element to be analyzed is chosen.



Background absorbance correction methods

Spectral interference occurs when other molecules absorb the element's resonance beam at the wavelength of the element to be analyzed and is called background absorbance and occurs when there are the following factors:

1- Molecular absorbance

2- Molecular scattering

To remove these factors, we use background correction methods, which are:

A- The two-line spectral method:

The first step includes passing the element's resonance beam in the atomic cloud or flame for that element and recording the absorbance A1, representing the atomic absorbance with the molecular absorbance. The second step includes passing a resonance beam close to the resonance beam of the element to be analyzed in the atomic cloud and measuring the absorbance A2, which represents the molecular absorbance only, and the difference between these absorbances gives the true absorbance value.

B- D2 Lamp Method

The deuterium lamp (D2 Lamp) will work in addition to the HCL lamp. The method involves passing the resonance beam of the element to be analyzed RRλ emitted by the HCL lamp in the atomic cloud and measuring the atomic absorbance and the background molecular absorbance, which is symbolized by A2. At the same time, the continuous spectrum of hydrogen emitted by the deuterium lamp is passed and the background molecular absorbance is measured because the beam is not resonant and therefore is absorbed only by the scattered molecules, which is symbolized by A1. The background is corrected by the difference between the absorbances, which gives the value

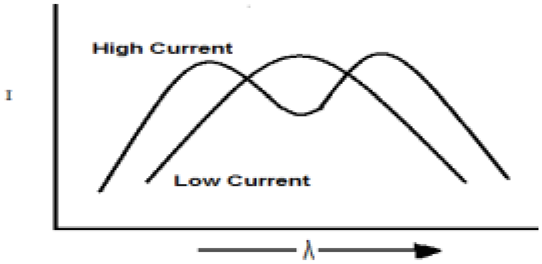
$$A_{at} = A2 - A1$$

C- Self- Reversal Method

It is also called the self-reflection method, only the HCL lamp is used, and the method is summarized from the fact that the absorbance decreases when a high current is passed through the lamp, causing reverse self-absorption, as follows:

First, a high current of 500 milliamperes is passed through the lamp, and the absorbance is recorded, which represents the absorption of the spectrum by non-atomic particles only, the background absorbance, because it is a non-resonant beam and no atomic absorption occurs, and it is symbolized by A1. The second step is done by passing a low current of 10 milliamperes through the lamp, which gives an absorbance value that represents the atomic absorbance by the free atoms, in addition to the non-atomic molecular absorbance, the background absorbance, and it is symbolized by A2, and the background is corrected by calculating the difference between the absorbances.

$$A_{at} = A2 - A1$$



Sensitivity

The sensitivity in atomic absorption is the concentration of the element in parts per million ppm, which gives an absorbance of 0.0044.

$$\text{Sensitivity} = \frac{0.0044 \times C}{A}$$

Benefits of sensitivity:

1- Knowing the efficiency of the device by measuring a known concentration and comparing the expected results

2- It is taken as a measure of the validity of the device as sensitivity decreases with age.

3- Calculating the range of concentration of samples that give the maximum absorbance and are between 100 - 10 times

Detection limit

The analytical detection limit of an element using the atomic absorption method is the lowest concentration of the element that gives a signal (S) to noise (N) ratio of 2. The detection limit is calculated as follows:

$$D.L = \frac{2\ S\ C}{\bar{X}}$$

$$S = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$$

C = concentration, $\dot{X}$ = absorbance rate, S = standard deviation, N = number of readings

Applications of atomic absorption analysis:

1- Atmospheric air: Atmospheric air contains metal oxides, metals, non-metals, etc., and metals are analyzed by atomic absorption.

2- Food and beverages : Food, meat, fruits, and vegetables can be analyzed by taking a specific weight of them and dissolving them in H_2SO_4 + HNO_3 or HNO_3 + $HClO_4$ acid and heating them until the white vapors are no longer released or , before drying, then diluting them with ionic water to the mark and the absorbance is measured by an atomic absorption spectrometer. As for beverages, most of which are aqueous, the CO_2 gas is first disposed of, then diluted with water and the absorbance is measured.

3- Oil and its derivatives: Oil contains vanadium V, nickel Ni, and other elements in the form of organic compounds and is treated in a special way, where the oil sample is diluted with an organic solvent.

4- Silicon materials : Silicon materials are dissolved before atomization and preferably dissolved in acids.

5- Soil and plants: Nutrients and toxic elements are estimated by electrothermal atomization and by the standard addition method. When estimating volatile elements, the wet method is used, i.e. adding acid or by extracting elements of plant importance.