Pharmaceutical Instrumental Analysis

الأستاذ الدكتور جمعه الزهوري (دكتوراه صيدلة-ألمانيا 1991)

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Faculty of Pharmacy

ATOMIC Spectroscopy

مقياس الطيف الذري

Atomic Spectroscopy

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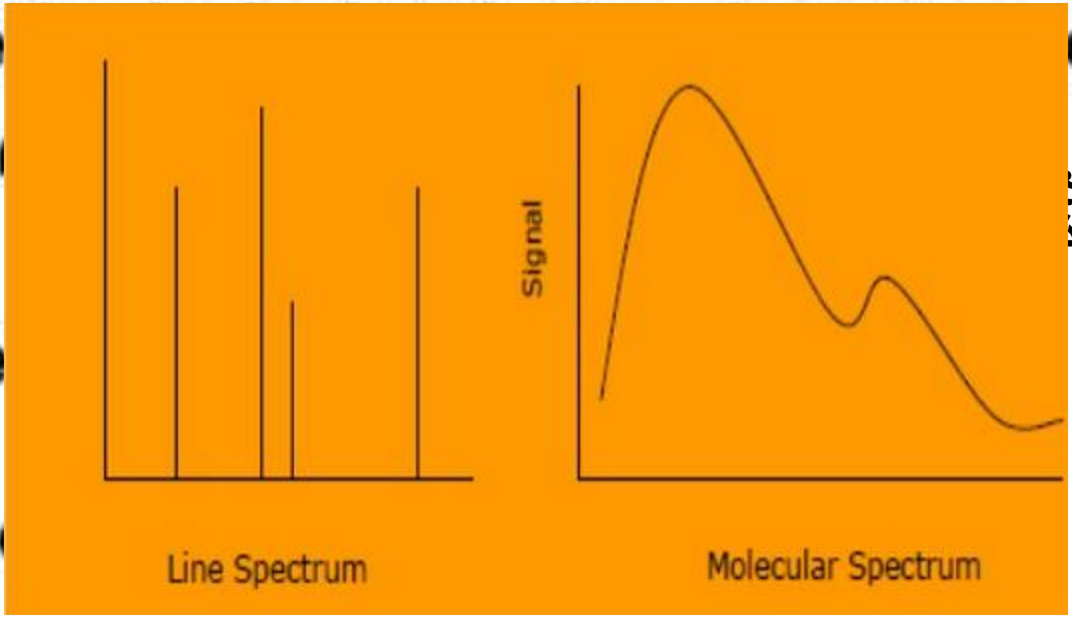


- تتعامل الطريقة م
امتصاص أو اصدار ال
للأشعة
- ذرات
- الطيف خطي
- كيفي +كمي

Specific spectral lines can be used for elemental analysis - both qualitative and quantitative.

Atomic Spectroscopy

Atomic emission Spectroscopy

AES (Flam)

مقاس ضوء الأصدار(الأنبعاث) الذري أو مقياس الضوء اللهبي

Atomic absorption Spectroscopy

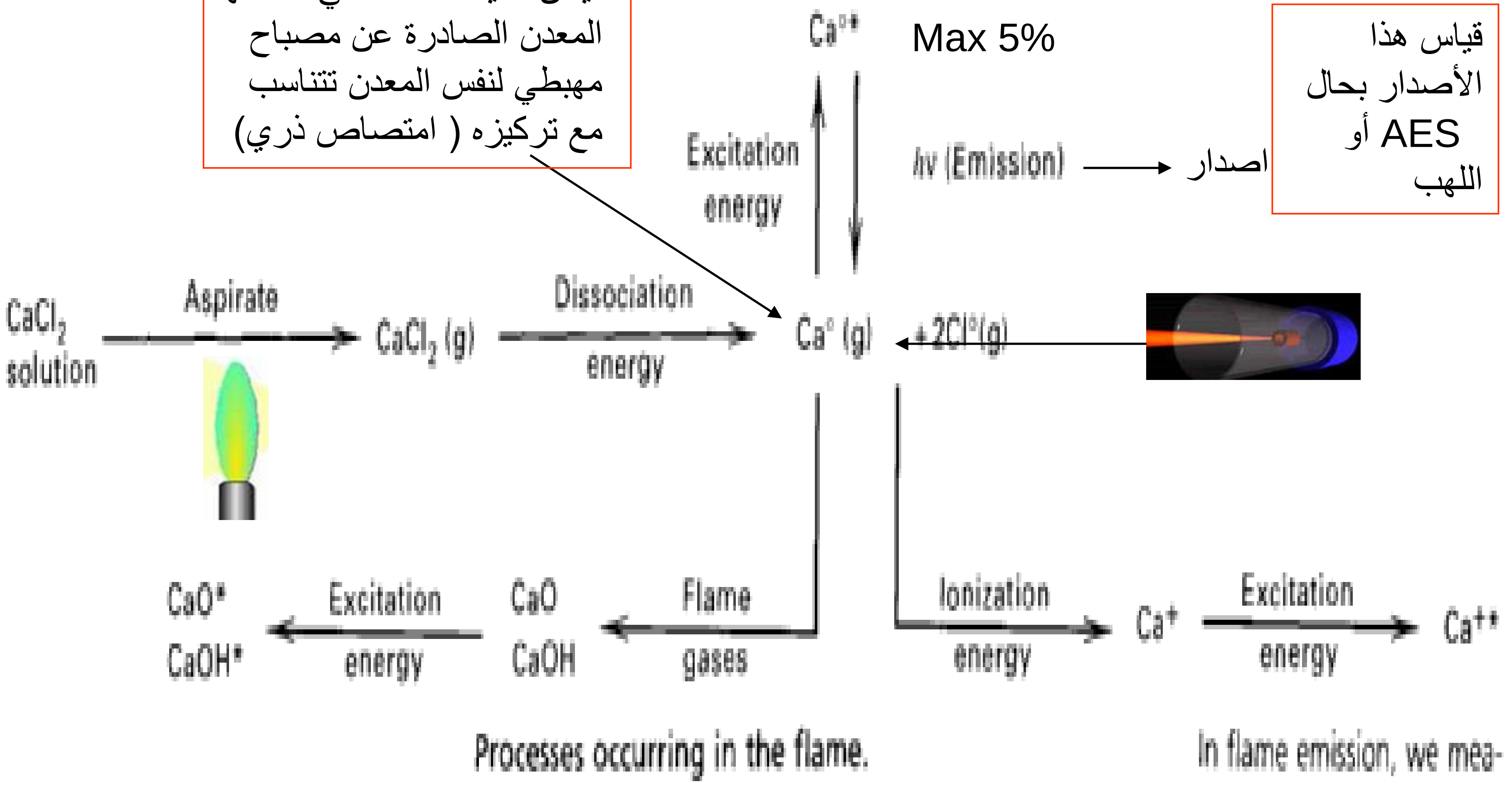
AAS

مقياس الطيف الضوئي بالأمتصاص الذري

قياس كمية الأشعة التي امتصها المعدن الصادرة عن مصباح مهبطي لنفس المعدن تتناسب مع تركيزه (امتصاص ذري)

Max 5%

قياس هذا الأصدار بحال AES أو اللهب



Processes occurring in the flame.

In flame emission, we measure Ca^{o*}. In atomic absorption, we measure Ca^o.

Prof. J. Al-Zehouri

Atomic Emission Spectro-scopy(-metry) AES

ATOMIC EMISSION SPECTROMETRY

(*Ph. Eur. method 2.2.22*)

Atomic emission spectrometry is a method for determining the concentration of an element in a substance by measuring the intensity of one of the emission lines of the atomic vapour of the element generated from the substance. The determination is carried out at the wavelength corresponding to this emission line.

Apparatus

(*Ph. Eur. method 2.2.22*

This consists essentially of an atomic generator of the element being determined (flame, plasma, arc, etc), a monochromator and a detector. <u>If the generator is a flame, water is the solvent of choice for preparing test and reference [standard] solutions</u>, although organic solvents may also be used if precautions are taken to ensure that the solvent does not interfere with the stability of the flame.

Development of AES

- 1850 Kirochaff & Bunzen ,Na &K in Flame give yellow and violet color.
- 1870 Gony ,Assay of Na&K throw the measure of emission.
- 1875 Lundegradh , use of Nebulizer.
- 1880 Harty use of spark instead of Flame.
- 1930 commercial uses.
- 1955 Walsh , use of AAS
- 1963 Winefordner , use of AFS
- Use of Plasma ((last years)

atomic generator of the element

1- Thermal (Flame) الحرارية

2- Electrical (Spark or arc) الكهربائية

3- radiative (beam of radiation)الأشعاعية

4- Plasma

- ***ICP = Inductively coupled argon plasma***
- ***DCP = Direct current argon plasma.***
- ***MIP = Microwave-induced argon plasma.***
- ***GDP = Glow discharge plasma (AA)***

- The most important of these plasmas is the inductively coupled plasma (ICP).

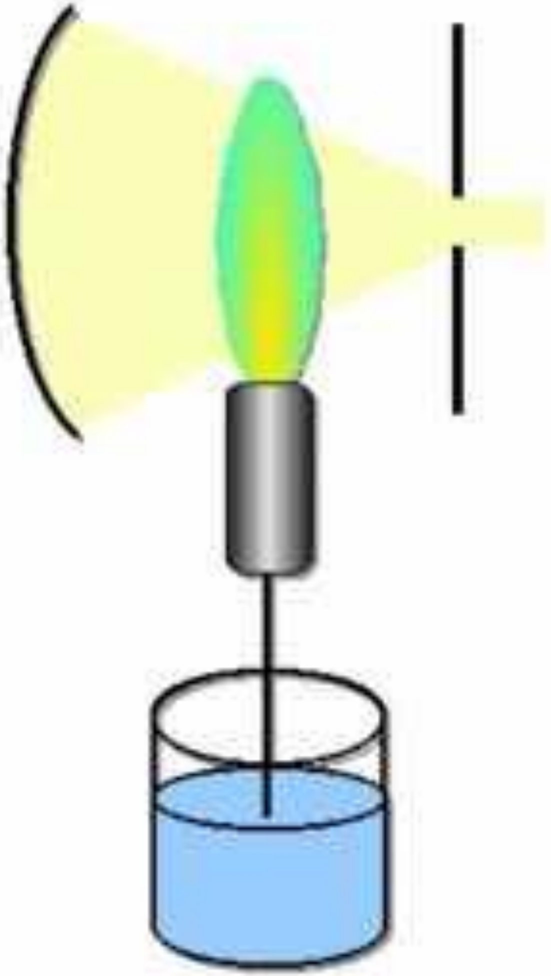
I- Thermal Method الحرارية

Excitation Sources

Flames

This approach works best for Group IA and IIA elements because they are easier to ionize.

Samples are introduced via aspiration into the flame so must be liquids or gases.



IA (Li, Na ,K ,Rb ,Cs ,Fr)

IIA (Be ,Mg, Ca, Sr, Ba, Ra)

Prof. J. Al-Zehouri

Excitation sources

Flame excitation

This method of excitation is of relative low temperature:

fuel

oxidation
محترقة

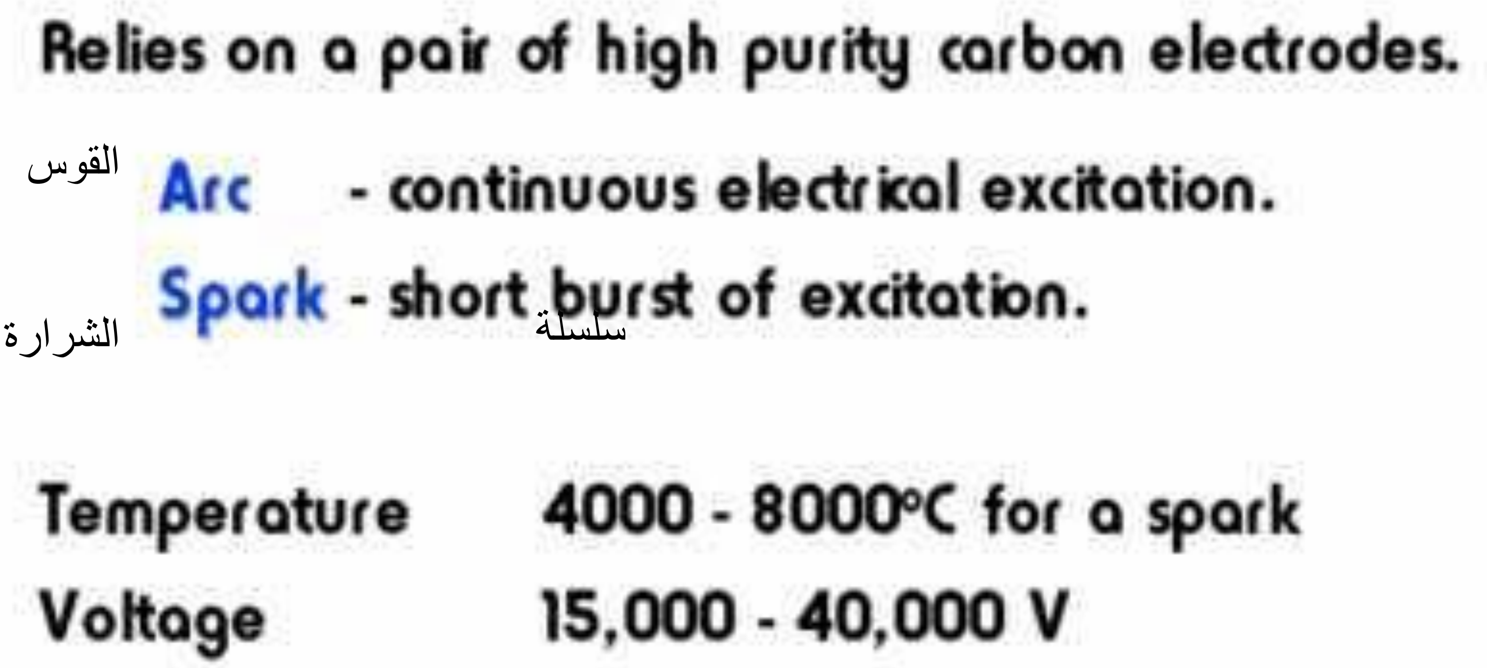
حارقة

Air/H_2	2100°C
O_2/H_2	2700°C
N_2O/C_2H_2	3050°C

This results in only a very small percentage of the atoms being ionized (<1%). One option is to go to higher T - Plasma emission.

Excitation Sources

II - Electrical الكهربائية



Relies on a pair of high purity carbon electrodes.

القوس **Arc** - continuous electrical excitation.

الشرارة **Spark** - short burst سلسلة of excitation.

Temperature	4000 - 8000°C for a spark
Voltage	15,000 - 40,000 V

A- ICP Inductively coupled argon plasma

Excitation Sources

III- Plasma

By definition, a plasma is an electrical conducting gaseous mixture containing a significant concentration of cations and electrons. غاز ناقل للكهرباء ويحوي تركيز واضح من الشوارد الموجبة والأليكترونات

Similar to flame photometry.

An RF field is used to excite an inert gas (typically argon) which in turn ionizes our sample.

يستخدم مجال راديوي لإثارة الغاز الخامل الذي بدوره يؤين العينة

Higher temperatures ($\geq$10,000K) are achieved so we obtain better sensitivity than with a flame.

*RF = Radio frequency

- ***The use of plasmas as excitation sources for atomic emission is very important in recent years.***

- ***Inductively coupled plasma (ICP) spectrometers are used for multielement determination.***

- ***The ICP discharge is caused by the effect of a radio frequency field on a flowing gas. (Argon).***

للأعلى

- ***Argon gas flows upward through a quartz tube, around which is wrapped a copper coli or solenoid .***

لولبي

- ***The coli is energized by a radio frequency generator operating at 5 to 75 MHz and 1 to kW power, creating a changing magnetic field in the flowing gas inside the coli.***

- ***This induces a circulating eddy current in a conductor (the gas) ,which, in turn, heats it.***

- ***Argon is not a conductor at room temperature, but it can be made electrically conducting by heating it.***

يبدأ

- ***To initiate the ICP discharge, a discharge from a Tesla coli or a Pilot spark is applied to the flowing argon.***

- ***The argon is quickly heated, with a stable plasma being produced having a core temperature of about 9000 to 10000 K.***

Nikola tesla

B- The Direct Current Plasma Source : (DCP)

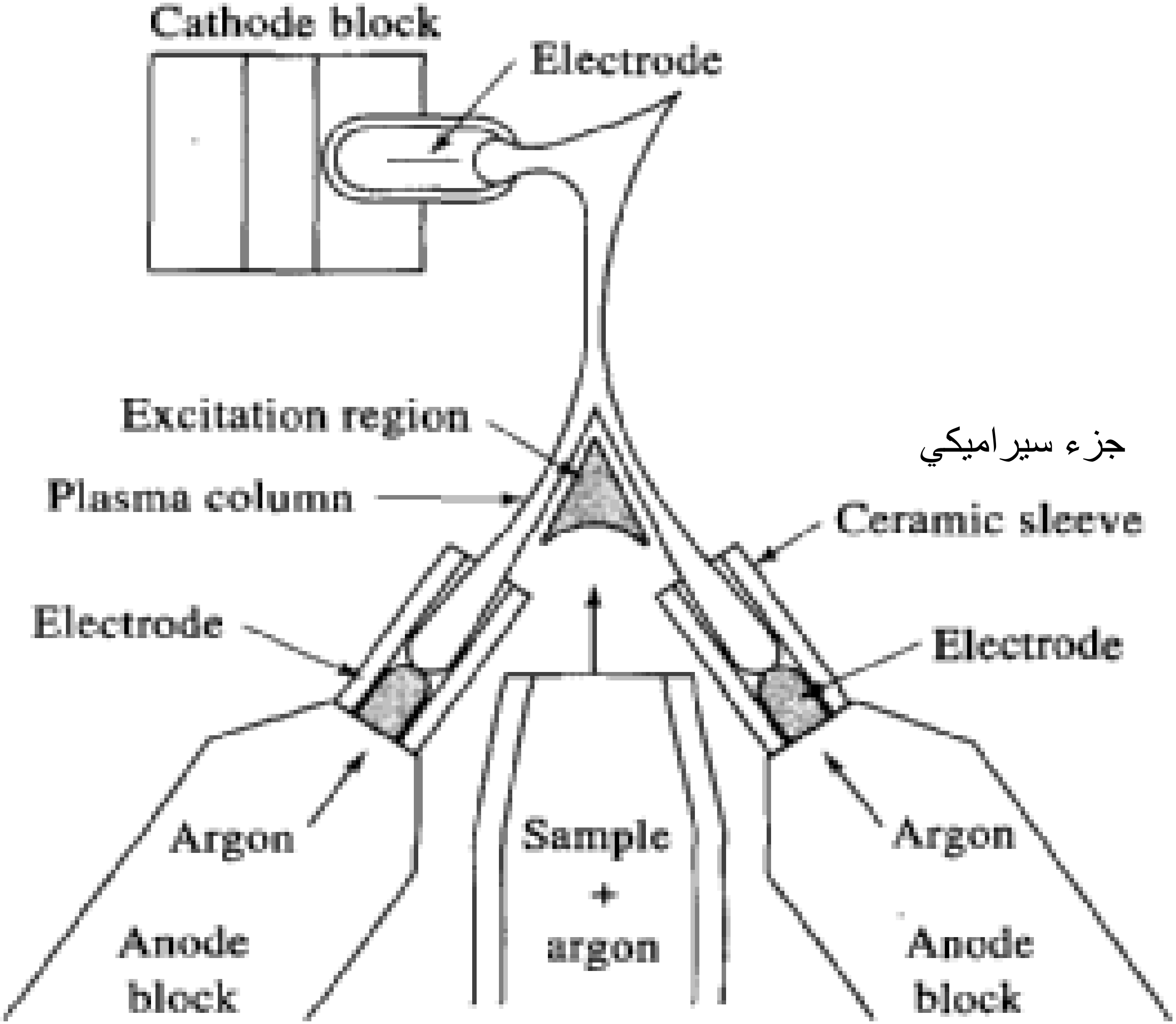
- ***This plasma jet source consists of three electrodes arranged in an inverted Y configuration.***
- ***A graphite anode is located in each arm of the Y and a tungsten cathode at the inverted base.***
- ***Argon flows from the two anode blocks toward the cathode.***

منفث

- ***The plasma jet is formed by bringing the cathode momentarily in contact with the anodes.***
- ***Ionization of the argon occurs and a current develops (≈ 14 A) that generates additional ions that sustain the current indefinitely.***

يغذي، يساند
يؤازر،

بلاحدود



A three-electrode dc plasma jet.

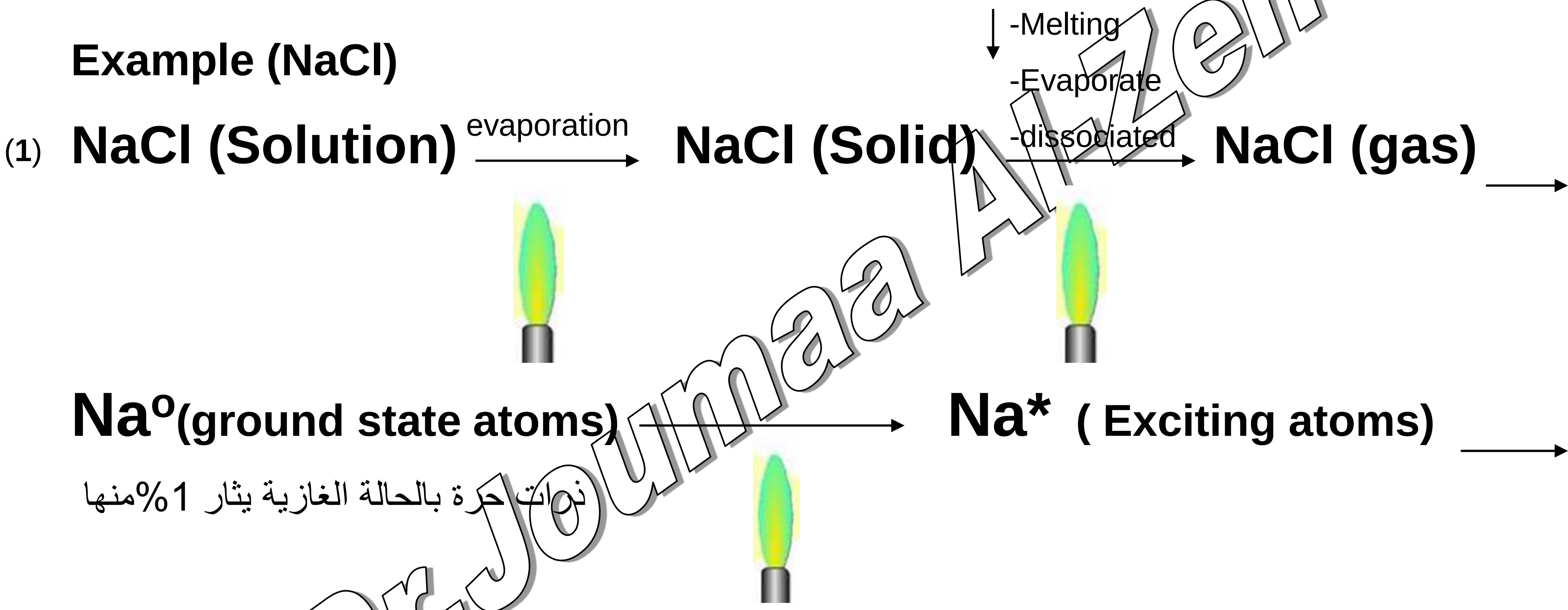
وبالتالي حسب طريقة توليد الذرات الحرة يمكن أن تسمى طريقة الأنبعاث(الأصدار) الذري :

- باللهب
- بالكهرباء (قوس ، شرارة)
- بالبلازما (حسب الطريقة)
- ....

Flame Photometry

مقياس الضوء اللهبي

Flame Atomic Emission



Example (NaCl)

-Melting

-Evaporate

-dissociated

(1) **NaCl (Solution)** $\xrightarrow{\text{evaporation}}$ **NaCl (Solid)** $\longrightarrow$ **NaCl (gas)** $\longrightarrow$

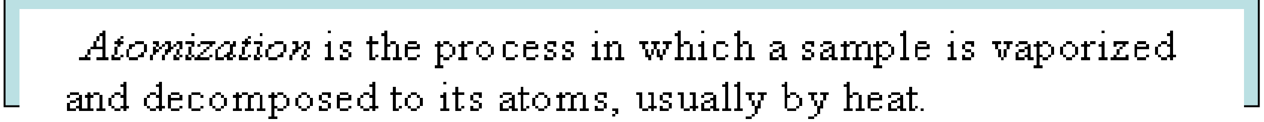
Na^{o}(ground state atoms) $\longrightarrow$ **Na* (Exciting atoms)** $\longrightarrow$

ذرات حرة بالحالة الغازية يثار 1%منها

Na^{o} (ground state atoms) + hv (resonance Line, The highest intents)

الأشعة المنبعثة تتكون من عدة خطوط لذا نقيس عند الخط ذو الشدة الأعلى (خط الرنين)حيث تمرر الأشعة المنبعثة عبر موحد طول الموجة لفصل هذا الخط عن الباقي حيث يتم قياس هذه الأشعة

(1)= atomization



Atomization is the process in which a sample is vaporized and decomposed to its atoms, usually by heat.

أقسام الجهاز

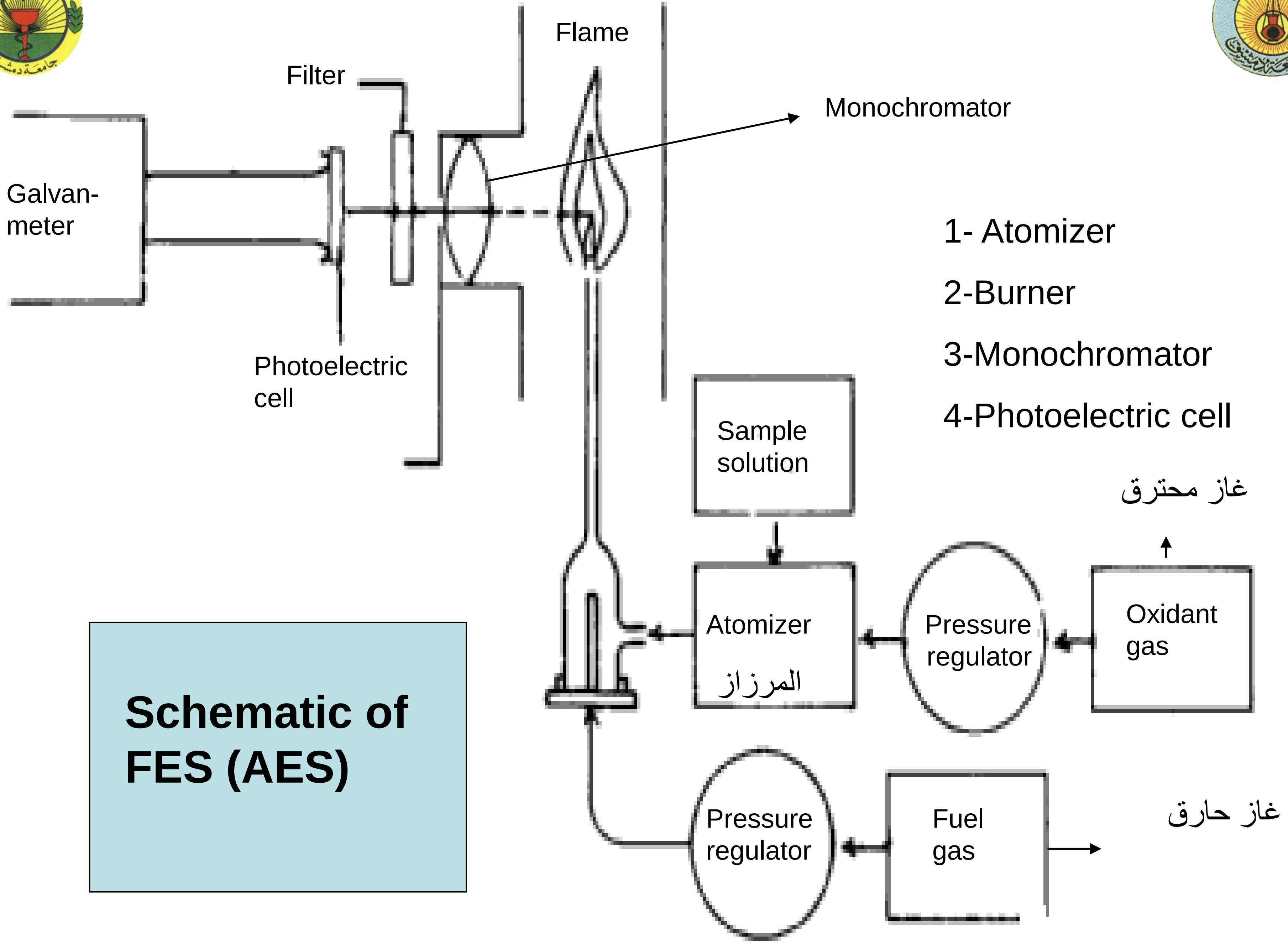
1- ATOMIZER *المرذاذ* : مهمته ادخال العينة على شكل رذاذ داخل اللهب بمساعدة مضخة هوائية

2- BURNER *الحارق* (الموقد) واللهب : حيث يتم تبخير المحلول وتحويل المادة لذرات حرة بحالتها الغازية وإثارتها

3- MONOCHROMATOR *مستفرد اللون* : لتحديد طول الموجة .

4- PHOTOELECTRIC CELL(DETECTOR) *المتحري* : خلية ضوئية تحول الضوء لتيار كهربائي .

Schematic of FES (AES)



Flame

Filter

Monochromator

Galvan-
meter

Photoelectric
cell

Sample
solution

Atomizer
المرزاز

Pressure
regulator

Oxidant
gas

غاز محترق

Pressure
regulator

Fuel
gas

غاز حارق

1- Atomizer

2-Burner

3-Monochromator

4-Photoelectric cell

Types of Flames

- Flame consist of two gases ,fuels حارق (H_2,C_2H_2) and oxidants محترق (air,O_2,N_2O)
- Not that temperatures of 1700-2400^{o}C are obtained with the various fuels when air serves as the oxidant.(at these temperature only easily decomposed samples are atomized , Na, K ..).
- معندة
  For more refractory samples, oxygen or nitrous oxide must be employed as the oxidant (2500-3100^{o}C , Ti , Si ,
- The burning velocities are of considerable important because flames are stable in certain ranges of gas flow rates only.

Types of Flames

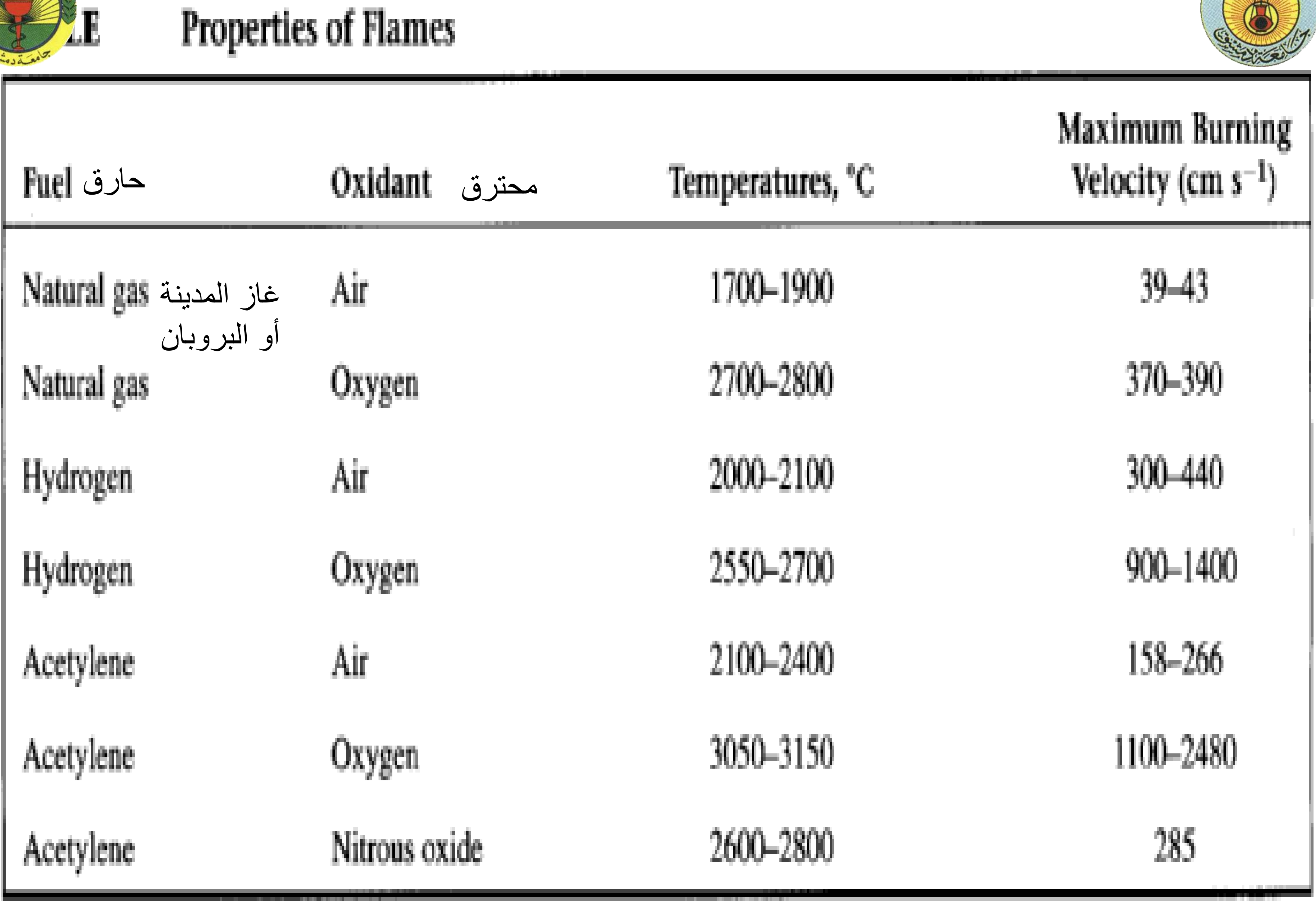
ينتشر انتشار

- If the gas flow rate exceed the burning velocity ,the flame propagates itself back into the burner, giving flashback.

يجب أن لا تتجاوز سرعة الغاز سرعة الأحتراق لكي لا يحصل انبعاث خلفي

- As the flow rate increases ,the flame rises until it reaches a point above the burner where the flow velocity and the burning velocity are equal. This region is where the flame is stable.

يجب أن تكون السرعتان متساويتان



LE Properties of Flames

Fuel حارق	Oxidant محترق	Temperatures, °C	Maximum Burning Velocity (cm s^{-1})
Natural gas غاز المدينة أو البروبان	Air	1700–1900	39–43
Natural gas	Oxygen	2700–2800	370–390
Hydrogen	Air	2000–2100	300–440
Hydrogen	Oxygen	2550–2700	900–1400
Acetylene	Air	2100–2400	158–266
Acetylene	Oxygen	3050–3150	1100–2480
Acetylene	Nitrous oxide	2600–2800	285

Natural gas = propane

Sample introduction

- In flame spectroscopic methods the sample introduced into excitation in the form of a solution.(and gases).
- Water is the solvent of choice for preparation of sample solution.
- Unfortunately ,many materials of interest, such as soils, animal tissues, plants…. are not directly soluble in water.

تربة

Burner

هو الجزء الذي يتم فيه اختلاط الغاز الحارق مع المحترق للحصول على اللهب ويوجد منه نوعان .

- The part which the mixing of the fuel gas and the oxidant gas is happen.

two type of Burner :

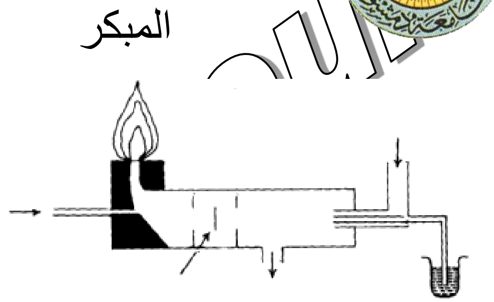
1- premixed burner. (most used now)

الحارق(الموقد) ذو الأختلاط المبكر

2- non-premixed burner.

الحارق ذوالأختلاط المتأخر

Premixed burner



- The mixing happen before the flame
- ***Disadvantage*** (possibility of explosion) especially when the Burning velocity of gas mix is greater than it flow rate (H_2+O_2 or acetylene+O_2).

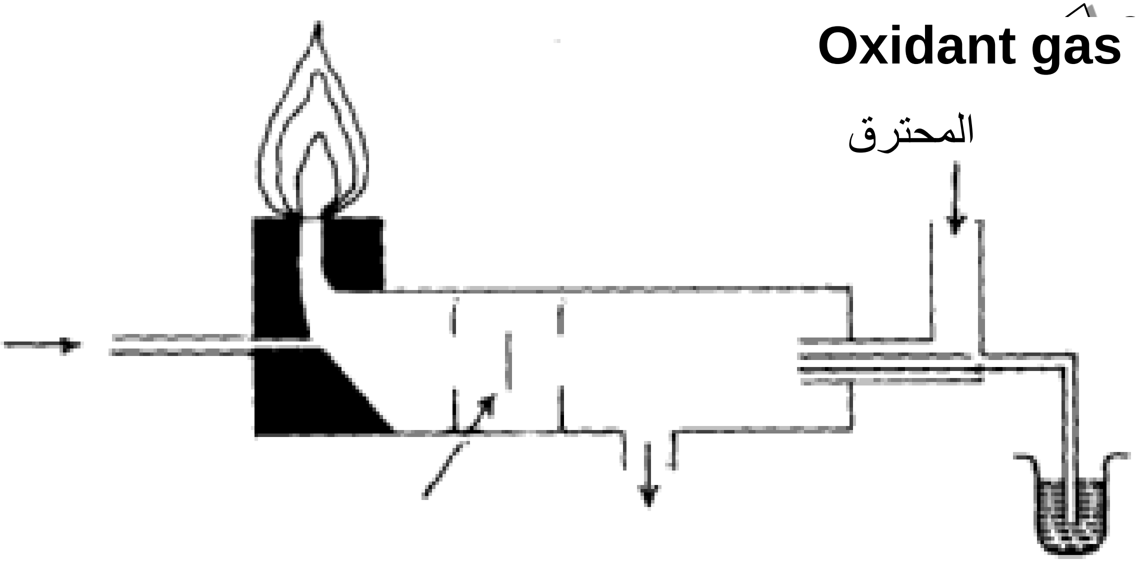
خاصة عندما تكون سرعة احتراق الغاز أعلى من سرعته مما يؤدي لأحتمال دخول اللهب لداخل الأنبوبة مسببا الأنفجار

- We can avoid the danger by arrangement of close and open of gases (Oxidant first when the flam an ,and close the fuel gas first when the flame put off, and the ratio of oxidant to fuel gas must be correct.($C_2H_2+ 2.5\ O_2 \longrightarrow 2CO_2+H_2O$)

يمكن تفادي الأنفجار بفتح وأغلاق الغازات بالترتيب حيث يفتح الغاز المحترق أولاً عند الاشتعال وِيغلق الغاز الحارق أولاَ عند الأطفاء .

بالرغم من كل ماذكر لايفضل استخدام الأوكسجين بهذا النمط

Flame



Oxidant gas

المحترق

Fuel gas

الحارق

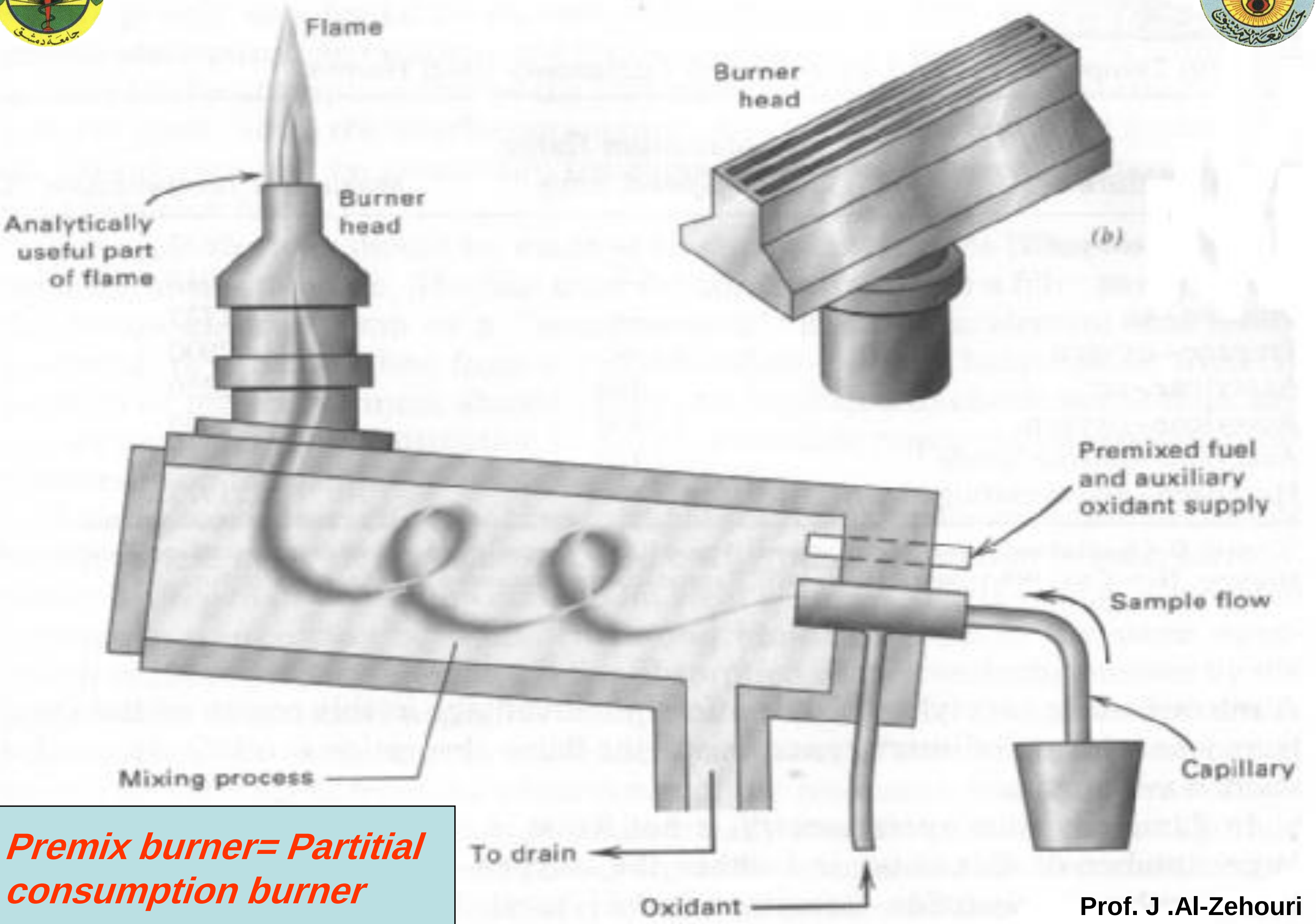
Mixing plate

drain

Sample Solution

Premixed burner

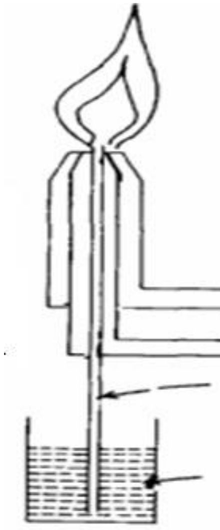
يتم المزج قبل اللهب



Premix burner= Partitial consumption burner

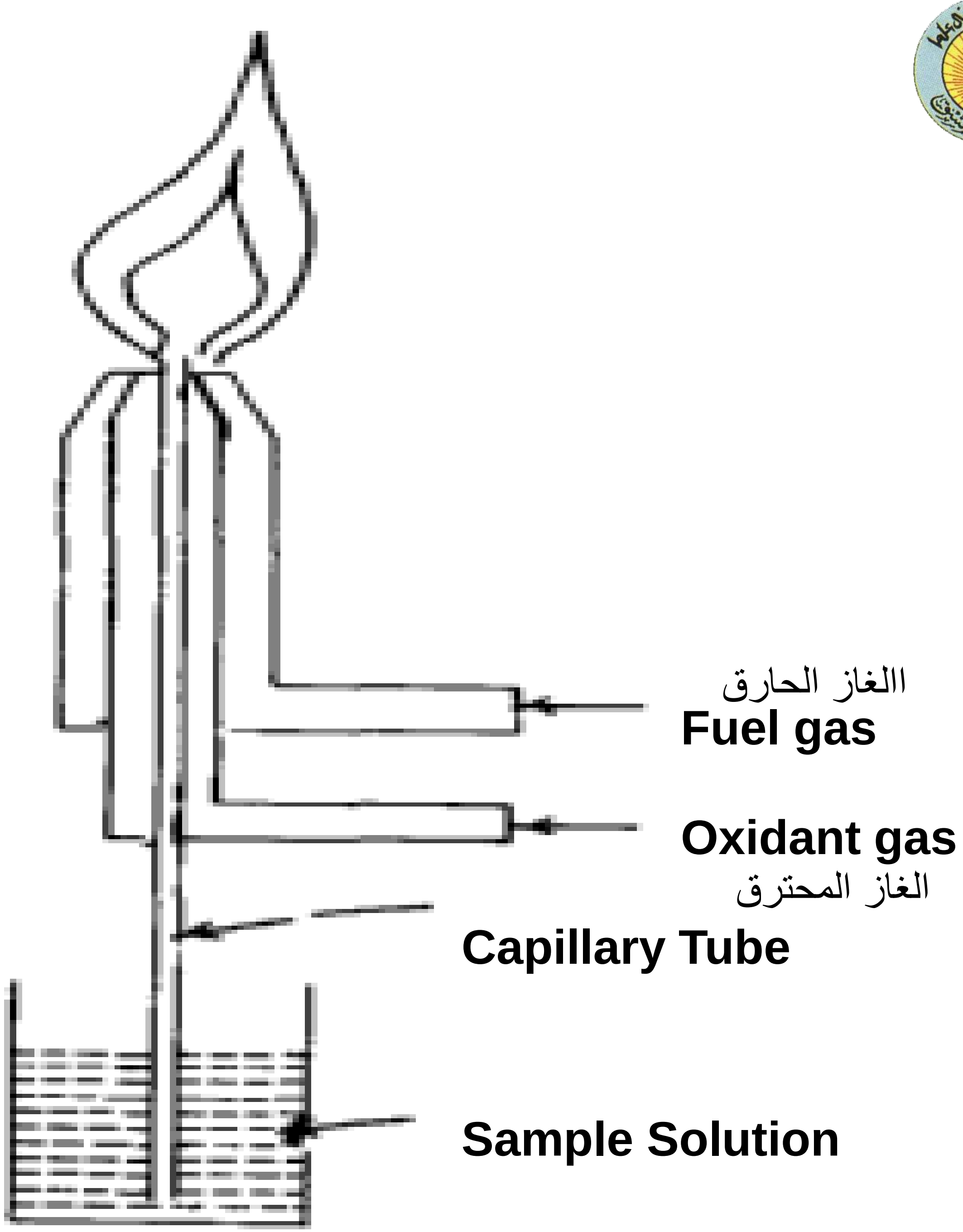
Non-premixed burner المتأخر

- The mixing of gases happen directly at the flame.
- ***Each gas has separator bath (No danger of explosion)***
- The flame is not homogenous (opposite the flame in premixed burner) therefore the premixed is more common in use.

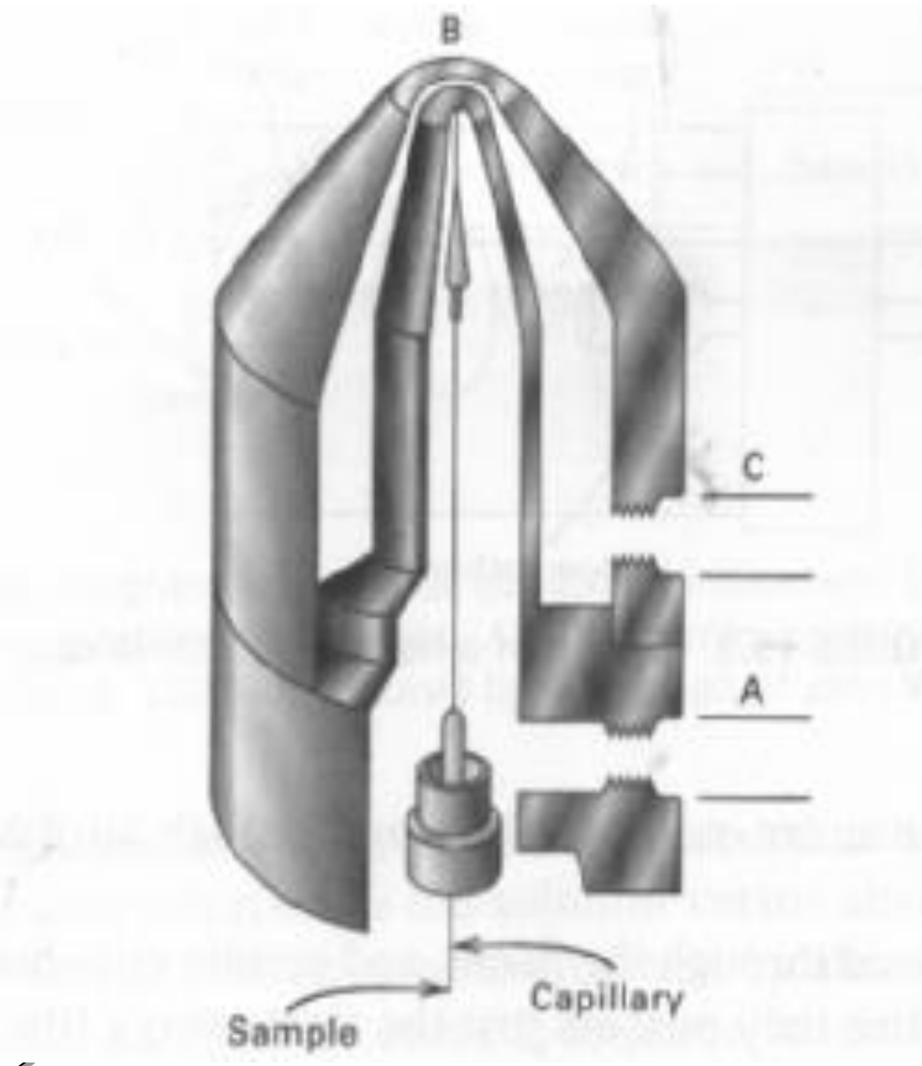


نظرا لأن هذا الموقد دائري الشكل ولايمكن جعله مستطيلا لذا يستخدم فقط بالأنبعاث وليس بالأمتصاص (
حيث أن الأمتصاص يتناسب مع طول مسار الأشعة داخل اللهب)

Non-premixed burner



Surface mixing



Fuel flow االغاز الحارق

Oxidant flow الغاز المحترق

Non-premixed burner = Total-consumption burner

Flame Structure

لا بد من أن يكون تركيب اللهب ودرجة حرارته ثابتتين وإلا سنحصل على انبعاث خلفي

- Stability of temperature and composition of flame is very important ,and must has less value of (flame background emission).

يجب أن لايصدر اللهب انبعاث بحال غياب العينة حتى لا يتداخل مع مع انبعاث العنصر

الأنبعاث الخلفي : هو الأنبعاث بغياب العينة نتيجة وجود بعض الجزيئات الكيمائية

- Flame background emission = flame emission in absence of sample solution. (due to gas particles ,OH,CH,O_2..)

عملياً اللهب غير متجانس حيث يتألف من عدة مناطق

- Practical the flame has several regions where the temperature and chemical composition are differ.

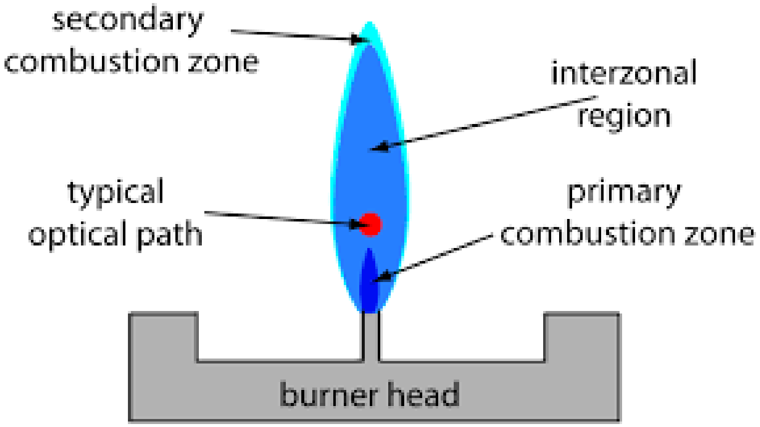
Flame Structure

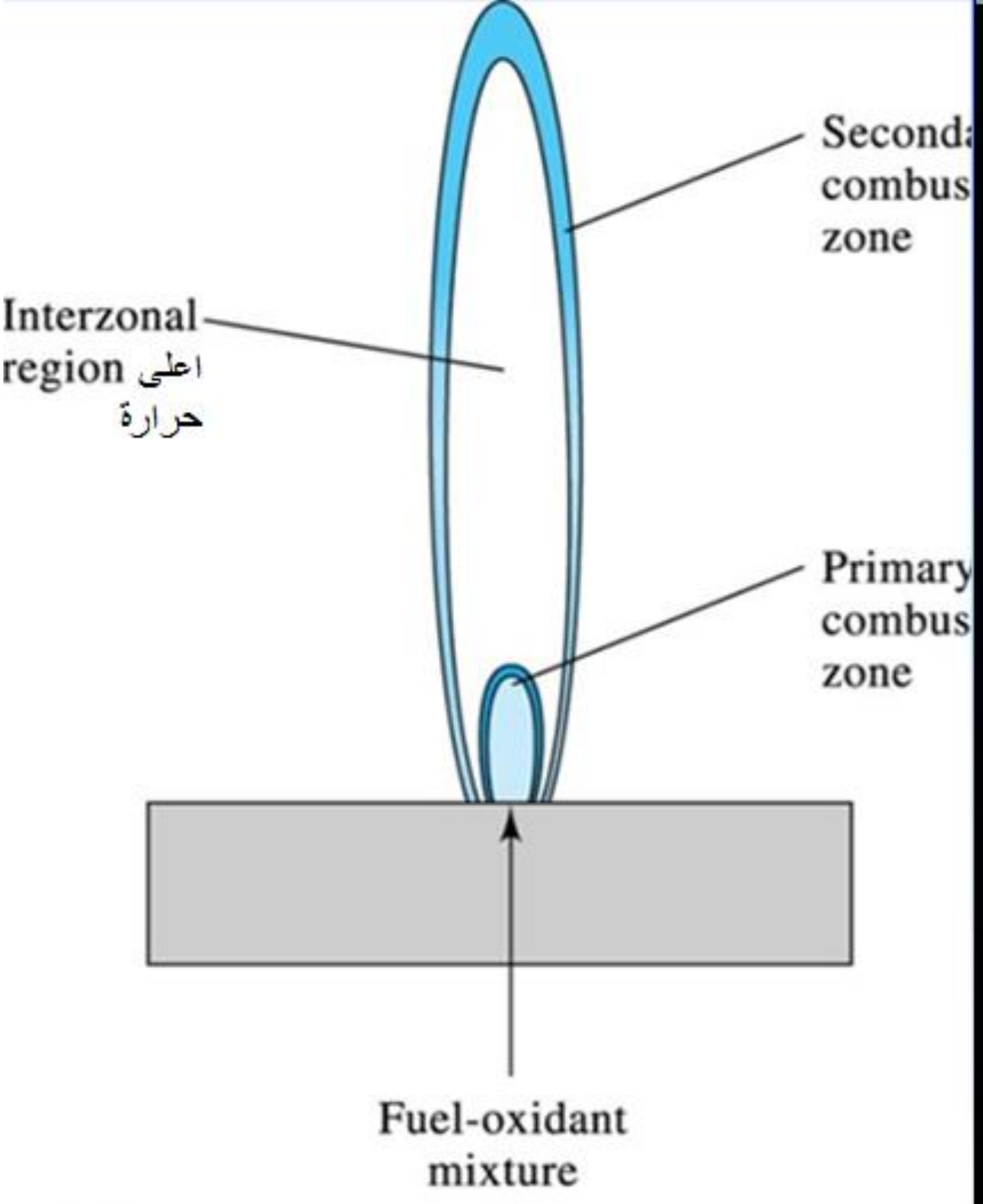
- ***The Important regions of a flame include :***

  1- Primary combustion zone. **منطقة الأحتراق الأولي**

  2- Interzonal region. **المنطقة الداخلية**

  3- Secondary combustion zone. **منطقة الحتراق الثانوي**


secondary combustion zone
interzonal region
typical optical path
primary combustion zone
burner head


Second
combus
zone
Interzonal region اعلى حرارة
Primary
combus
zone
Fuel-oxidant mixture

منطقة الأحتراق الأولي (الملاصقة للحارق)

- The appearance and relative size of these regions vary considerably with the fuel-to-oxidant ratio as well as with the type of fuel and oxidant.

شكل وسماكة هذه المنطقة يتأثر بنسبة الغاز الحارق والمحترق

- The primary combustion zone in hydrocarbon flame is recognizable by its blue luminescence arising from the band spectra of C_2,CH,and other radicals.
- Thermal equilibrium is ordinarily not reached in this region, and it is ,therefore, seldom used for flame spectroscopy.

لايكون التفاعل كامل بهذه المنطقة ولهذا لاتستخدم للقياس حيث أن الأنبعاث الناتج عن اللهب هنا كبير ويعزى لوجود بعض الجزيئات المثارة مثل C_2,CH .. وتتميزبالتألق الأزرق التابع لطيف هذه الجزيئات

المنطقة الداخلية(المخروطية)

تمتاز بتوازنها الحراري ، أعلى حرارة ، مناسبة لتكوين الذرات وإثارتها ، الأنبعاث الخلفي أقل مايمكن ،سمكها كبير

- The interzonal area ,which is relatively narrow in stoichiometric hydrocarbon flames, may reach several centimeters in height in fuel-rich acetylene/oxygen or acetylene/nitrous oxide sources.
- It has thermal equilibrium and highest temperature.
- The zone is often rich in free atoms and is the most widely used part of the flame for spectroscopy.

هذه المنطقة هي المستخدمة بطرق التحليل باللهب عامة لذا يتم وضع المتحري دائماً على امتداد هذه المنطقة ليقيس الأشعة المنبعثة منها مباشرة .

منطقة الأحتراق الثانوي

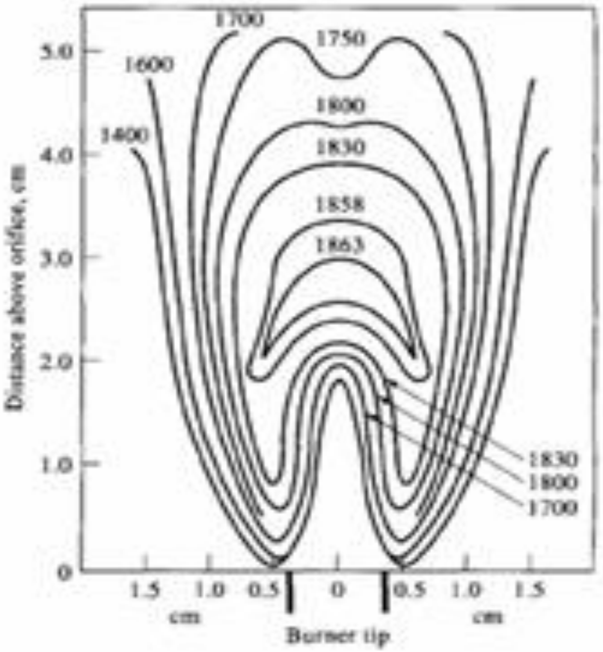
- In the secondary reaction zone, the products of the inner core are converted to stable molecular oxides that are then dispersed into the surroundings.
- A flame profile provides useful information about the processes that go on in different part of a flame,

هنا يختلط اللهب بالهواء مؤدياً لتخفيض حرارة هذه
المنطقة وقد يتدخل اكسجين الهواء بالأحتراق ، الأنبعاث
الناجم عن اللهب هنا كبير لذا لا تستخدم .

Temperature Profiles :

- The maximum temperature is located in the flame about 1 cm above the primary combustion zone.
- It is important-particularly for emission methods- to focus the same part of the flame on the entrance slit for all calibrations and analytical measurements.

سجلت أعلى درجة حرارة
على ارتفاع 1 سم فوق
منطقة الأحتراق الأولي



Temperature profiles in °C for a natural gas/air flame.

وسائل الأرذاذ

Atomization source

We need to be able to convert our sample to free atoms. Two approaches are used.

وسيلتين

Atomization is the process in which a sample is vaporized and decomposed to its atoms, usually by heat.

Flame atomization

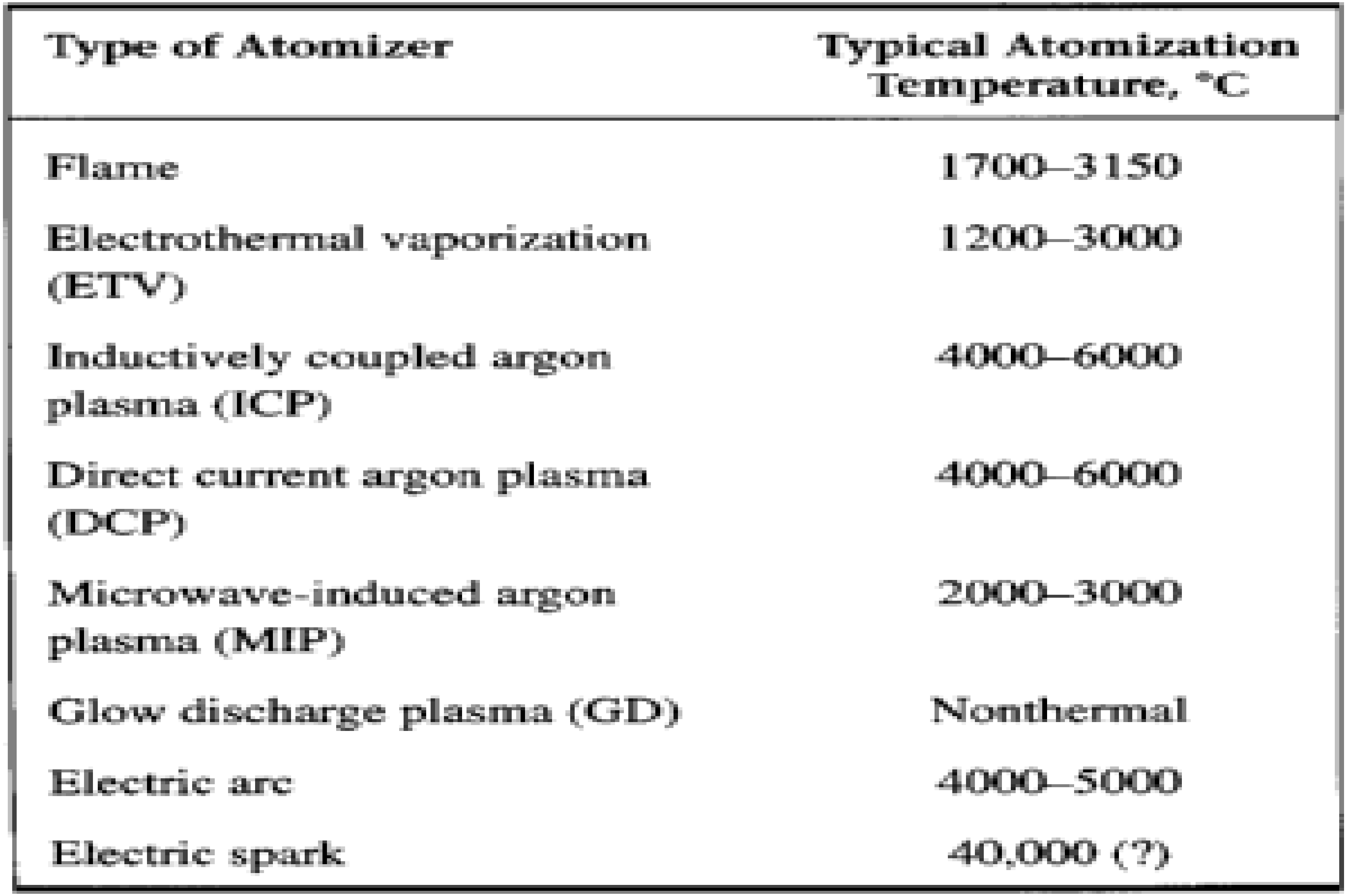
liquids and gases

Flameless atomization → **In AA & Atomic electric emission**

graphite furnace

liquids and solids

Types of Atomizers Used for Atomic Spectroscopy



Type of Atomizer	Typical Atomization Temperature, °C
Flame	1700–3150
Electrothermal vaporization (ETV)	1200–3000
Inductively coupled argon plasma (ICP)	4000–6000
Direct current argon plasma (DCP)	4000–6000
Microwave-induced argon plasma (MIP)	2000–3000
Glow discharge plasma (GD)	Nonthermal
Electric arc	4000–5000
Electric spark	40,000 (?)

Flame Atomizer

تمرر العينة هنا عبر البخاخ

- In a flame atomizer ,a solution of the sample is nebulized by a flow of gaseous oxidant, mixed with a gaseous fuel ,and carried into a flame where atomization occurs.
- A fraction of the molecules, atoms, and ions are excited by the heat of the flame, thus giving atomic, ionic, and molecular emission spectra.
- Some of the atoms so formed ionize to give cations and electrons.

Flame atomization (Nebulization or Aspiration)

- ***The sample introduce via nebulizer (sprayer) which has tow type:***

1- partial consumption nebulizer.

البخاخ ذو الأستهلاك الجزئي

2- total consumption type.

ذو الأستهلاك الكلي

Partial consumption Nebulization

البخاخ ذو الأستهلاك الجزئي

- Used in premixed burner. يستخدم غالبا مع الموقد ذو الأختلاط المبكر
- The sample drew via **Venturi effect** giving a small drops which mixed with gases.

يسحب السائل خلال أنبوبة شعرية نتيجة لأن الضغط في نهاية الأنبوبة يتناقص بفعل الغاز المؤكسد وهذا ما يدعى بتأثير فينتوري ويتحول لقطرات صغيرة تختلط بالغاز المؤكسد وغاز الوقود بحجرة خاصة تحتوي على خلاط يحول القطرات لحجم صغير و القطرات الكبيرة غير المرغوب بها تخرج من مصرف خاص لأن وجودها باللهب يضعف حرارته .

Advantages : homogeneous drops ≈10μm,10% of the solution reaches the flame, only small drops reaches the flame ,No radiation scatter.

90 % من العينة يخرج عبر المصرف

Disadvantage : great amount of sample solution, consumption of great amount of gases, it difficult to clean.

يستهلك كمية كبيرة من العينة والغاز

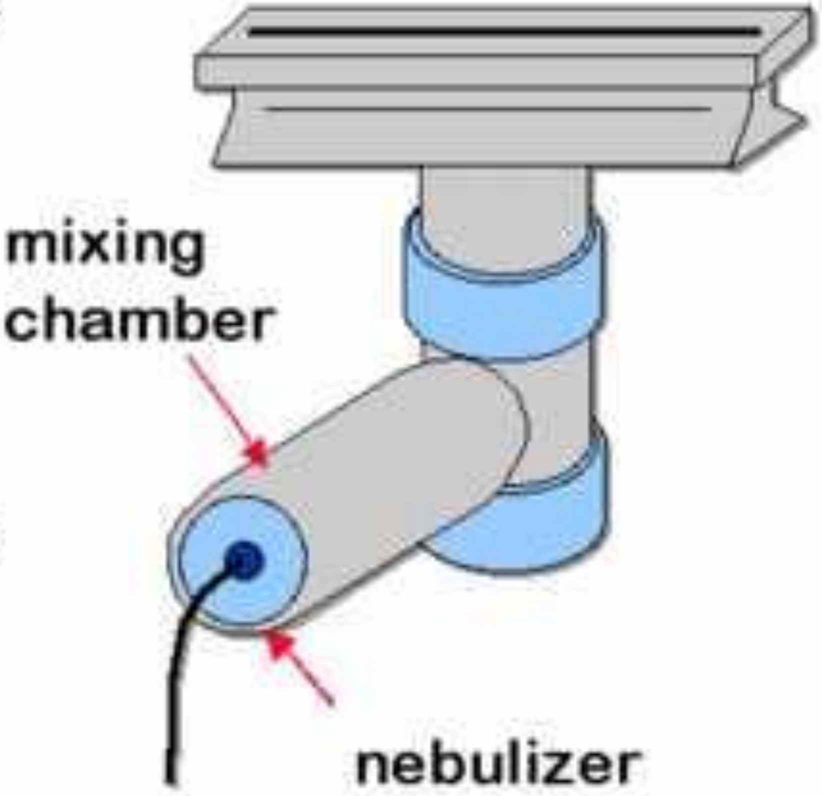
Flame atomization

A flame atomizer will usually have a long, narrow burner head that serves as a sample path (b).

Sample is introduced via aspiration.

The nebulizer controls sample flow, producing a mist. ضباب

The mixing chamber assures that the sample mixes with the oxidant and fuel prior to entry into the flame.



Total consumption Nebulization

البخاخ ذو الأستهلاك الكلي ، يستخدم غالبا مع الموقد ذو الأختلاط المتأخر

- Used often in non-premixed burner
- The sample drew via **Venturi effect** where the sample mixed with the gases out of burner.

- يدخل المحلول كامل للهب دون استبعاد القطرات الكبيرة ، حيث يصل معدل قطر القطرة ل 20 ميكرومتر أو أكبر وهذه القطرات لا تتبخر كلياً مؤدية لتبعثر الأشعة عندما تصدم بها وتؤدي لبعض التتداخلات الكيميائية .

Advantages : It is easy to clean , analysis of high viscosity samples (blood ,Urine ..), the flam concentrate in small area which is useful for measuring the emission more than the absorbance.

Disadvantages : non homogeneous drops ≈20μm,100% of the solution reaches the flame so no total sample evaporation, all drops reaches the flame , radiation scatter.

Flame atomization

The most common fuel to use is acetylene.

Either air or nitrous oxide are used as oxidants, with N_2O producing a hotter flame.

	Temperature, °C
C_2H_2/Air	2100 - 2400
C_2H_2/N_2O	2600 - 2800

N_2O also tends to produce a noisier flame.

Flame atomization

Flame atomization tends to produce stable signals in the ppm range for most metals.

It is a dynamic method

- Sample is constantly being consumed.
- Large sample size (>1 ml).
- Your sample must be a fluid.

The detection limits are relatively high since only a small portion of your sample is present in the flame at any given time.

Flameless atomization

(Electrothermal Atomization)

Samples are placed in a carbon tube which is heated electrically - graphite furnace

Sample residence time is greater so you have improved detection limits and sensitivity.

Solid samples can also be assayed.

Flameless atomization

You can't simply heat your sample to atomization temperatures or the sample will splatter.

We use a temperature program to ensure reproducible atomization.

A three stage program is the most common.

Excitation Methods

يمكن أن نميز نوعين رئيسيين من طرق إثارة العنصر في اللهب

- Physical excitation : as a result of strike the samples atoms with the gas radical,

$$M + H^{o} \longrightarrow M^{*}$$

$$M + e^{-} \longrightarrow M^{*}$$

عندما تصدم الأليكترونات أو جذور الهيدروجين الموجودة باللهب بذرات العنصر المراد معايرته تنتقل الطاقة الحركية لتلك المكونات لذرات العنصر التي تثار ، وبالرغم من عدم أهمية هذه الأثارة بطرق الأنبعاث إلا أنها أساسية بالأمتصاص

- Chemical excitation :

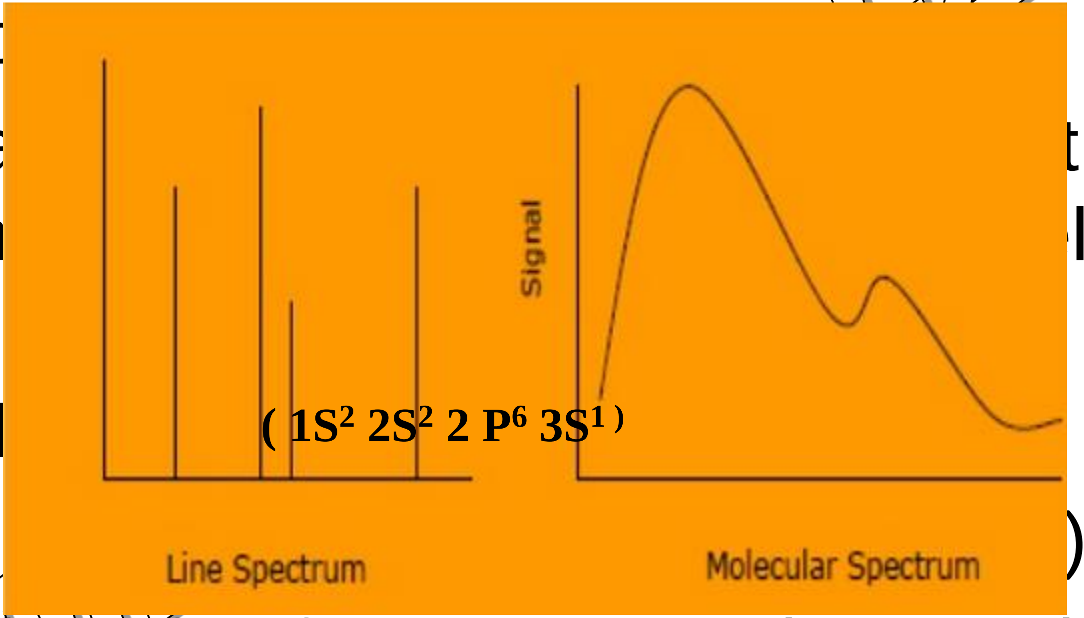
$$H^{o} + H^{o} \longrightarrow H_2 + (\text{ energy})$$

$$\text{energy} + M \longrightarrow M^{*}$$

حيث يتضمن هذا النوع تحول الطاقة الكيميائية لطاقة إثارة نتيجة تفاعل كيميائي بين جذرا هيدروجين مثلاً فتتحرر طاقة مقدارها 4.5 ev - تستخدم لأثارة ذرات بعض العناصر وكلما كانت حرارة اللهب قليلة كلما نشط هذا النوع من الأثارة .

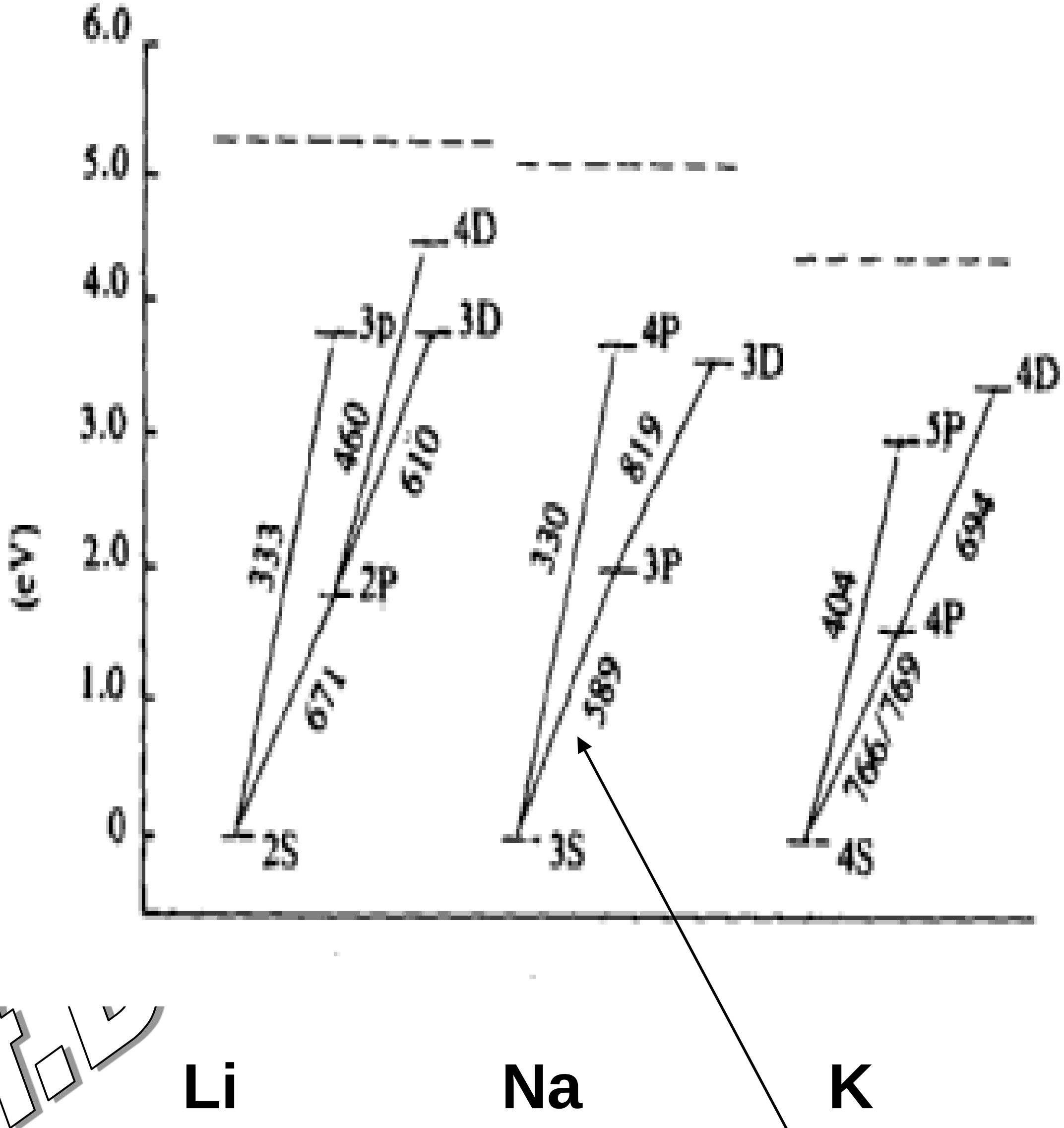
Flame spectra

- Consist of several lines via the excitation transitic
- Resona tion happen l to the ground
- Exampl
  - transit)
  - transition of e- from 4p to 3s (330 nm)
  - other transition is less sensetivity.



($1S^2\ 2S^2\ 2\ P^6\ 3S^1$)

1S,2S,2P.3S.3P,4S,3d,4p,5S,4d, …..



خط الرنين للصوديوم ينتج عن انتقال الأليكترون من 3p، الى 3s عند 589 نم

The relation between T and N_i

العلاقة مابين حرارة اللهب و عدد الذرات المثارة ، حيث يتوقف عدد الذرات المثارة على حرارة اللهب فعند الحرارة T تحسب عدد الذرات المثارة Ni إلى عدد الذرات المستقرة No من

- T= Temperature.
- N_i= Number of exiting atoms.
- Maxwell-Boltzmann equation :

معادلة ماكسويل - بولتزمان

$$\frac{N_i}{N_0} = \frac{g_i}{g_0} e^{-\Delta E/KT}$$

While N_o = Nr. of ground state atoms ,K= Boltzmann

constant = 1.4×10^{-16} erg/deg.

$\Delta E = E_i - E_o$, g_i and g_o constant related to the quantum Nr.

Element Resonance Line nm	Excitation energy (eV)	g_1/g_0	% of Excitation Atoms		
			2000K	3000K	4000K
Cs (852.1)	1.46	2	0.04	0.72	2.98
Na (589.0)	2.11	2	1×10^{-3}	0.06	0.44
Ca (422.7)	2.93	3	1×10^{-3}	4×10^{-5}	0.06
Zn (213. 9)	5.80	3	7×10^{-13}	6×10^{-8}	1×10^{-5}

هنا نلاحظ أن الزنك لايمكن تقديره بالأنبعاث لقلة عدد الذرات المثارة

Conclusion :

- At high temperature ,the ratio of Nr of N_i to N_o very small, their for the sensitivity of flame method is not very high.

- The emission is temperature depended so any change in temperature → Change in emission.

- The table refer that it is difficult to assay Zn in flam method.

Interferences

- Self-Absorption. (abs .of emit radiation)
- Ionization (loss of electron)

$$\begin{tikzcd} M^* \arrow[rr, "\text{high T}"] \arrow[dr, "\text{suitable T}"] & & M^+ + e^- \\ & M^o + h\nu & \end{tikzcd}$$

- Chemical (reaction of the element with the others)
- Physical (viscosity, rate of gases)
- Spectral (present of several element ,
  emission of radiation from the element
  oxide Mg = 285,21 ,Na = 285,28 nm)

الأمتصاص الذاتي :

أحياناً تمتص الأشعة الصادرة عن الذرات المثارة في وسط اللهب من قبل الذرات المستقرة والموجودة في الأجزاء الخارجية الباردة من اللهب مؤدية لتقليل شدة الأشعة الصادرة .

يزداد هذا الأمتصاص الذاتي بزيادة التركيز ويكون ضئيل جداً في المحاليل القليلة التركيز .

ويمكن التقليل من الأمتصاص الذاتي بأستخدام موقد دائري

التداخلات الشاردية أو الأيونية :

أحياناً وبحالات معينة (كأن تكون الحرارة باللهب عالية جدا وفرق كمون ذرات العنصر منخفض) فإنه قد يتخلى العنصر عن اليكترون أثناء عودته من الحالة المثارة للحالة المستقرة وهذ سوف يقلل من الذرات لذا فإن هذا النوع من التداخل يؤثر على الأنبعاث والأمتصاص (اي يقلل من الأنبعاث أو الأمتصاص)

$$\begin{tikzcd}
M^* \arrow[r, "\text{حرارة عالية جدا}"] \arrow[d, "\text{حرارة ملائمة}"'] & M^+ + e \\
M^o + h\nu &
\end{tikzcd}$$

التداخلات الفيزيائية :

تؤثر الخواص الفيزيائية للمحلول على الأنبعاث وكذلك الأمتصاص المقاس في اللهب وذلك بسبب تأأثير لزوجية المحلول على سرعة المحلول للهب .

سرعة غازات اللهب وكثافة ولزوجية المحلول كلها تلعب دور بحجم القطرات في البخاخ لذلك لا بد من تجانس خواص المحاليل العيارية ومحاليل العينة .

التداخل الطيفي :

بحال وجود عنصرين بالمحلول فمن الممكن أن يتم تتداخل خط إحدى العنصرين مع خط العنصر الآخر وهنا فإن الأصدار المقاس عند هذا العنصر لايمثل عنصراً واحداً بل عنصرين فمثلا لايمكن معايرة المغنزيوم عند طول الموجة 285 نم بوجود الصوديوم الذي يعطي اصدار عند 285.28 ولابد من البحث عن طول موجة أخرى لقياس المغنزيوم ، أو التخلص من الصوديوم من المحلول بطريقة مناسبة (استخلاص أو حجب أو ...) وهذا التتداخل شائع بالأصدار الذري ومحدود جداً بالأمتصاص الذري ، (السبب أنه بالأمتصاص لكل عنصر انبوب خاص لذا فإن الأشعة الساقطة لاتمتص إلامن العنصر نفسه ، حتى بوجود عناصر أخرى) .

التداخلات الكيميائية :

أي تفاعل العنصر المراد معايرته مع عناصر او مركبات أخرى موجودة في محلول العينة أو في اللهب وهو يؤ ثر على الأصدار والأمتصاص ومن الأمثلة على ذلك تحول الكالسيوم لفوسفات الكالسيوم صعبة التفكك باللهب وهذا يؤدي لنقص عدد ذرات الكالسيوم الحرة باللهب وبالتالي نقص في شدة الأنبعاث أو الأمتصاص .

Interferences

- To avoid the chemical interferences we can use the releasing agent :

example : to avoid the effect of phosphate on the determination of calcium we add lanthanium (La) as releasing agent where an replacement reaction occur :

$$Ca_3(PO_4)_2 + 2La \longrightarrow 2LaPO_4 + 3Ca$$

كما يمكن اضافة ال EDTA حيث يتشكل معقد مع الكالسيوم وليس مع الفوسفات ويجب معاملة المحاليل العيارية بنفس الطريقة

تحضير العينة :

تحل العينة غير العضوية في حمض مناسب أو أي مذيب مناسب كما تحل المواد العضوية في محل عضوي مناسب ثم تمدد للتركيز المطلوب .

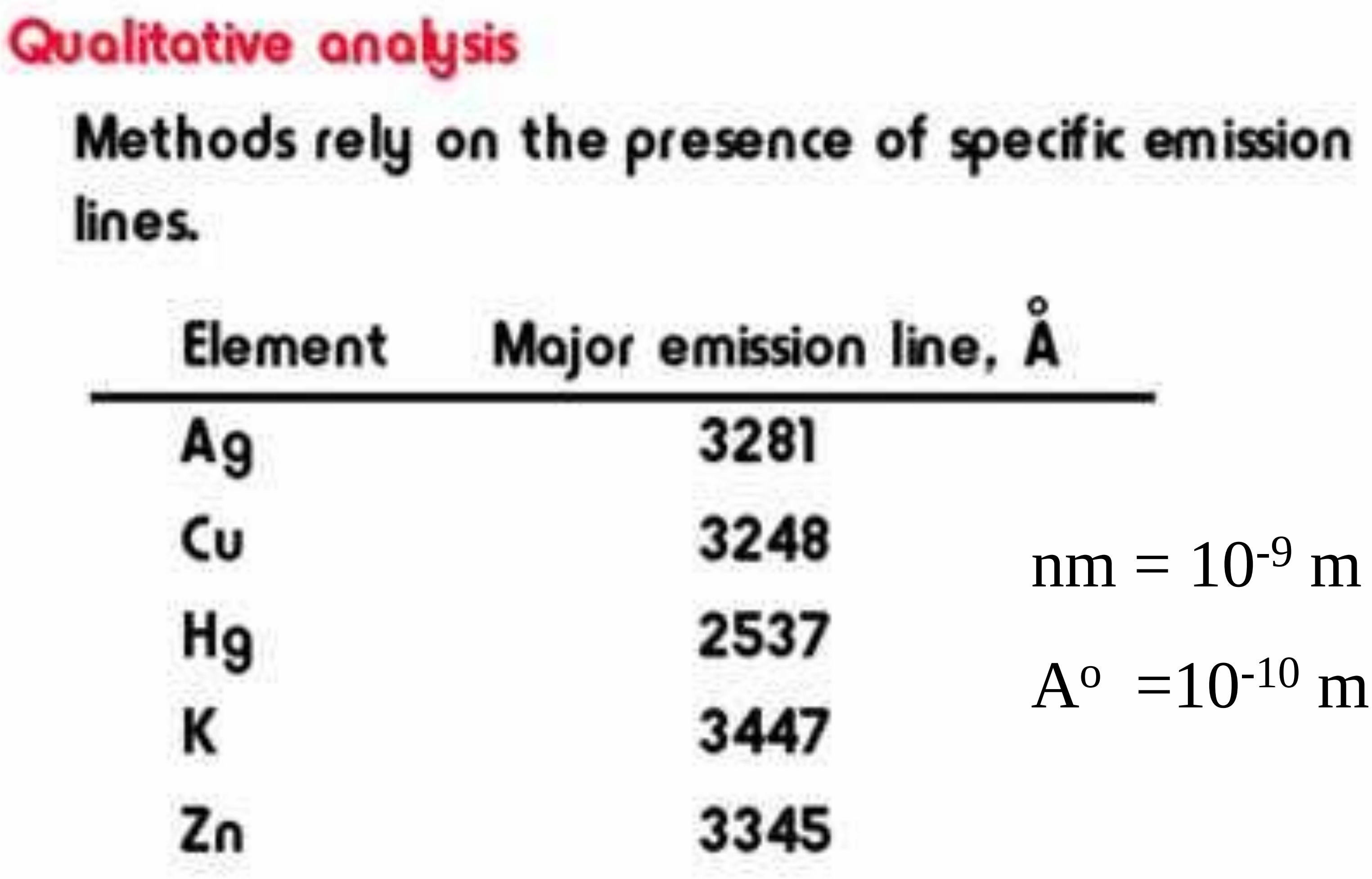
المحلول الحمضي يحسن الحساسية وكذلك استخدام مذيب عضوي مناسب كالميثانول يمكن زيادة شدة الأنبعاث الذري باللهب حيث يمكن أن يصل تركيز المحل العضوي لغاية 80% ذلك أن الماء لوحده يمكن أن يبرد اللهب أضافة الى أن المحلات العضوية تزيد من سرعة جريان المحلول للهب بسبب لزوجيتها المنخفضة كما أنها تولد قطرات صغيرة في البخاخ لأنها تعمل على خفض التوتر السطحي .

ونظرا لأن شدة الأشعة تتناسب مع تركيز العنصر عند موجة معينة فيمكن رسم منحني المعايرة واجراء المعايرة الكمية .

Application

- Determination of Na and K in serum.
- Determination of Ca and Mg in water.
- Determination of some drug which contains metals. or determine the trace metal in raw material
- Simple and rapid method.
- Simultaneous determination is possible.(plasma)
- Calculation : use of standard series or internal standard.
- Disadvantages : limited to some element and the necessary to use standard solution.

Atomic emission



Qualitative analysis

Methods rely on the presence of specific emission lines.

Element	Major emission line, Å
Ag	3281
Cu	3248
Hg	2537
K	3447
Zn	3345

nm = 10^{-9} m

A^{o} =10^{-10} m

Atomic emission

Quantitative analysis

Based on measuring the intensity of an emission line.

intensity = K c

Best for metals, sensitivity $\geq$ 0.001%

Large relative error, ± 1 - 5%

Sensitivity and error are highly dependent on the element and line being used.

Method

Operate an atomic emission spectrometer in accordance with the manufacturer's instructions at the prescribed wavelength setting. Introduce a blank solution into the atomic generator and adjust the instrument reading to zero. Introduce the most concentrated reference [standard] solution and adjust the sensitivity to give a suitable reading.

Determinations are made by comparison with reference [standard] solutions with known concentrations of the element to be determined either by the method of direct calibration (Method I) or the method of standard additions (Method II).

Use Method I unless otherwise directed.

Method I: Method of direct calibration

Prepare the solution of the substance to be examined (test solution) as prescribed. Prepare not fewer than three reference [standard] solutions of the element being determined the concentrations of which span the expected value in the test solution. Any reagents used in the preparation of the test solution are added to the reference [standard] solutions in the same concentration. Introduce the test solution and each reference [standard] solution into the instrument at least three times and record the steady reading. Rinse the apparatus with blank solution each time and ascertain that the reading returns to its initial blank value. Prepare a calibration curve from the mean of the readings obtained with the reference [standard] solutions and determine the concentration of the element in the test solution from the curve so obtained.

Method II: Method of standard addition

Add to at least three similar volumetric flasks equal volumes of the solution of the substance being examined (test solution) prepared as prescribed. Add to all but one of the flasks progressively larger volumes of a reference [standard] solution containing a known concentration of the element to be determined to produce a series of solutions containing increasing concentrations of that element known to give responses in the linear part of the curve. Dilute the contents of each flask to volume with solvent.

Compound Sodium Lactate Intravenous Infusion

يمكن انجاز هذه المعايرة في مصل الدم بدقة عالية

Assay ***For Na*** Prepare a suitable dilution in *water* and determine by *atomic emission spectrophotometry*, Appendix II D, measuring at 589 nm and using *sodium standard solution (200 ppm Na)*, suitably diluted with *water*, for the standard solutions.

For K Prepare a suitable dilution in *water* and determine by *atomic emission spectrophotometry*, Appendix II D, measuring at 767 nm and using *potassium standard solution (600 ppm K)*, suitably diluted with *water*, for the standard solutions.

Atomic emission Spectrophotometry (AES)

- KEYPOINTS

Principles

Atoms are thermally excited so that they emit light and the radiation emitted is measured.

Applications in pharmaceutical analysis

- Quantification of alkali metals in : alkali metal salts,infusin and dialysis solutions.
- Determination of metallic impurities in some of the other inorganic salts used in preparing these solutions.

Strengths

Flame photometery provides a robust , chep and selective method based on relatively simple instrumentation for quantitative analysis of some metals

Limitation

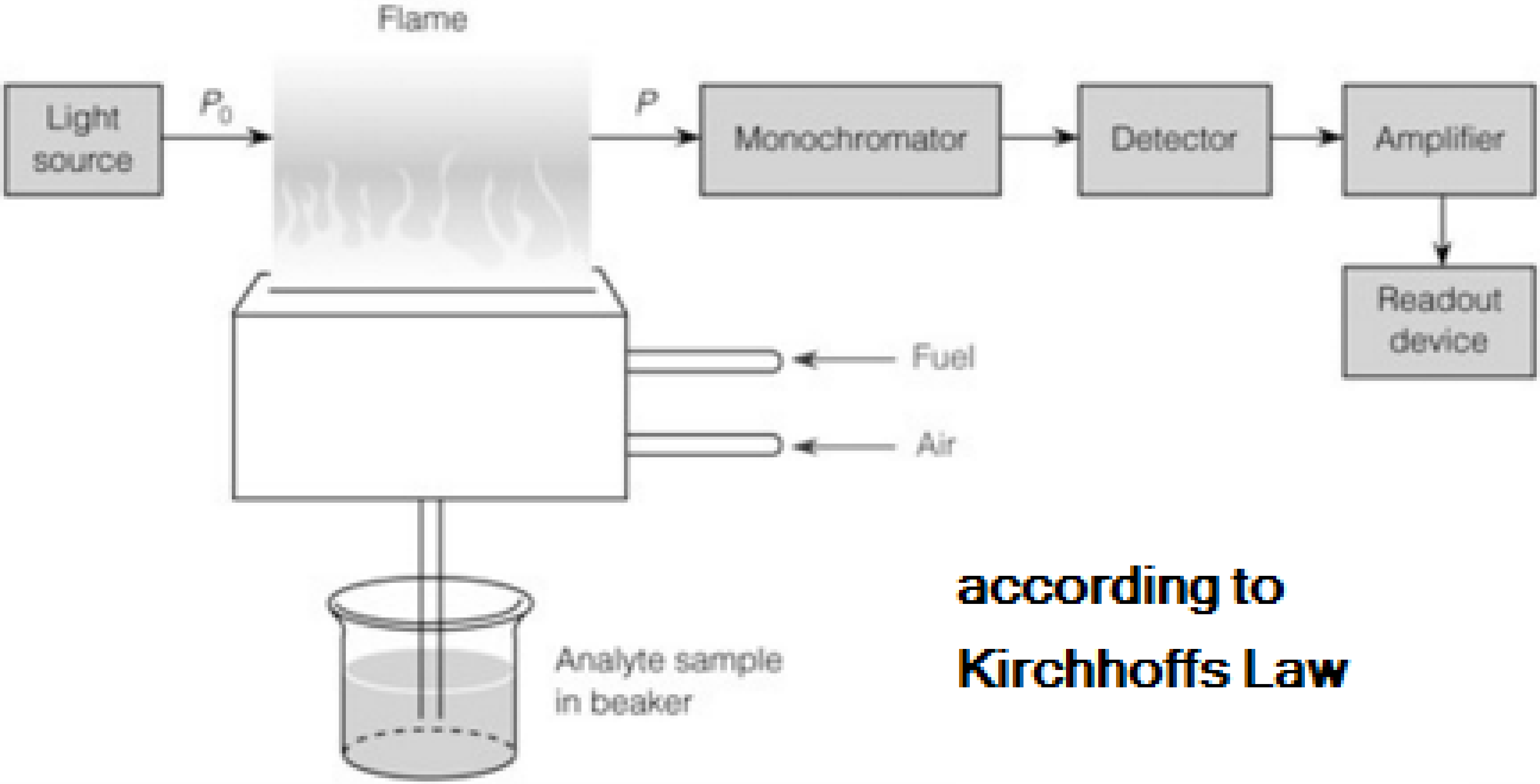
Only applicable to the determination of alkali and some alkaline earth metals.

ATOMIC

ABSORPTION

SPECTROPHOTOMETRY

What is Atomic Spectroscopy?



according to

Kirchhoffs Law

Absorption methods

Atomic absorption spectroscopy (AA)

طريقة للتحليل الكمي تعتمد على امتصاص الذرات للضوء وهي بحالتها الحرة المستقرة

A quantitative method of analysis based on the absorption of light by atoms in the free atomic state.

The method relies on the Beer-Lambert relationship - calculations are the same as with molecular absorption methods.

تعتمد الطرية بالحساب على قانون لامبير وبيير

Atomic absorption

Basis of method

With electrical or flame excitation, most atoms remain in the unexcited state. بإثارة الذرات باللهب أو كهربائياً معظم اذرات يبقى دو إثارة

Even with plasma emission, this is still true but not as large a problem.

If we can look at the free atoms, we can potentially develop a more sensitive method of analysis.

مبدأ الطريقة :

ذكرنا أن كحد أقصى 5% فقط من الذرات هي التي تثار باللهب وهذا الجزء فقط الذي استخدم في معايرة العناصر بالأنبعاث الذري أما القسم الأعظم من الذرات التي لم تثار تبقى مستقرة لذا فعندما يتم تسليط حزمة من الأشعة على هذه الذرات المستقرة(هذه الأشعة نابعة عن نفس العنصر) فإنها سوف تمتص من قبل هذه الذرات ، حيث تتناسب كمية امتصاصها مع تركيزها طردا ،

ATOMIC ABSORPTION SPECTROMETRY

(Ph. Eur. method 2.2.23)

Atomic absorption spectrometry is a method for determining the concentration of an element in a substance by measuring the absorption of radiation by atomic vapour of the element generated from the substance. The determination is carried out at the wavelength of one of the absorption lines of the element concerned.

أقسام الجهاز :

يتألف الجهاز من أربعة أقسام أساسية هي :

1- مصدر أشعة خطي يتألف من من مصباح ذي مهبط مجوف Hollow cathode lamp

2- محول المادة لذرات حرة (موقد) باستخدام اللهب أو وسيلة أخرى باستخدام المرزاز

3- مستفرد طول الموجة ، مهمته فصل خط الرنين (الطنين) المطلوب

4- خلية ضوئية مضاعفة تستخدم كمتحري

Apparatus

This consists essentially of a source of radiation, an atomic generator of the element to be determined (flame, furnace etc), a monochromator and a detector.

The method of introducing the substance to be analysed depends on the type of atomic generator used. If it is a flame, substances are nebulised and *water* is the solvent of choice for preparing test and reference [standard] solutions although organic solvents may also be used if precautions are taken to ensure that the solvent does not interfere with the stability of the flame. When a furnace is used, substances may be introduced dissolved in *water* or an organic solvent, but with this technique solid sampling is also possible.

الزئبق يحول لبخار خارج الجهاز

Apparatus

The atomic vapour may also be generated outside the spectrometer, for example, the cold vapour method for mercury or certain hydrides. For mercury, atoms are generated by chemical reduction and the atomic

يجرف

vapour is swept by a stream of an inert gas

الموجودة

into an absorption cell mounted in the optical path of the instrument. Hydrides are either mixed with the gas feeding the burner or swept by an inert gas into a heated cell in which they are dissociated into atoms.

Method

Operate an atomic absorption spectrometer in accordance with the manufacturer's instructions at the prescribed wavelength setting. Introduce a blank solution into the atomic generator and adjust the instrument reading so that it indicates maximum transmission. Introduce the most concentrated reference [standard] solution and adjust the sensitivity to obtain a suitable absorbance reading.

Determinations are made by comparison with reference solutions with known concentrations of the element being determined either by the method of direct calibration (Method I) or the method of standard additions (Method II).

Use Method I unless otherwise directed.

Sources

A molecular spectrophotometer relies on a broad band light source.

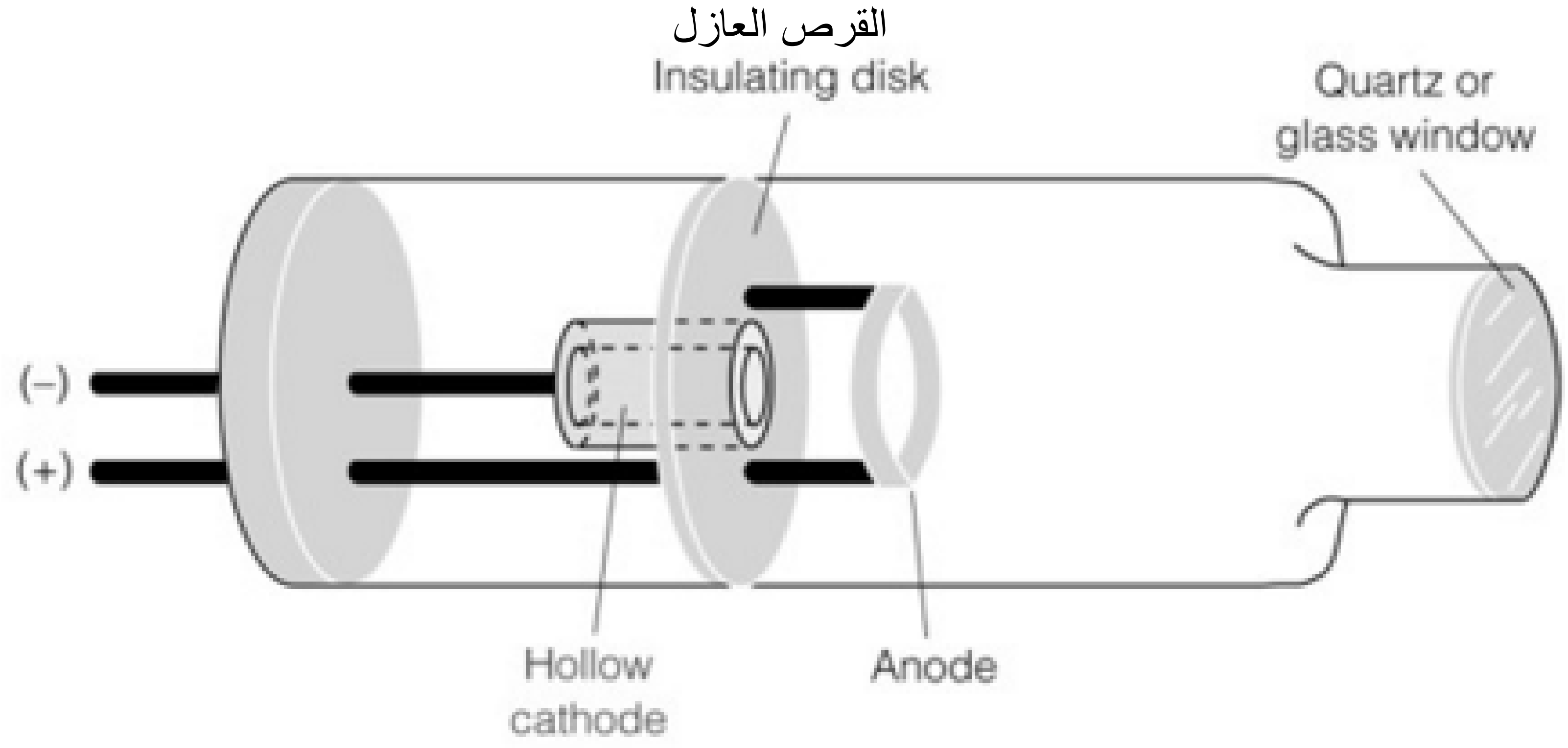
With atomic absorption, a line source is required to reduce interferences from other elements and background.

Two basic types

- Hollow cathode lamp - HC مصباح ذو المهبط المجوف
- Electrodeless discharge lamp - EDL مصباح التفريغ عديم الأقطاب

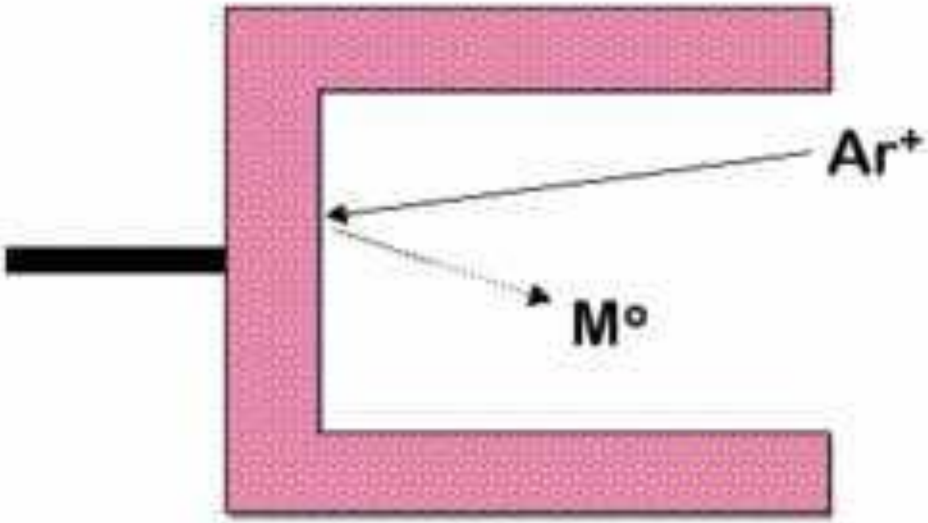
Hollow Cathode Lamps

Cathode composed of the same element as the analyte. As long as line broadening within the cathode is less than within the flame, the linewidth of the lamp is always less than the linewidth of the absorbing atoms and Beer's Law is followed.



Hollow cathode lamp

The lamp is filled with an inert gas like argon or neon. When a potential is applied, it causes the gas to become excited and it is driven towards the cathode.



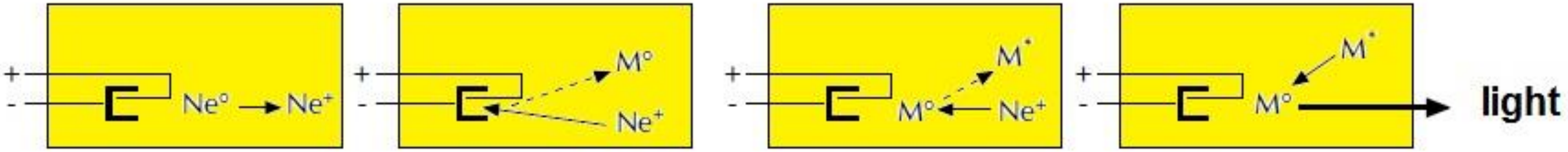
عند امرار تيار كهربائي بين المصعد والمهبط فسوف
يتأين الغاز ويأخذ شحنة موجبة تصطم بسطح المهبط
مؤدية لأنتشار ذرات المعدن في فضاء الأنبوب

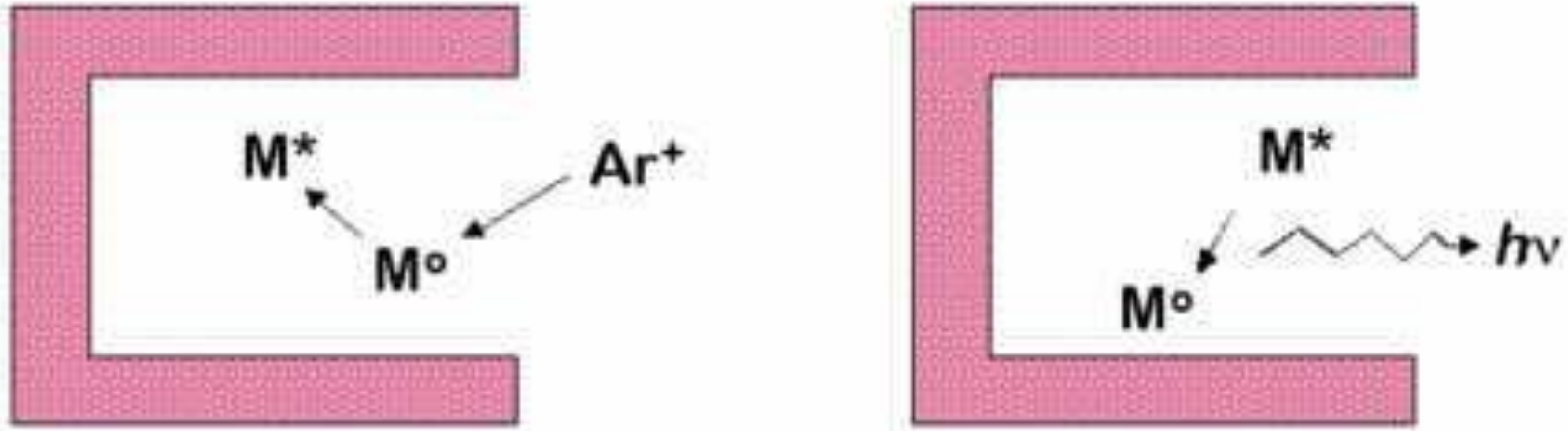
Metal atoms are then sputtered off the surface of the cathode.

Hollow cathode lamp

اصطدام

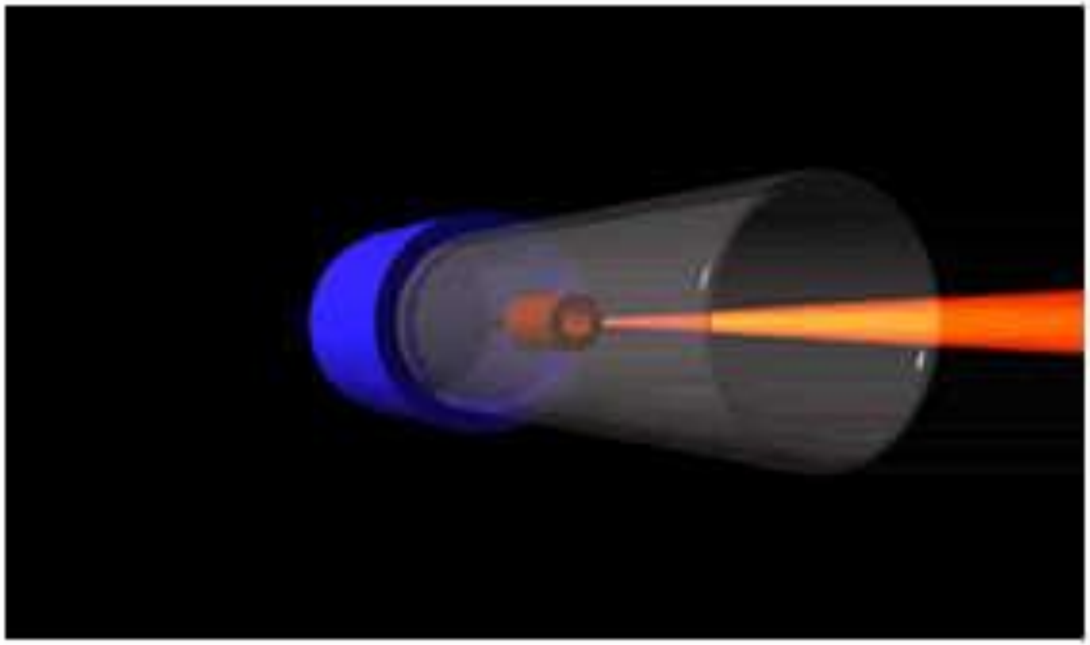
1. Ionization
2. Sputtering
3. Excitation
4. Emission





Hollow cathode lamp

This source produces emission lines specific for the element used to construct the cathode.



The cathode must be capable of conducting a current.

Hollow cathode lamp

An HC lamp will only produce the emission lines for the cathode element.

Multi-element HC lamps are available but are limited.

Not all metals will make suitable cathodes

- Metal is too volatile
- A good cathode can't be produced
- The metal may not be good conductors

Electrodeless discharge lamp

مصباح مفرغ عديم الأأقطاب

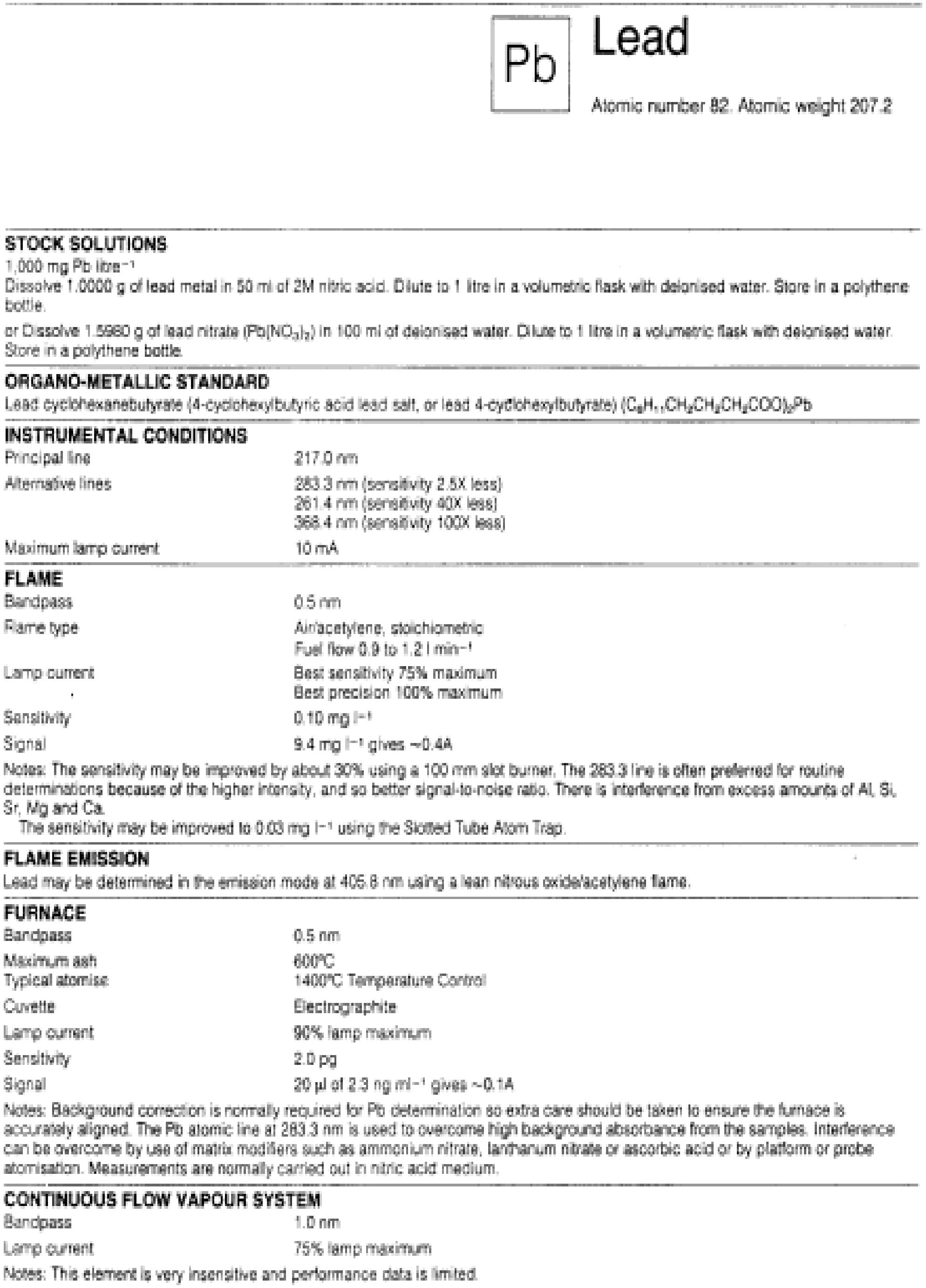
An alternative to the hollow cathode lamp.

A salt containing the metal of interest is sealed in a quartz tube along with an inert gas.

ملح لنفس المعدن بشكل بيضوي محاط
بوشيعة وموضوع ضمن انبوب مغلق
مع غاز خامل

An RF field is used to excite the gas which in turn causes the metal be be ionized.

Light intensity is about 10-100 times greater but are not as stable as HC lamps.



Pb Lead

Atomic number 82. Atomic weight 207.2

STOCK SOLUTIONS

1,000 mg Pb litre^{-1}

Dissolve 1.0000 g of lead metal in 50 ml of 2M nitric acid. Dilute to 1 litre in a volumetric flask with deionised water. Store in a polythene bottle.

or Dissolve 1.5980 g of lead nitrate ($Pb(NO_3)_2$) in 100 ml of deionised water. Dilute to 1 litre in a volumetric flask with deionised water. Store in a polythene bottle.

ORGANO-METALLIC STANDARD

Lead cyclohexanebutyrate (4-cyclohexylbutyric acid lead salt, or lead 4-cyclohexylbutyrate) $(C_6H_{11}CH_2CH_2CH_2COO)_2Pb$

INSTRUMENTAL CONDITIONS

Principal line	217.0 nm
Alternative lines	283.3 nm (sensitivity 2.5X less) 261.4 nm (sensitivity 40X less) 368.4 nm (sensitivity 100X less)
Maximum lamp current	10 mA

FLAME

Bandpass	0.5 nm
Flame type	Air/acetylene, stoichiometric Fuel flow 0.9 to 1.2 l min^{-1}
Lamp current	Best sensitivity 75% maximum Best precision 100% maximum
Sensitivity	0.10 mg l^{-1}
Signal	9.4 mg l^{-1} gives ~0.4A

Notes: The sensitivity may be improved by about 30% using a 100 mm slot burner. The 283.3 line is often preferred for routine determinations because of the higher intensity, and so better signal-to-noise ratio. There is interference from excess amounts of Al, Si, Sr, Mg and Ca.

The sensitivity may be improved to 0.03 mg l^{-1} using the Slotted Tube Atom Trap.

FLAME EMISSION

Lead may be determined in the emission mode at 405.8 nm using a lean nitrous oxide/acetylene flame.

FURNACE

Bandpass	0.5 nm
Maximum ash Typical atomise	600°C 1400°C Temperature Control
Cuvette	Electrographite
Lamp current	90% lamp maximum
Sensitivity	2.0 pg
Signal	20 µl of 2.3 ng ml^{-1} gives ~0.1A

Notes: Background correction is normally required for Pb determination so extra care should be taken to ensure the furnace is accurately aligned. The Pb atomic line at 283.3 nm is used to overcome high background absorbance from the samples. Interference can be overcome by use of matrix modifiers such as ammonium nitrate, lanthanum nitrate or ascorbic acid or by platform or probe atomisation. Measurements are normally carried out in nitric acid medium.

CONTINUOUS FLOW VAPOUR SYSTEM

Bandpass	1.0 nm
Lamp current	75% lamp maximum

Notes: This element is very insensitive and performance data is limited.

Method I: Method of direct calibration

Prepare the solution of the substance being examined (test solution) as prescribed. Prepare not fewer than three reference [standard] solutions of the element to be مدى determined the concentrations of which span the expected value in the test solution. Any reagents used in the preparation of the test solution are added to the reference [standard] and blank solutions at the same concentration. Introduce the test solution and each reference [standard] solution into the instrument at least three times and record the steady reading. Rinse the apparatus with blank solution تأكد each time and ascertain that the reading returns to its initial blank value. If a furnace is being used, it is fired between افصل readings.

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Method I: Method of direct calibration

Prepare a calibration curve from the mean of the readings obtained with the reference [standard] solutions and determine the concentration of the element in the test solution from the curve so obtained.

If a solid sampling technique is required, full details of the procedure to be followed are provided in the monograph.

Method II: Method of standard addition

Add to at least three similar volumetric flasks equal volumes of the solution of the substance being examined (test solution) prepared as prescribed. Add to all but one of the flasks progressively larger volumes of a reference [standard] solution containing a known concentration of the element being determined to produce a series of solutions containing increasing concentrations of that element known to give responses in the linear part of the curve. Dilute the contents of each flask to volume with solvent.

Introduce each of the solutions into the instrument at least three times and record the steady reading. Rinse the apparatus with solvent each time and ascertain that the reading returns to its initial blank value. If a furnace is being used, it is fired between readings.

Method II: Method of standard addition

Calculate the linear equation of the graph using a least-squares fit and derive from it the concentration of the element to be determined in the test solution. Alternatively, plot on a graph the mean of readings against the added quantity of the element to be determined. Extrapolate the line joining the points on the graph until it meets the concentration axis. The distance between this point and the intersection of the axes represents the concentration of the element being determined in the test solution.

If a solid sampling technique is required, full details of the procedure to be followed are provided in the monograph.

Atomic absorption

Advantages over emission

☑ Fewer interferences

☑ Less dependent on temperature

☑ Most elements exhibit better sensitivity and accuracy - ppb range with ±2% accuracy.

Disadvantages over emission

☑ Metals only - most other elements form oxides to rapidly.

☑ Quantitative analysis only.

Ascorbic Acid

Copper Not more than 5 ppm of Cu, determined by atomic absorption spectrophotometry (*Method I, 2.2.23*).

Test solution. Dissolve 2.0 g of the substance to be examined in *0.1*M *nitric acid* and dilute to 25.0 ml with the same acid.

Reference solutions. Prepare reference solutions containing 0.2 ppm, 0.4 ppm and 0.6 ppm of Cu by diluting *copper standard solution (10 ppm Cu) R* with *0.1*M *nitric acid*.

Measure the absorbance at 324.8 nm using a copper hollow-cathode lamp as a source of radiation and an air-acetylene flame. Adjust the zero of the apparatus using *0.1*M *nitric acid*.

Iron. Not more than 2 ppm of Fe, determined by atomic absorption spectrophotometry (*Method I, 2.2.23*).

Test solution. Dissolve 5.0 g of the substance to be examined in *0.1*M *nitric acid* and dilute to 25.0 ml with the same acid.

Reference solutions. Prepare reference solutions containing 0.2 ppm, 0.4 ppm and 0.6 ppm of Fe by diluting *iron standard solution (20 ppm Fe) R* with *0.1*M *nitric acid.*
Measure the absorbance at 248.3 nm using an iron hollow-cathode lamp as a source of radiation and an air-acetylene flame. Adjust the zero of the apparatus using *0.1*M *nitric acid.*

Calamine

Lead Not more than 150 ppm when determined by *atomic absorption spectrophotometry*, Appendix II D, Method II, measuring at 283.3 nm or 217 nm and using an air-acetylene flame. Carefully add 5 g of the substance being examined to 25 ml of *hydrochloric acid* and allow to stand for 18 hours. Add 5 ml of *nitric acid* and sufficient *water* to produce 200 ml. Use *lead standard solution (100 ppm Pb)* suitably diluted with a 3.5% v/v solution of *nitric acid* to prepare the standard solution.

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Atomic absorption spectrophotometry (AAS)

Principles

Atoms of metals are volatilised in aflame and their absorption of a narrow band of radiation produced by a hollow cathode lamp, coated with the particular metal being determined , is measured.

Applications in pharmaceutical analysis

Determination of metal residues remaining from the manufacturing process in drugs.

Strengths

More sensitive than AES, A highly specific method of analysis useful in some aspects of quality control

Limitations

Only application to metallic elements

Each element requires a different hollow cathode lamp for its determination

Q&A

AAS