CHEMISTRY 5 (INSTRUMENTAL)

AGRICULTURAL BIOTECHNOLOGY, LEVEL 2

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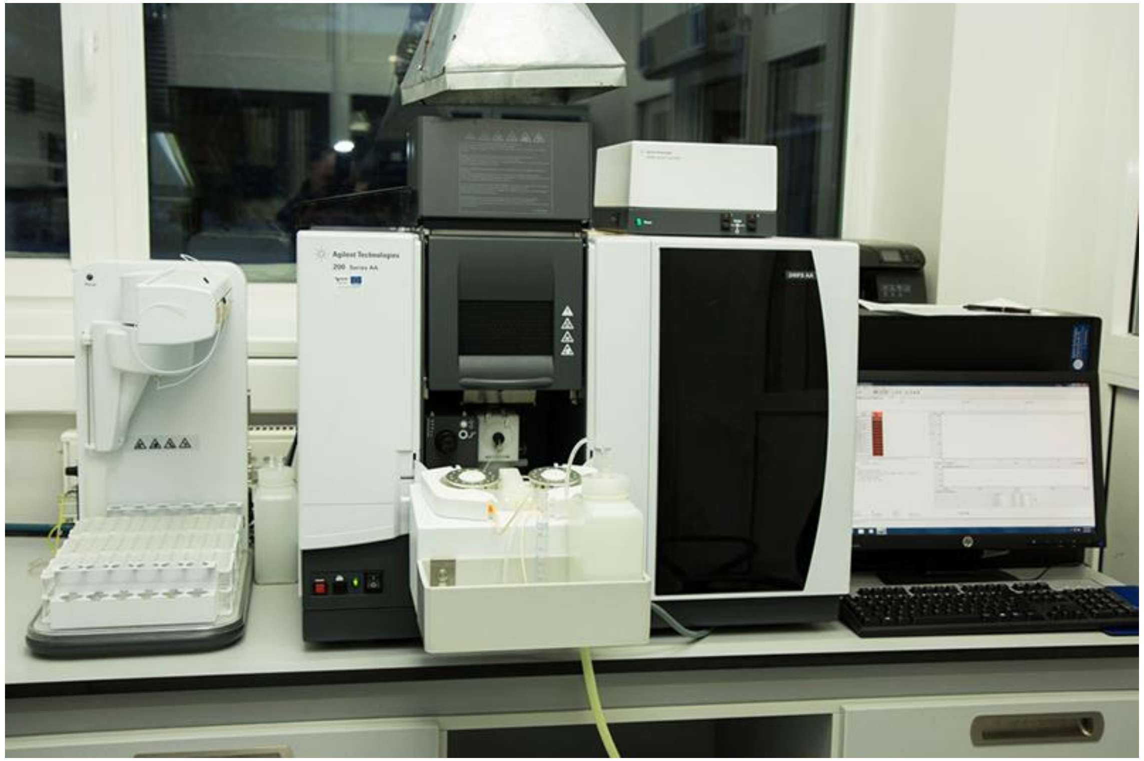
CONTENTS

- What is Atomic Absorption Spectroscopy (AAS)?
- Atomic Absorption Spectroscopy Principle
- Instrumentation of AAS
- Atomic Absorption Spectroscopy Applications
- References

WHAT IS ATOMIC ABSORPTION SPECTROSCOPY (AAS)?

- **AAS** is a spectroanalytical procedure for the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. Atomic absorption spectroscopy is based on absorption of light by free metallic ions.
- AAS is used for determining the **concentration** of a particular element (the analyte) in a sample to be analyzed.



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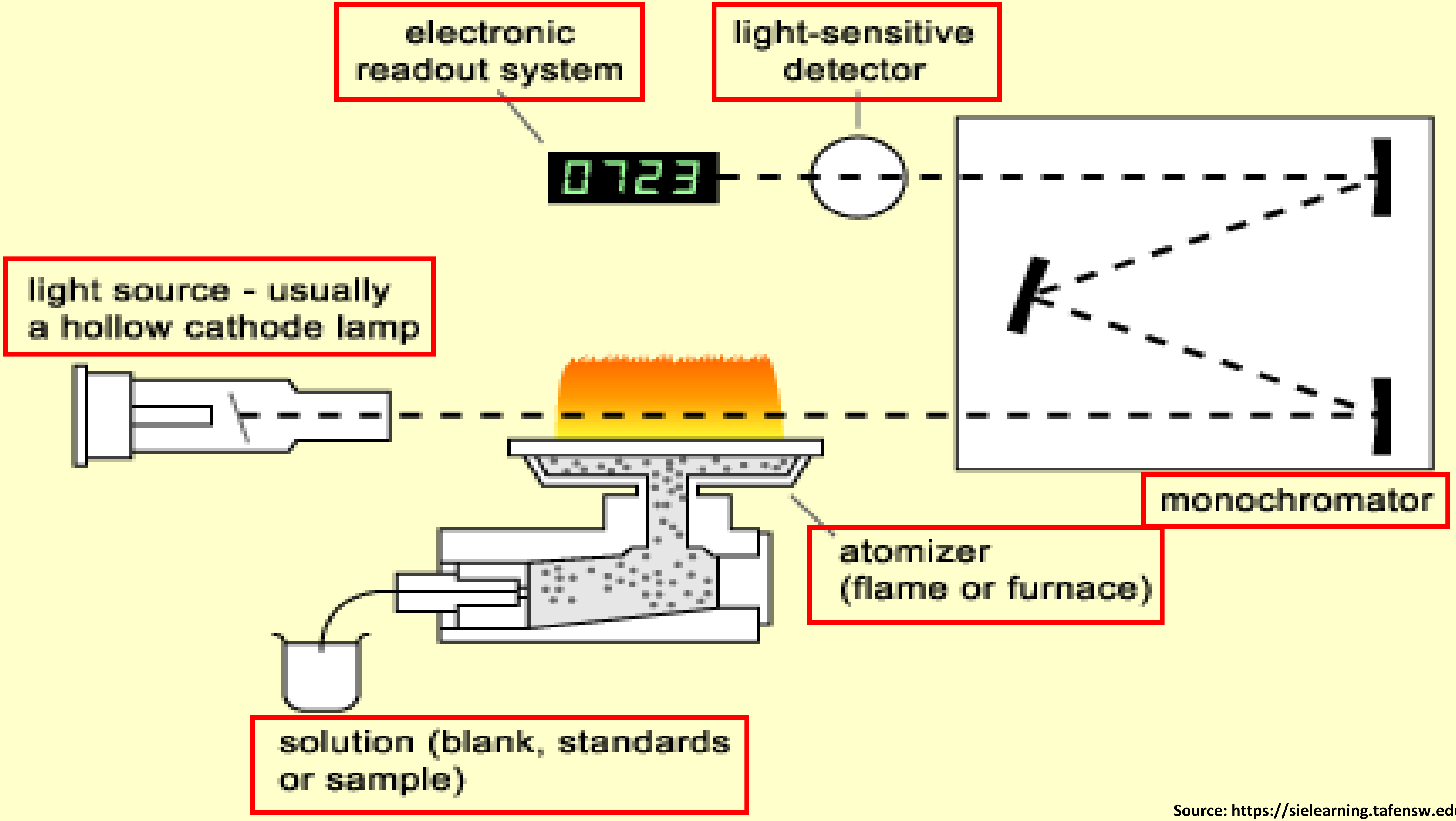
ATOMIC ABSORPTION SPECTROSCOPY (AAS)

- PRINCIPLE,
- INSTRUMENTATION,
- APPLICATIONS

- The modern form of AAS was largely developed during the 1950s by a team of Australian chemists. They were led by Sir Alan Walsh at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Chemical Physics, in Melbourne, Australia.

PRINCIPLE

- **Atomic absorption Spectroscopy (AAS)** is a technique in which free gaseous atoms absorb **electromagnetic radiation** at a **specific wavelength** to produce a corresponding measurable **signal.** The absorption signal is proportional to the **concentration of the free atoms** present in the optical path.
- The technique makes use of the atomic absorption spectrum of a sample in order to assess the concentration of specific analytes within it.
- It requires standards with known analyte content to establish the relation between the **measured absorbance** and **the analyte concentration** and relies therefore on the **Beer–Lambert law**.



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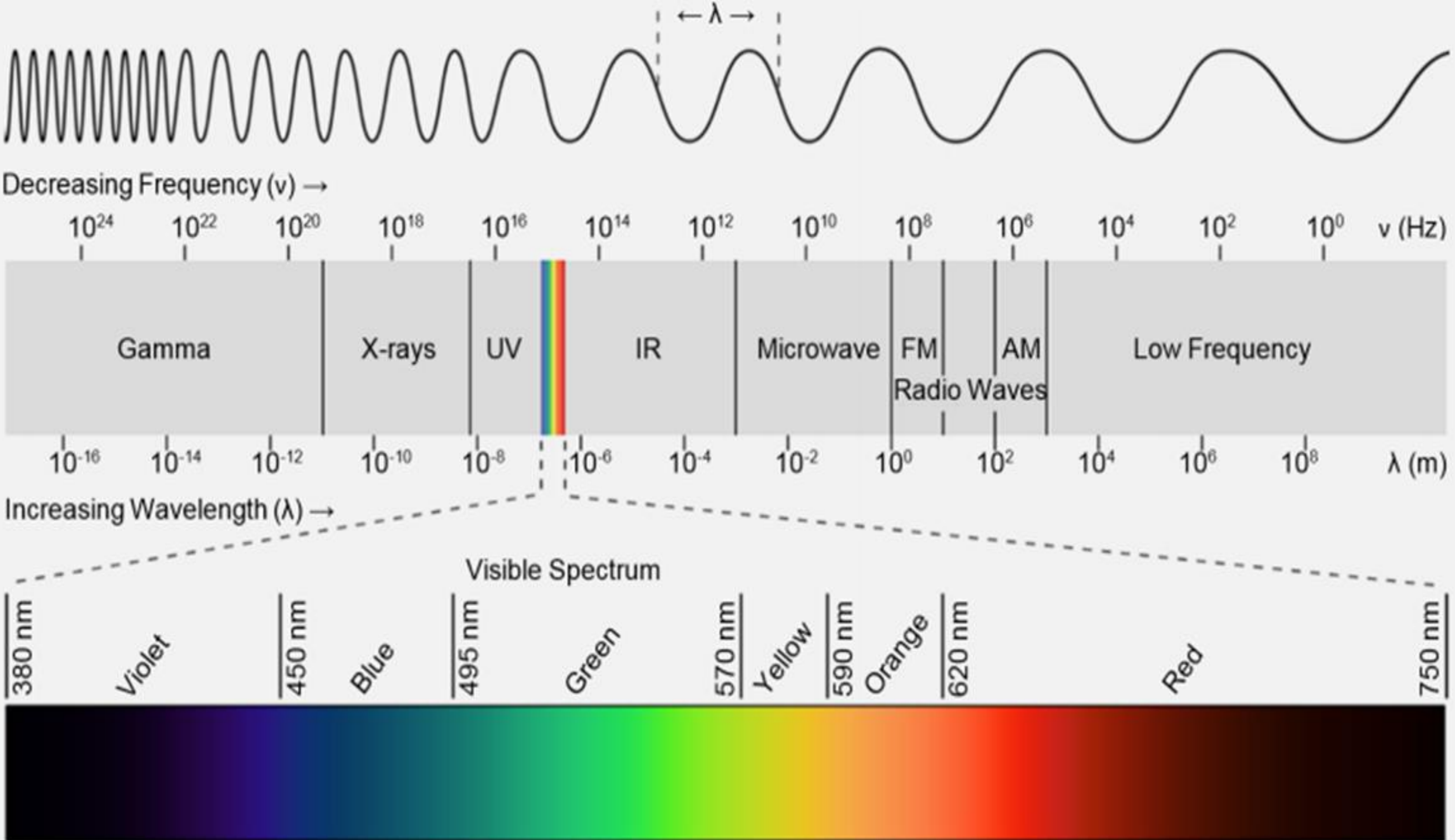

←λ→
Decreasing Frequency (ν) →
10^{24} 10^{22} 10^{20} 10^{18} 10^{16} 10^{14} 10^{12} 10^{10} 10^{8} 10^{6} 10^{4} 10^{2} 10^{0} ν (Hz)
Gamma
X-rays
UV
IR
Microwave
FM
AM
Radio Waves
Low Frequency
10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4} 10^{6} 10^{8} λ (m)
Increasing Wavelength (λ) →
Visible Spectrum
380 nm
Violet
450 nm
Blue
495 nm
Green
570 nm
Yellow
590 nm
Orange
620 nm
Red
750 nm

INSTRUMENTATION

The essential components of Atomic absorption Spectroscopy (AAS) instrumentation include:

An **AAS** consists of **five basic functional parts:**

1. **Light source:** which is usually a Hollow Cathode Lamp.
2. **Nebulizer & Atomizer section:** for atomizing the sample which could be a flame or an electrothermal or a cold vapor/hydride generation system.
3. **Monochromator:** for selecting the analysis wavelength for the target element.
4. **Detector:** for measuring the amount of light absorbed
5. **Recorder:** for recording the output from the detector.

1. Light source (Radiation source):

- The Hollow Cathode Lamp is perhaps the most commonly used light source in an AAS.
- The Hollow Cathode lamp produces narrow emissions from atomic species.
- The Hollow Cathode Lamp consists of a cup-shaped cathode which is made from element of interest and an Anode which is usually made from tungsten and placed in a hollow tube filled with an inert gas such as Ar or Ne.
- Application of a high potential difference across the electrodes causes a discharge of electrons.
- These gaseous ions blast the cathode and eject metal atoms from the cathode in a process called **sputtering**. Some sputtered atoms are in excited state and emit radiation (light) characteristic of the metal as they fall back to the ground state.

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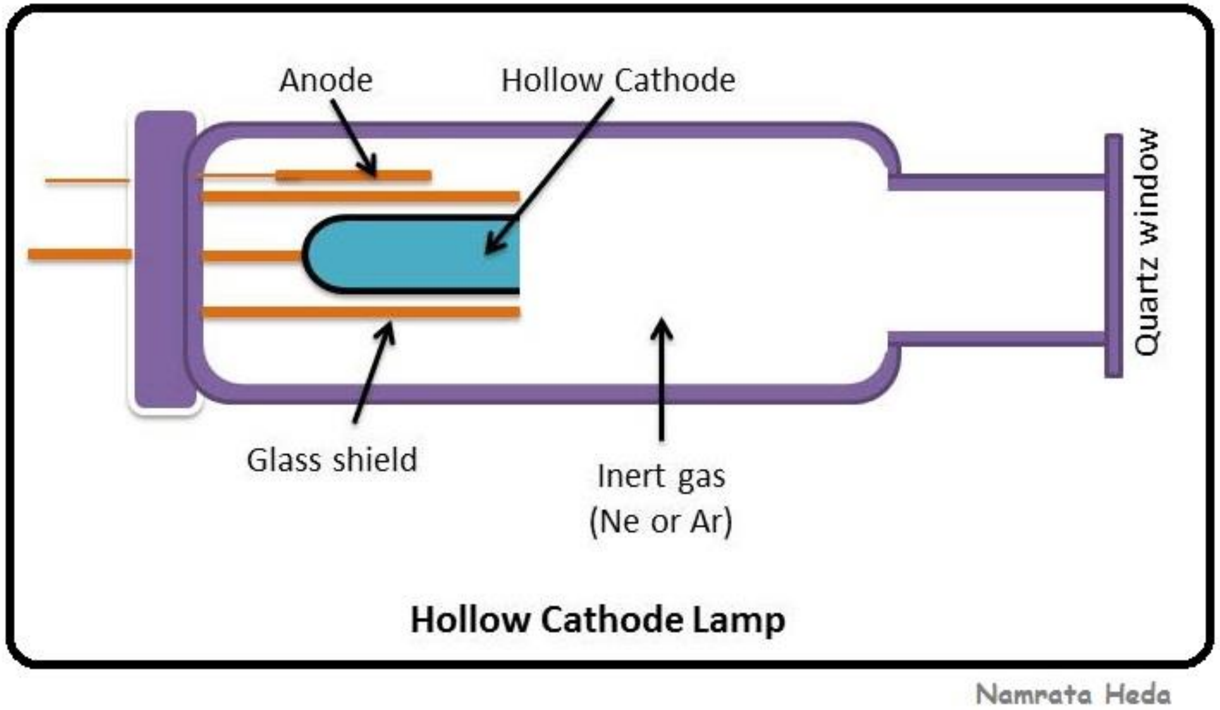
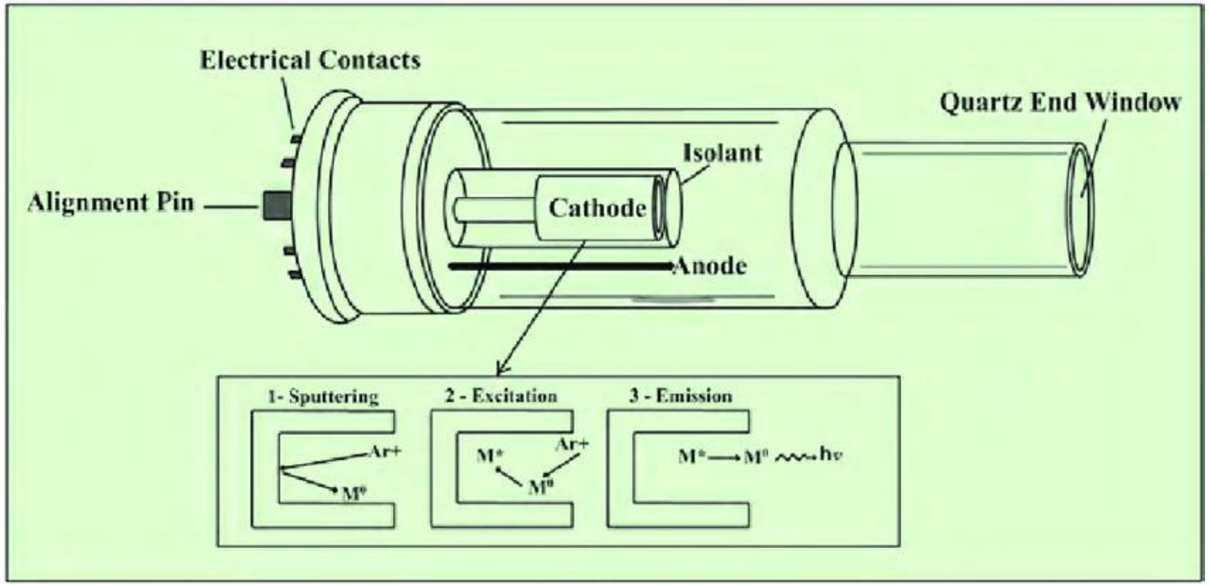
Type of light or radiation source:

1. Electrode-less Discharge Lamps (EDLs)
2. Hollow Cathode Lamps
3. Deuterium Lamps





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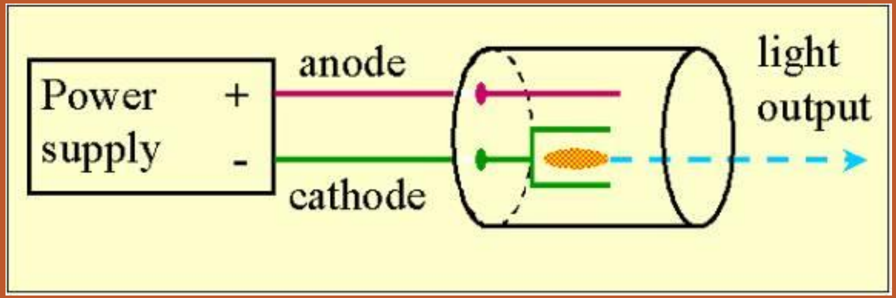
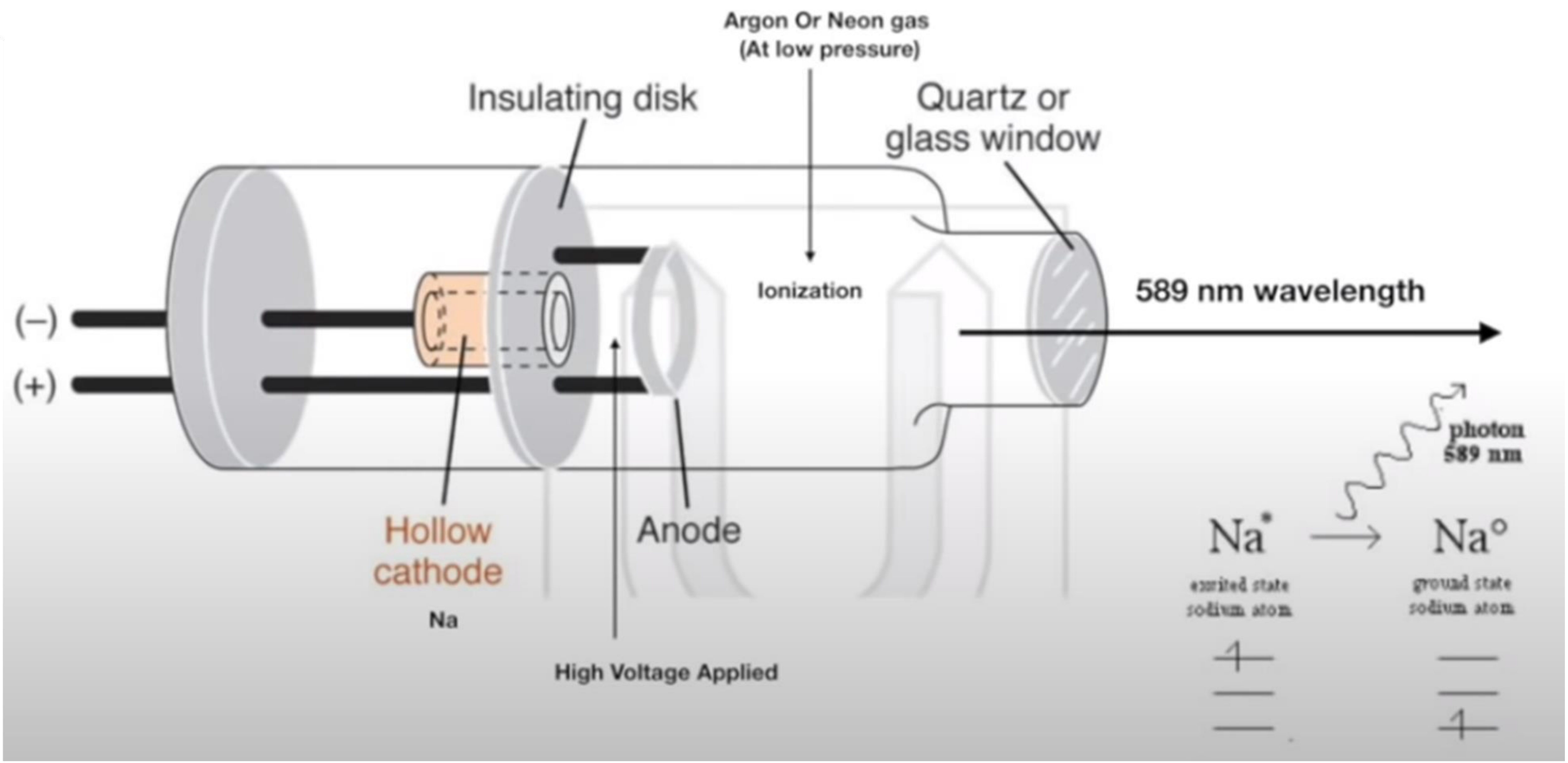


https://web.nmsu.edu/~esevosti/lamp.htm


Argon Or Neon gas
(At low pressure)
Insulating disk
Quartz or
glass window
(–)
(+)
Ionization
589 nm wavelength
photon
589 nm
Hollow
cathode
Na
Anode
High Voltage Applied
Na*
Na°
excited state
sodium atom
ground state
sodium atom

2. Nebulizer & Atomizer section:

- This consists basically of the burner for flame analysis or a graphite furnace for electrothermal analysis or cold vapor or a hydride system.
- The Nebulizer introduces the sample as a fine mist and the spray chamber to create a good mix for both air and the fuel gas.

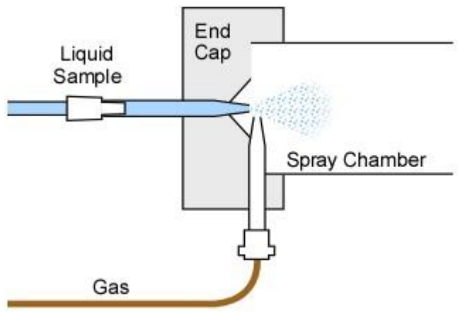
A Nebulizer:

is a device that introduces a liquid sample into the AAS.

The most common types of Nebulizer: pneumatic and ultrasonic nebulizers.

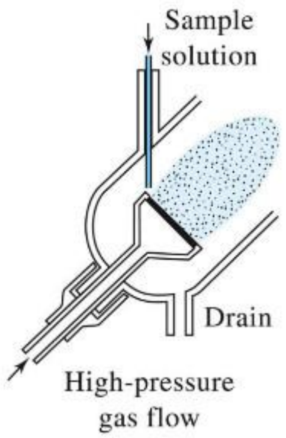
- **<u>Pneumatic Nebulizers</u>**

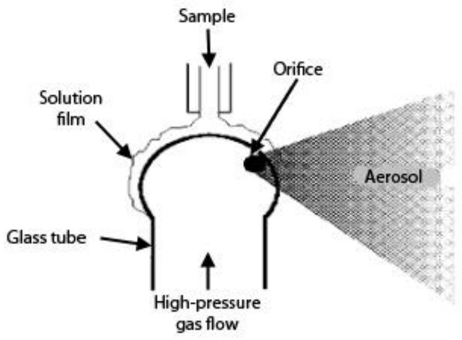
A pneumatic nebulizer converts a sample solution into an aerosol of tiny droplets using a jet of compressed gas. The flow of inert gas carries the droplets to an atomizer. Several versions of pneumatic nebulizers are available as shown here.



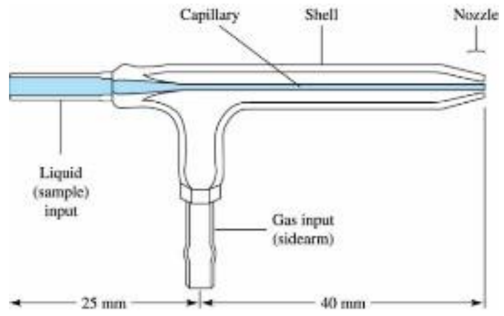
Cross-flow Nebulizer

Fritted Disk Nebulizer





Babington Nebulizer



Concentric Tube Nebulizer

- **Ultrasonic Nebulizers**

An ultrasonic nebulizer creates **an aerosol** of tiny droplets by pumping a sample solution onto the surface of a **piezoelectric crystal** that vibrates at a frequency of 20 kHz to several MHz. The vibrations convert the sample into a dense and more homogeneous aerosol than what a pneumatic nebulizer can achieve. However, viscous liquids and particulates lower its efficiency. The aerosol is then carried to an **atomizer** by an inert gas.

3. Monochromator:

- This is used to isolate a single atomic resonance line from the spectrum of lines emitted from the interaction of the sample with the resonance light from hollow cathode lamp. Essentially it is an adjustable filter that selects a specific narrow region of the spectrum for transmission to the detector and excludes all wavelengths outside this region.

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Atomizer section

- Atomic Absorption Spectroscopy requires the conversion of the sample to gaseous atoms, which absorb radiation. In AAS the sample is most commonly introduced as a solution.
- The solution is drawn in through a small tube and taken to the nebulizer where the solution is broken up into a fine mist (this is similar to an aerosol can). The fine mist is carried to the atomizer, such as a flame, by a carrier gas. When the mist reaches the flame, the intense heat breaks up the sample into its individual atoms.
- This final process is called atomization.

Atomizer section

There are **two main types of atomizers**: discrete and continuous.

Continuous atomizers: introduce the analyte in a steady manner whereas

discrete atomizers: introduce the analyte discontinuously.

- The most common **continuous atomizer** in AAS is a **flame**, and the most common **discrete atomizer** is the **electrothermal atomizer**.

Sample atomization limits the **accuracy**, **precision**, **and limit of detection** of the analytical instrument.

The purpose of the atomization step is to convert the analyte to a reproducible amount of gaseous atoms that appropriately represents the sample.

4. Detector:

- It converts light coming from a monochromator into an amplified electrical signal which can be recorded. The amount of light getting to the detector is a function of the concentration of the element of interest in the sample being analyzed.
- The type of detector found in AAS is the **photomultiplier tube** – the principle of operation is the emission of electrons upon exposure to radiation.

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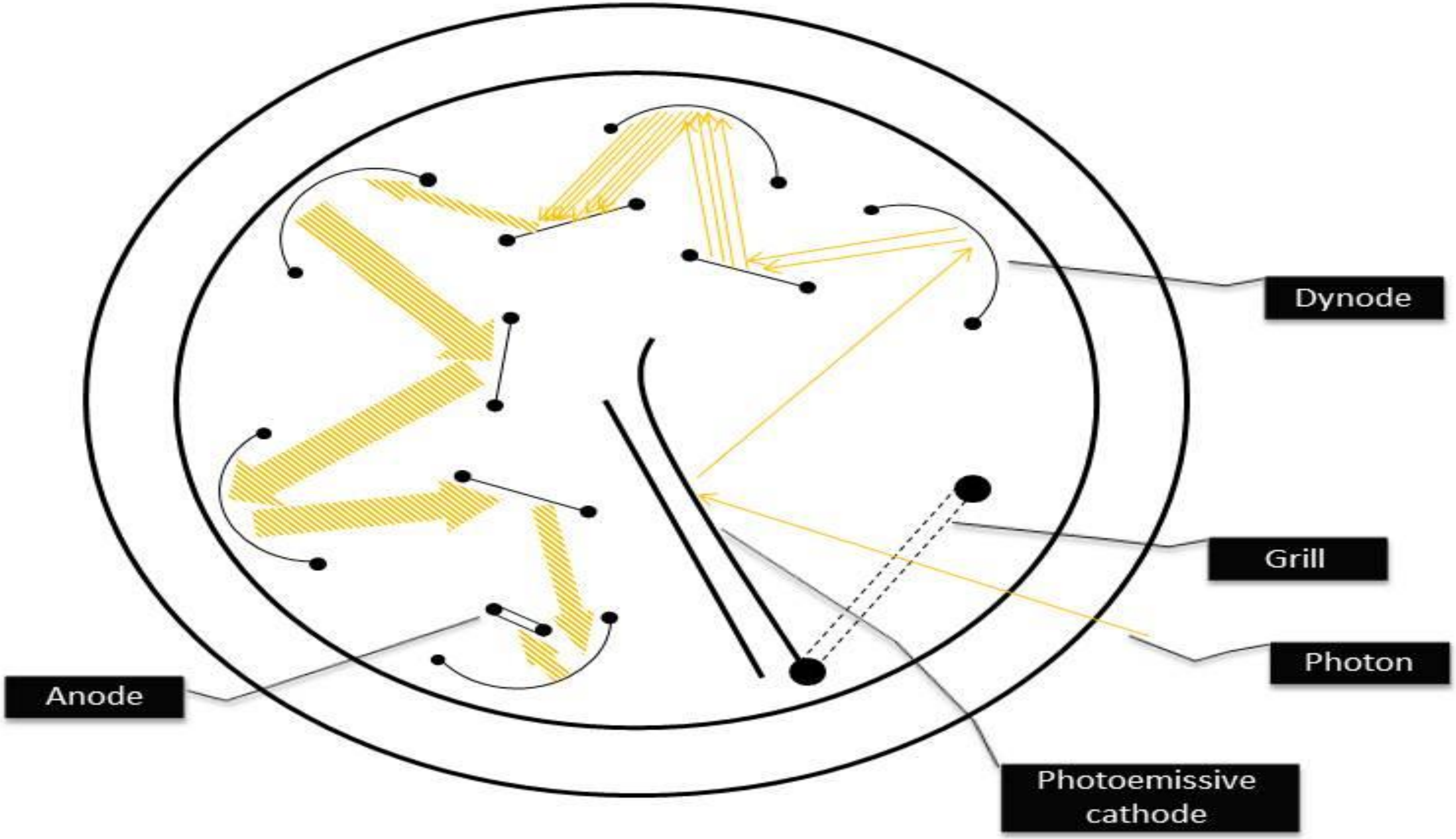
Photomultiplier tube



https://blogs.maryville.edu/aas/detection/

5. The Recorder:

- Nowaday, is usually a computer system and a suitable software, receives the analog signals from the detector and converts it to readable responses.

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APPLICATIONS

We've stated, atomic absorption spectroscopy is utilized in a wide variety of industries and areas of scientific study. Some of the more common applications for this technique are listed below.

AA or AE spectrometers have been used in many different industrial and academic settings.

For example, a medical laboratory could detect the type and amount of toxic metals that could be present in patient's urine or blood.

Environmental scientists could monitor metal pollutants in soil and water.

The pharmaceutical industry uses these machines to determine if a metal catalyst after a drug has been purified. Lastly, the mining industry would utilize these devices to detect the quantity and presence of precious metals like gold and silver.

REFERENCES

- Link
- Link

THANK YOU