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NOTES**

**INSTRUMENTAL
METHODS OF ANALYSIS**

PART-1

IR SPECTROSCOPY

**INTRODUCTION
& PRINCIPLE**

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IR Spectroscopy:

γ -rays

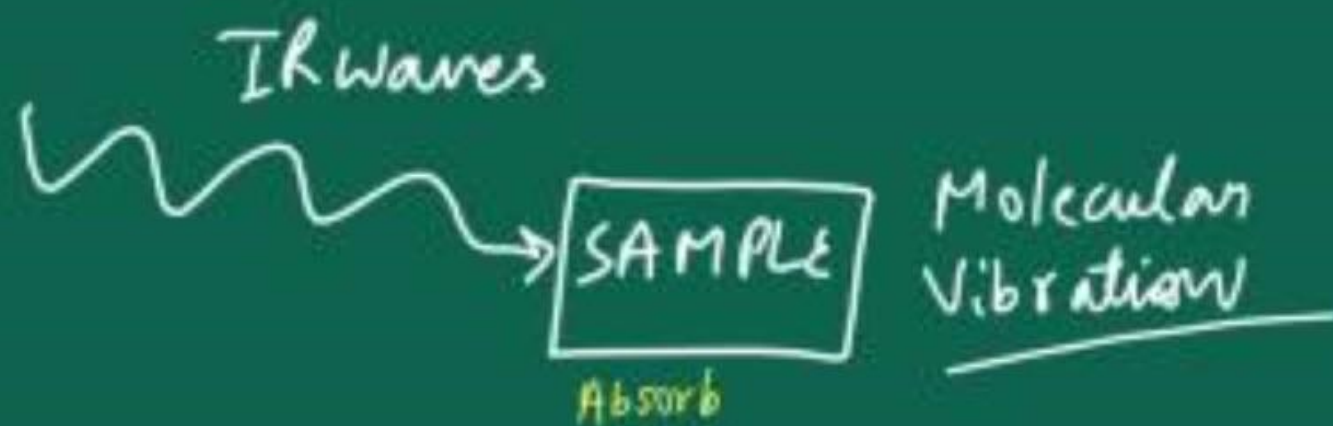
X-rays

IR*

UV

Microwave

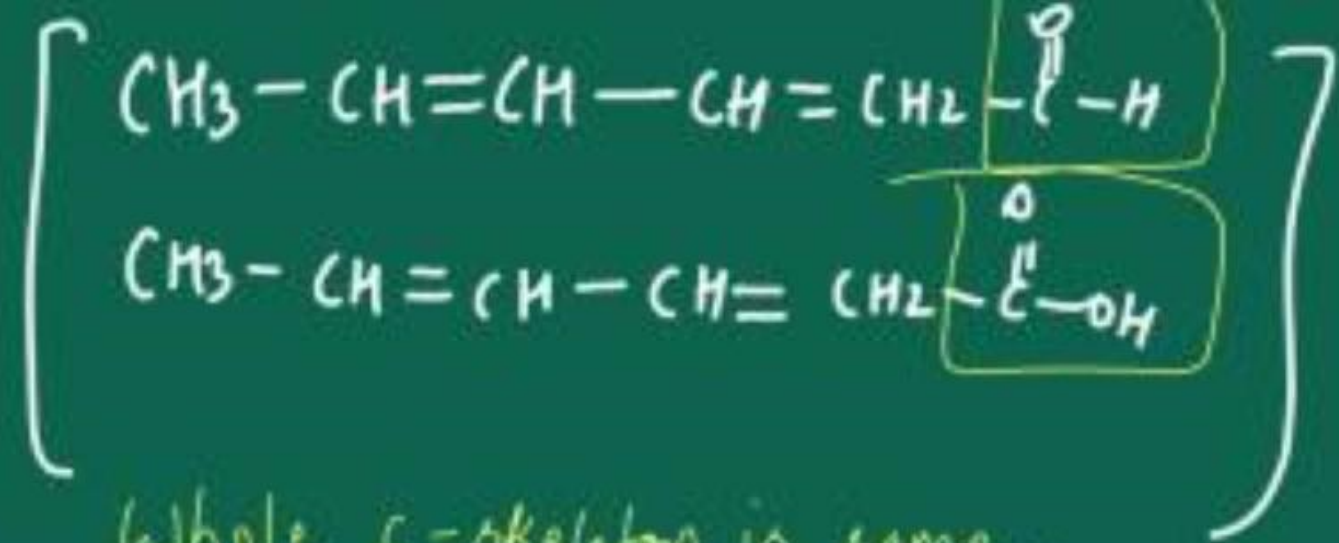
Radiowave



also known as Vibrational Spectroscopy.

$\sim 4000 - 400 \text{ cm}^{-1}$ (IR Range)

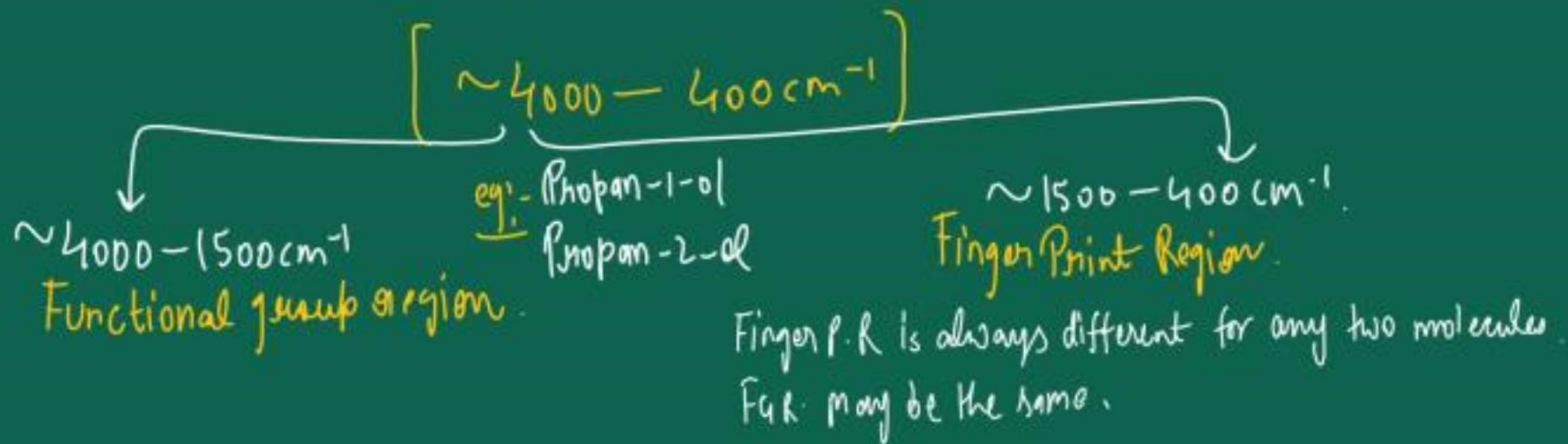
$\sim 2.5 \mu\text{m} - 25 \mu\text{m}$



Whole C-skeleton is same,

Just Functional group is different

& it can be identified by IR spectroscopy.





Atom

Starts vibrating to
lose energy &
gain stability

Generates a
Vibrational wave.

Energy;

$E = (n + \frac{1}{2}) h \nu$

To gain the stability, molecule needs to emit the energy.

Degree of freedom (Mode of Energy Transfer)

→ Translation

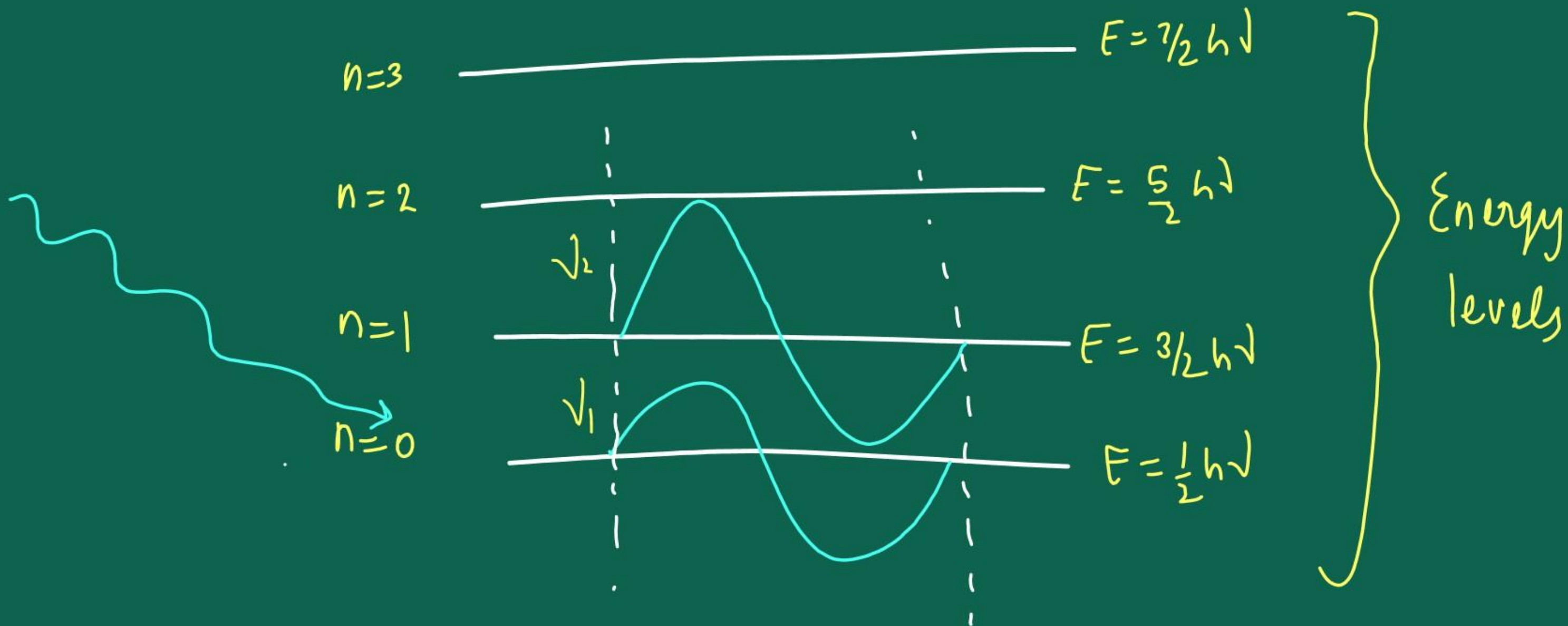
→ Vibrational ★★

→ Rotational

n = Vibrational Quantum no.

ν = freq.

$$\left[E = \left(n + \frac{1}{2} \right) h\nu \right]$$



Principle :-

When the absorption happens, the Ground state Vibrational frequency absorbs the Energy of ν_2

It starts vibrating with high energy & amplitude

Then detector can detect the frequency of absorbed radiation.

4 shows a peak corresponding to that radiation.

almost same
Freq.

$$[\nu_1 \approx \nu_2] \text{ Coupling of waves.}$$

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**INSTRUMENTAL
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PART-2

IR SPECTROSCOPY

**MODES OF
VIBRATIONS**

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Pharmaceutical Analysis

Sem – 7

Unit – 2

Topic : Modes of Vibration



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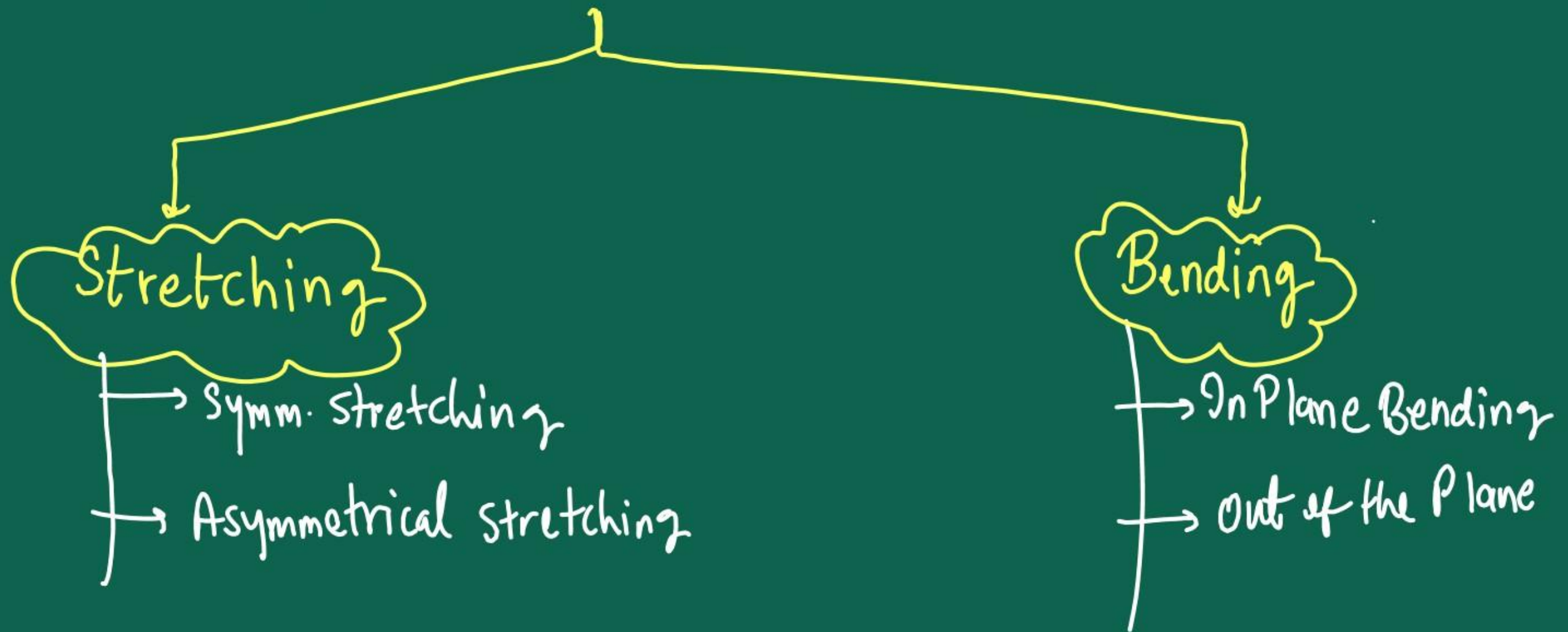
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Modes of Vibration

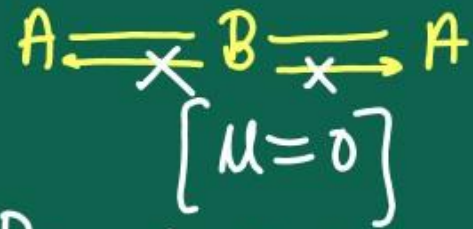
A molecule that can show the vibration in different direction/modes in its Ground state.



Stretching

Symmetrical Stretching

let, A Triatomic linear molecule



Dynamic dipole moment $\rightarrow \times$

Asymmetrical Stretching

Triatomic molecule.



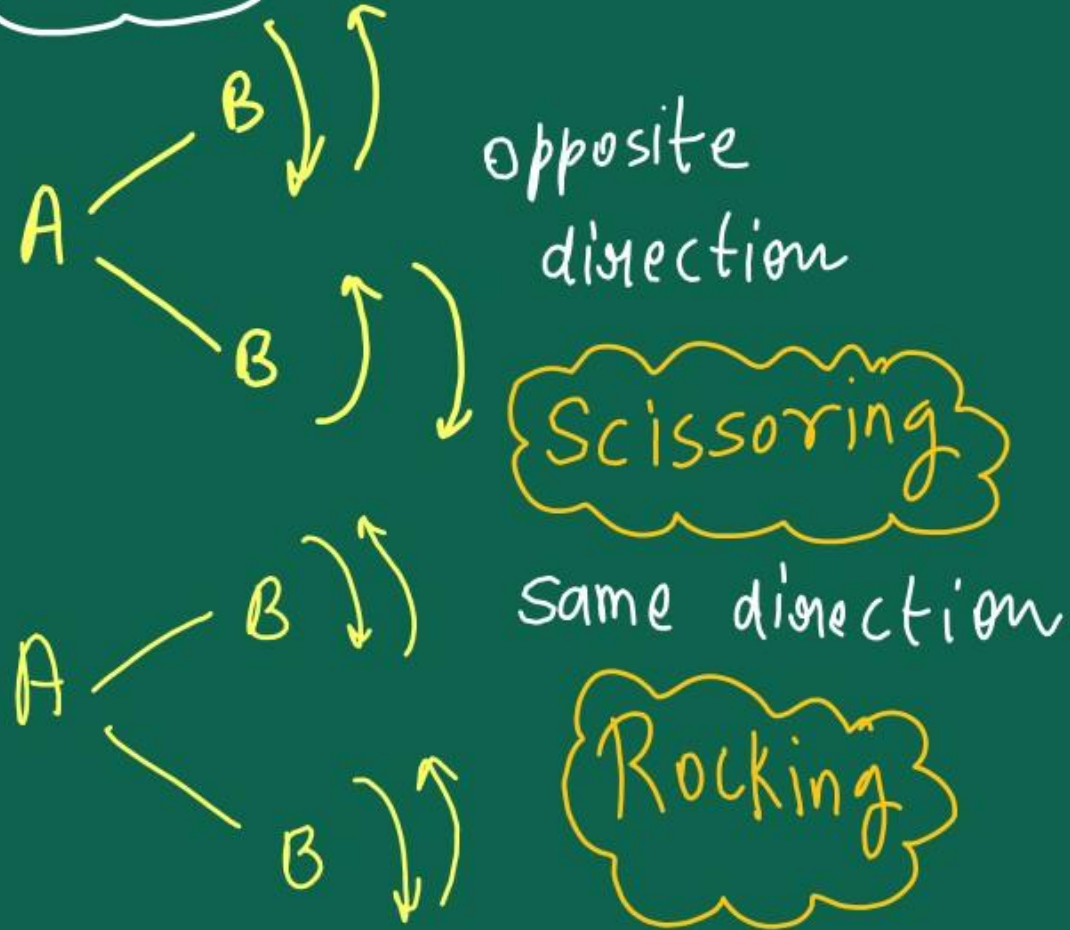
$\mu \neq 0$

Dynamic dipole moment $\rightarrow \checkmark$

Here, we have observed that different bonds are having different strengths & they'll absorb different IR radiations

Bending ($\mu \neq 0$) IR Active modes

In-Plane



Out of the Plane



 : Wedge : Above the Plane

 : dash : Below the Plane

If,

Dynamic Dipole moment is Present :- IR Active .

D.D.M is absent - IR inactive.

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**INSTRUMENTAL
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PART-3

IR SPECTROSCOPY

**SAMPLE
HANDLING**

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Sample Preparation Techniques

Sampling Techniques

- It depends on the type of sample, such as,
- Solid
- Liquid
- Gas



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Sampling of Solids

- Solid Run in Solution
- Solid Films
- Mull Technique
- Pressed Pellet Technique

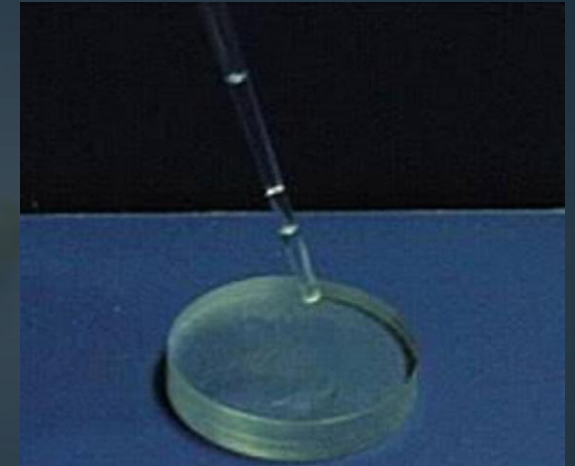


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Solid run in Solution

- Solids dissolved in a non-aqueous solvent.
- No chemical interaction.
- No absorption by the solvent.
- Solution is used directly in sample cells for liquids.



Solid Films

- Solid dissolved in a non-aqueous solvent.
- A drop of the solution is placed on the alkali metal disc.
- Allows solvent to evaporate, leaving a thin film.



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Mull Technique :

- A finely ground solid sample is mixed with Nujol to make a thick paste.
- Paste is spread between IR transmitting windows which is mounted in the path of IR.
- This technique is used to prepare solid samples for analysis.
- It involves grinding a solid sample with Nujol (a brand of mineral oil) to create a thick paste (mull), which is then sandwiched between IR-transparent plates for analysis.
- This technique is particularly useful for samples that are not suitable for other methods like KBr disks, such as those that absorb moisture or are difficult to dissolve.



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Disadvantages of Nujol:

- It has a strong absorption at 2915, 1462, 1376, and 719 cm^{-1} , which can interfere with the analysis of the sample.
- The method is less suitable for samples that require high-resolution spectra, as the presence of the dispersing medium can broaden the absorption bands.



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Pressed Pellet Technique :

- This technique involves mixing a solid sample with an IR-transparent material, typically **potassium bromide (KBr)**, grinding the mixture, and then pressing it into a pellet to be analyzed.

It involves,

- **Sample preparation.**
- **Pellet formation.**
- **IR analysis.**



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Pressed pellet technique :

• Advantages

- This technique is suitable for a variety of solid samples.
- The pellet provides a more stable and uniform sample for analysis.
- KBr is IR-transparent and does not interfere with the sample's spectral bands.

• Disadvantages

- The pellet preparation is very time-consuming.
- KBr pellets can absorb moisture, potentially affecting the quality of the spectrum.
- This technique is not suitable for materials that can not be ground with KBr.



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Sampling Of Liquids

- No preparation is required.
- Directly placed into a cell made up of Sodium chloride (NaCl), Potassium bromide (KBr), etc.
- Cells are always protected from moisture.

The other important technique used for the sampling of liquids is,

➤ Attenuated total reflectance (ATR)



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Attenuated total reflectance (ATR)

- This is a technique that allows for the analysis of samples, including solids, liquids, and powders, without requiring sample preparation
- It allows easy and direct analysis of a sample's surface without complex preparation.
- In this method, an IR beam is passed through a crystal (such as **diamond or ZnS**) that is in contact with the sample. When the IR light reflects within the crystal at the surface where it touches the sample, it creates an evanescent wave that penetrates a short distance into the sample. This wave interacts with the sample's molecular bonds and produces an absorption spectrum.
- ATR is widely used because it is fast, reliable, non-destructive, and suitable for solids, liquids, and gels.



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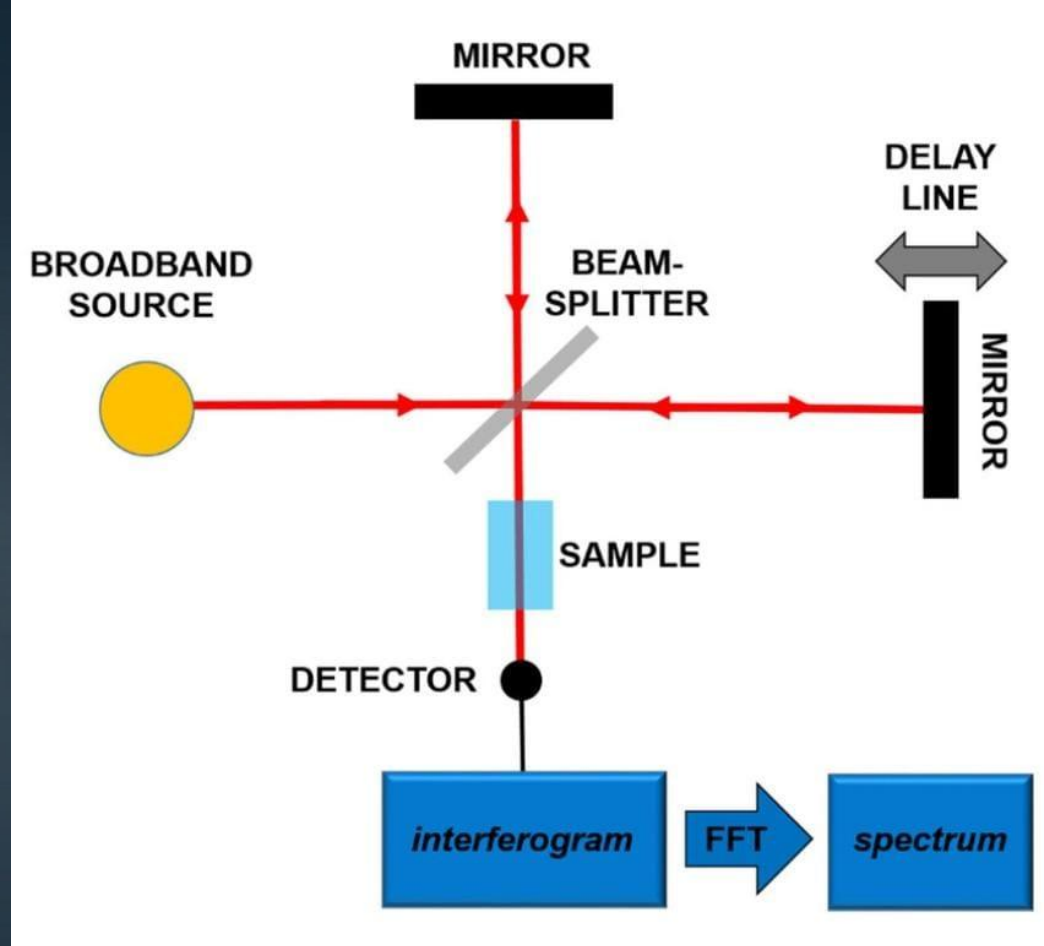
Fourier-transform infrared (FTIR)

- FTIR spectroscopy is a powerful analytical technique used in infrared (IR) spectroscopy to obtain high-resolution spectral data of gases, liquids, or solids.
- FTIR collects all wavelengths simultaneously using an interferometer, most commonly a **Michelson interferometer**.
- The resulting signal, called an **interferogram**, is then converted into an IR spectrum using a mathematical process called the **Fourier Transform**.
- In gas analysis, FTIR is especially useful because it provides fast, sensitive, and accurate detection of multiple gas components at once.
- FTIR is widely used in environmental monitoring, industrial process control, and research applications due to its non-destructive nature and the ability to analyze even trace levels of gases.



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FTIR Spectroscopy

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INSTRUMENTATION OF IR SPECTROPHOTOMETER



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INSTRUMENTATION :

- It is used to measure the intensity of any sample in the IR spectroscopy.
- The main components of an IR spectrometer are as follows;
 - Source of Radiation.
 - Monochromator (Wavelength selectors).
 - Sample cells.
 - Detectors.
 - Recording System.



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1. Source of Radiation :

- The IR spectrometer requires a source of radiant energy for narrow frequency bands.
- An incandescent solid is chosen as a source of IR radiation.

The following sources can be used;

1. Nernst Glower:

- It consists of a rod or hollow tube (2 cm long and 1 mm in diameter) made by sintering a mixture of Cerium, Zirconium, Thorium, etc.
- It is heated between 1000-1800 degrees Celsius.
- It provides maximum radiation at the 7100 cm^{-1} region.



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Globar :

It is a Silicon Carbide rod (5 cm long and 0.5 cm in diameter), which is also electrically heated between 1300 – 1700 degrees Celsius.

Nichrome wire :

A coil of this wire is heated by passing current

Rhodium wire :

The wire is sealed in a cylinder.

Tungsten Filament Lamp :

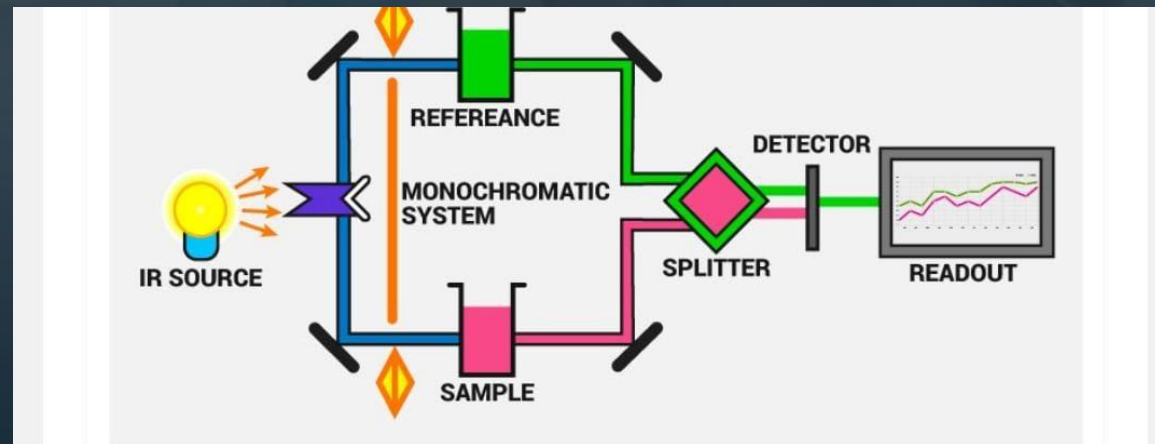
It is used for the near-IR region.



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- **Monochromator :**
- It is also known as the wavelength selectors.
- The source of radiation emits radiation of various frequencies.
- For IR, we required certain frequencies so the monochromator passed the desired frequencies and the other frequencies should be rejected.



Prism (Monochromator) :

- It is used as a dispersed element, which should be made up of a material that transmits in the IR regions.
E.g., Various metal halide salts, such as Sodium chloride, Potassium Bromide.
- It causes linear dispersion, and higher dispersion is achieved.

Sample cells and Sample handling :

- In this, we have to put the sample in an IR spectrometer, as we know it is an instrument that analyzes how molecules absorb infrared light, providing information about the bonds and many functional groups within a substance.



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Detectors :

- These are the devices which basically used to generate signals that we can read in the recording systems.
- Thermal detectors are the best choices for IR spectra.
- The following detectors are used:

Golay Cell :

- A Golay cell is an opto-acoustic detector, primarily used in infrared spectroscopy and terahertz radiation detection that leverages the thermal expansion of a gas to detect radiation.

Bolometer :

- A bolometer is a device that detects and measures the power or heat of incident electromagnetic radiation by using a temperature-sensitive element, typically a thermistor or barometer, whose resistance changes with temperature.



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Thermocouple :

- In IR spectroscopy, a thermocouple detector, a type of thermal detector, uses the Seebeck effect to convert absorbed IR radiation into an electrical signal, allowing for temperature measurement and analysis of IR spectra.

Thermistor :

- In infrared (IR) spectroscopy, thermistor detectors, also known as bolometers, are thermal detectors that detect IR radiation by measuring the change in resistance of a material due to temperature variations caused by absorbed IR energy.

Pyroelectric detectors :

- Pyroelectric detectors used in IR spectroscopy convert IR radiation into electrical signals by sensing temperature changes in pyroelectric material, offering fast response times and broad spectral response, making them suitable for FTIR.



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**INSTRUMENTAL
METHODS OF ANALYSIS**

IR SPECTROSCOPY

FLAME PHOTOMETRY

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FLAME PHOTOMETRY



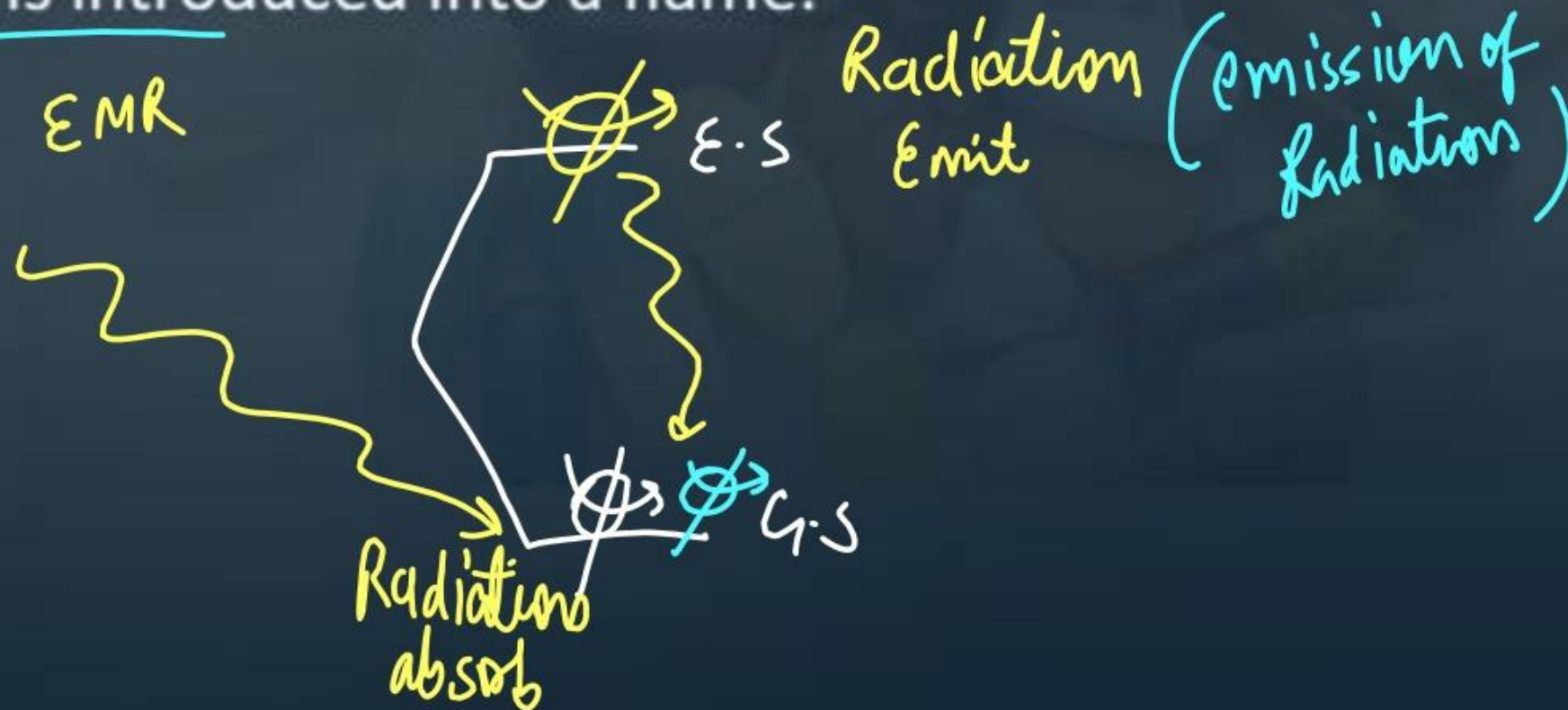
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Emission of Radiation

Introduction:

- Wavelength of Radiation $\rightarrow$ tells us what the Element is ?
Intensity of Radiation $\rightarrow$ tells us amount of Element Present .
- It is also called Flame Emission Spectroscopy (FES).
 - It is based on the measurement of intensity of the light emitted when a metal is introduced into a flame.



Principle of Flame Photometry

- Sample (as solution) → introduced into flame → converted to atoms/ions.
- Excited atoms → emit radiation (light) at characteristic wavelengths.
- Intensity of emitted light $\propto$ concentration of the element.

Example: Na $\rightarrow$ yellow light at 589 nm

K $\rightarrow$ violet light at 766.5 nm

Liquid sample $\xrightarrow{\text{K} \rightarrow \text{violet light at 766.5 nm}}$ Formation of droplets $\rightarrow$ Fine residues $\rightarrow$ Formation of Neutral atoms $\rightarrow$ Excitation
 Measurement of Wave-length & intensity $\leftarrow$ Emission $\leftarrow$



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Principle of Flame Photometry

- Sodium Emits → Yellow radiation (589 nm)
- Potassium Emits → Orange radiation (767 nm)
- Calcium Emits → Brick Red radiation emits (422, 562 nm)
- Lithium → Crimson Red
- Barium → Apple green

→ Neutral atoms converted into excited atoms by using thermal energy of radiation.

→ Excited atoms, return to the ground by emitting the radiation.



Instrumentation

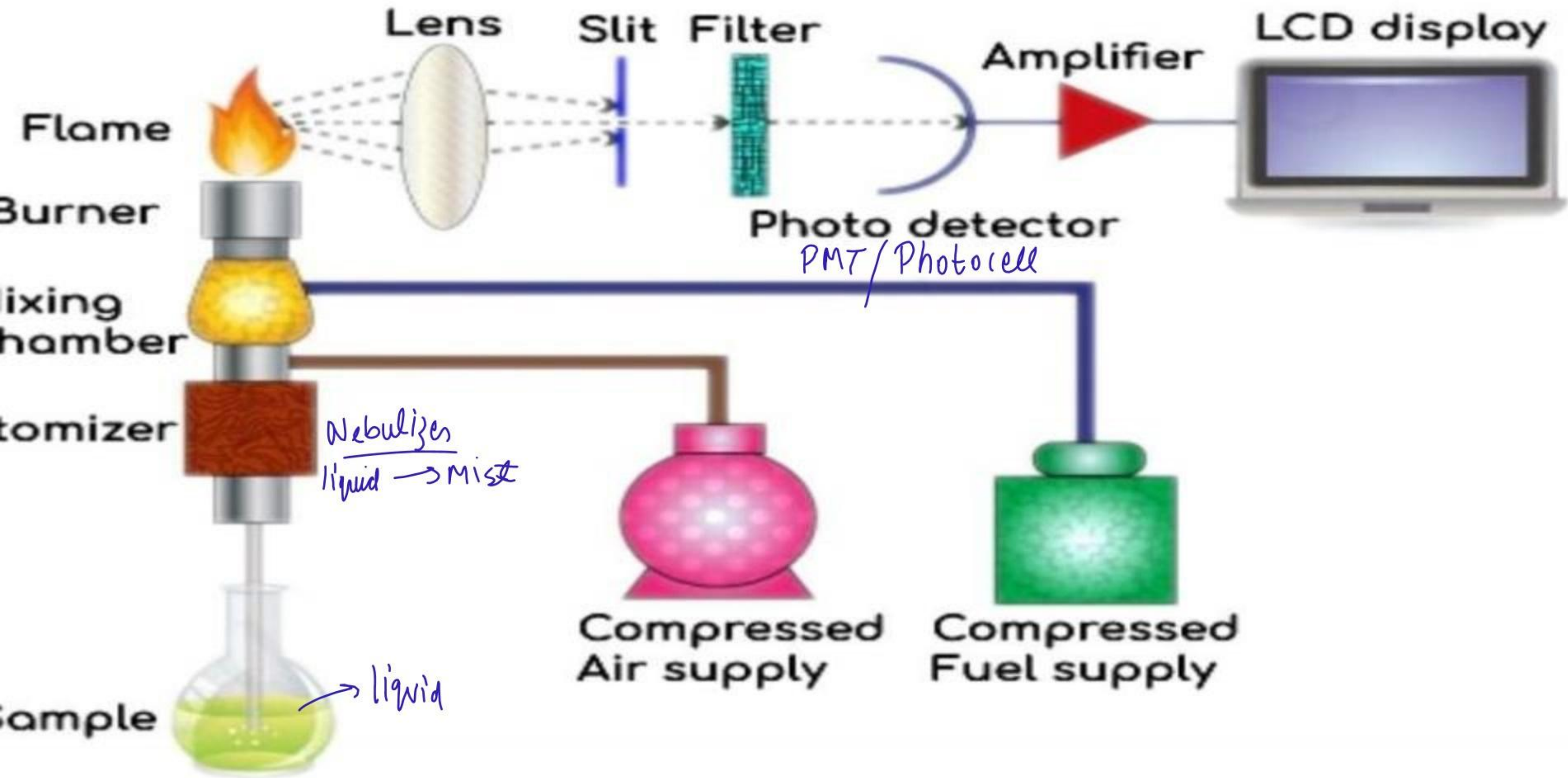
- Main components:

- ✓ Nebulizer & Burner – converts sample solution into fine mist.
- ✓ Flame Source – excitation of atoms (commonly propane, natural gas, or acetylene flame).
- ✓ Monochromator/Filter – selects specific wavelength.
- ✓ Detector (Photocell/PMT) – detects light intensity.
- ✓ Readout/Recorder – displays results (digital meter/graph).



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FLAME PHOTOMETER

Working of Flame Photometer

- Solution aspirated → nebulizer → burner → flame.
- Solvent evaporates → Salt converts into free atoms.
- Atoms get excited → emit light.
- Filter isolates the wavelength of interest. (Monochromator)
- Detector measures intensity → result proportional to concentration.



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Types of Flames

- Air–Acetylene Flame ✓
- HNO_2 • Nitrous Oxide–Acetylene Flame ✓
- Hydrogen Flame ✓

Choice of flame depends on the analyte & temperature needed.



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Applications of Flame Photometry

- Pharmaceutical Analysis: Determination of Na, K, Ca in formulations.
- Quality control of electrolyte injections (e.g., ORS, IV fluids).
- Clinical Applications: Na^+ , K^+ , Ca^{2+} estimation in body fluids.
- Environmental Testing – water & soil analysis.
- Food Industry – mineral analysis (milk, fruit juice).



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**INSTRUMENTAL
METHODS OF ANALYSIS**

IR SPECTROSCOPY

NEPHELOTURBIDOMETRY



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UNIT II –Nepheloturbidometry



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Introduction

- Nephelo-turbidometry is an analytical technique used to **measure the turbidity (cloudiness or haziness) of a solution** caused by suspended particles.
- It is commonly used in **pharmaceutical, clinical, and environmental analysis** to estimate the concentration of analytes that form precipitates.
- Based on the **scattering of light** by suspended particles in a solution.



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Principle

- A beam of monochromatic light is passed through a turbid solution.
- Particles present in the solution **scatter the incident light in different directions.**
- The intensity of scattered light (at an angle, usually 90° to the incident beam) is measured by a detector.
- The **amount of scattering is directly proportional to the concentration and size** of suspended particles.



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Instrumentation

A typical nephelometer consists of:

Light Source: Tungsten lamp (visible region) or Mercury lamp (UV region).

- Provides monochromatic light.

Monochromator/Filters:

- Used to select a specific wavelength of light.



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Instrumentation

Sample Cell (Cuvette):

- Holds the turbid solution.
- Usually made of glass or quartz (depending on wavelength).

Detector/Photocell:

- Placed at 90° angle to the incident light beam.
- Detects scattered light intensity.



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Instrumentation

Amplifier and Readout:

- Amplifies signal and provides digital/analog readout.

Output System:

- Gives concentration values directly or through calibration curves.



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Applications

Pharmaceutical Applications:

- Determination of sulfate, barium, or other precipitate-forming ions.
- Estimation of antibiotics like streptomycin, neomycin, etc.
- Measurement of suspension stability.
- Quality control of parenterals, eye drops, and suspensions.



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Applications

Clinical Applications

- Measurement of serum proteins (e.g., immunoglobulins, complement components).
- Estimation of antigens and antibodies using immunonephelometry.
- Detection of C-reactive protein (CRP), rheumatoid factor, hepatitis markers.



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Applications

Advantages

- High sensitivity for small particles.
- Non-destructive method.
- Applicable for clinical diagnosis (immune complexes).
- Rapid and simple.



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**INSTRUMENTAL
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PART-7

IR SPECTROSCOPY

**ATOMIC ABSORPTION
SPECTROSCOPY**



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Atomic Absorption Spectroscopy



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Introduction

- **Atomic Absorption Spectroscopy (AAS)** is a widely used analytical technique for the **quantitative determination of elements**, particularly metals, in various types of samples.
- Developed in the mid-20th century, AAS is prized for its **sensitivity, specificity, and simplicity**, making it a common method in fields such as:
 - Environmental monitoring
 - Clinical analysis
 - Pharmaceutical quality control
 - Food and beverage safety testing
 - Mining and metallurgy



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Principle of Atomic Absorption Spectroscopy

- The principle of **AAS** is based on the **absorption of radiation by free, ground-state atoms** in the gas phase.
- Each element absorbs light of a specific wavelength, and the amount of light absorbed is directly proportional to the concentration of that element in the sample
- The step-by-step working principle is as follows,



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Atomization of the Sample:

- The sample, usually in liquid form, is introduced into a flame, **graphite furnace**, or other atomizer system.
- In the flame method, a **nebulizer** converts the liquid into a fine mist, which is carried into a flame (usually air-acetylene or nitrous oxide-acetylene).
- The heat of the flame or graphite furnace causes the sample to dry, decompose, and ultimately form free atoms of the element being analyzed.
- These free atoms are now capable of absorbing radiation.



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Radiation Source (Hollow Cathode Lamp - HCL):

- A **hollow cathode lamp** specific to the element being analyzed emits light of that element's characteristic wavelength.
- For example, a **sodium lamp** emits light at around 589 nm, while a **lead lamp** emits light near 283.3 nm.
- The lamp light passes through the cloud of atoms in the flame or furnace.



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Absorption of Light:

- As the light passes through the atomized sample, atoms of the target element absorb radiation of a specific wavelength.
- The extent of absorption depends on the number of ground-state atoms present in the flame or furnace—this correlates directly with the concentration of the element in the sample.



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Measurement and Detection:

- A **monochromator** isolates the specific wavelength of interest from the lamp.
- A photodetector measures the intensity of the transmitted light (i.e., light not absorbed by the atoms).
- The difference in light intensity before and after passing through the flame is used to calculate absorbance.



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Quantitative Analysis:

- The absorbance values are plotted against known concentrations to generate a **calibration curve**.
- The concentration of the unknown sample is determined by comparing its absorbance with the calibration curve using **Beer-Lambert's law**.

$$A = \log(I/I_0) = \epsilon \cdot c \cdot l$$

Where,

A = Absorbance

I_0 = Intensity of incident light

I = Intensity of transmitted light

ϵ = Molar absorptivity

C = concentration of the element



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Atomic Absorption Spectroscopy Instrumentation



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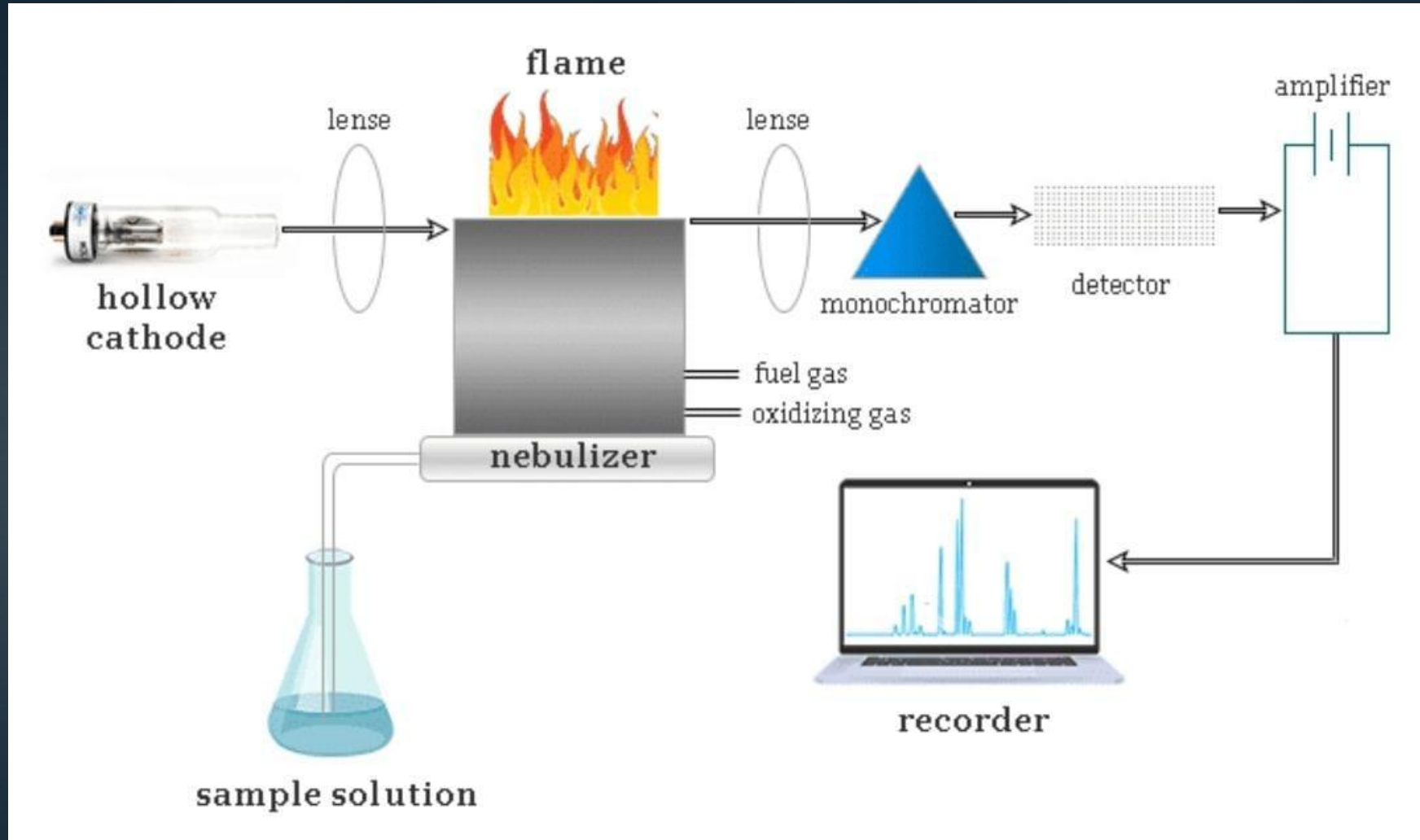
Atomic Absorption Spectroscopy (AAS)

- Atomic Absorption Spectroscopy (AAS) is a powerful analytical technique used to determine the concentration of metal elements in a sample.
- The instrumentation of AAS consists of several key components that work together to detect and quantify elements with high specificity and sensitivity.



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1. Radiation Source (Hollow Cathode Lamp or Electrodeless Discharge Lamp):

- It provides the light of a specific wavelength corresponding to the element being analyzed.
- **Hollow Cathode Lamp (HCL):**
 - It contains a cathode made of the element of interest and an anode.
 - Filled with an inert gas (like neon or argon).
 - When voltage is applied, the gas gets ionized, and the ions strike the cathode, releasing atoms of the element, which emit light of characteristic wavelengths.



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1. Radiation Source (Hollow Cathode Lamp or Electrodeless Discharge Lamp):

- Electrodeless Discharge Lamp (EDL):
- Offers higher intensity light.
- Uses microwave or radiofrequency energy to excite the atoms.
- Used when more sensitivity is needed (e.g., for elements like **As**, **Se**).



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2. Atomizer:

- It converts the sample into free atoms in the gaseous state.

Types of Atomizers:

■ **Flame Atomizer:**

- A flame (usually air-acetylene or nitrous oxide-acetylene) is used to vaporize the sample.
- The sample is aspirated into the flame via a nebulizer.
- Suitable for elements with moderate excitation energy.



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Atomizer:

■ Graphite Furnace Atomizer (Electrothermal AAS):

- Uses a small graphite tube that is electrically heated.
- Offers higher sensitivity and requires a smaller sample volume.
- Useful for trace analysis.

■ Hydride Generation System:

- For elements like As, Se, Sb, and Hg that form volatile hydrides.
- Hydrides are formed chemically and then introduced into a heated quartz tube for atomization.



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3. Sample Introduction System

- It delivers the sample to the atomizer.

- **Nebulizer (in flame AAS):**

It converts a liquid sample into a fine aerosol.

- **Autosampler (optional):**

Automates sample injection, improves reproducibility, and reduces human error.

- **Injection Port (for graphite furnace):**

Injects a small volume of sample directly into the furnace.



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4. Monochromator:

- It isolates the specific wavelength of light absorbed by the analyte.

Components:

1. Entrance slit:

It controls the amount of light entering.

2. Dispersion device:

Usually, a diffraction grating separates light into component wavelengths.

3. Exit slit:

Selects the desired wavelength for measurement.

It ensures that only the light matching the electronic transition of the target element reaches the detector.



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5. Detector:

- Detector measures the intensity of light and converts it into an electrical signal.
- The types of detectors are as follows;

❑ **The Photomultiplier Tube (PMT)** is most commonly used.

- Extremely sensitive to low levels of light.
- Converts light into current via photoemission, amplifies the signal.
- The signal corresponds to the amount of light absorbed by the atoms in the flame or furnace.



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6. Signal Processor and Readout Device:

It amplifies, processes, and displays the data.

- **Amplifier:** Strengthens the detector's signal.
- **Analog-to-Digital Converter (ADC):** Converts signal to digital form.
- **Microprocessor/Computer System:** Performs calibration, data processing, and quantitative analysis.
- **Display/Printer/Output Interface:** Provides concentration values and plots.



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7. Gas Control System

It regulates the flow of gases used in atomization.

- **Fuel (e.g., acetylene)** and **oxidant (e.g., air or nitrous oxide)** for flame AAS.
- Flow controllers and safety systems are critical.



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Detection of Non-metals:

- Non-metals such as H, N, O, S, P, Cl, etc., do not atomize easily into free atoms in typical AAS conditions.
- Most form stable molecules (e.g., O₂, N₂, HCl) instead of atomic vapors.
- Their atomic transitions often do not fall within AAS light sources' range.
- Lack of suitable hollow cathode lamps for many non-metals.



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Special Cases:

- **Metalloids and Volatile Compounds:**
- Some metalloids and semi-metals,
- such as Arsenic (As), Selenium (Se), Antimony (Sb), can be detected using **Hydride Generation AAS (HG-AAS)**, which converts the analyte into a volatile hydride (e.g., AsH_3).
- Hydride is then atomized and measured using AAS



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Alternatives to AAS for Non-Metals:

- To detect non-metals, other analytical techniques are more effective:

Non-metal	Recommended Method
• Nitrogen (N)	UV-Vis or TOC analyzers
• Oxygen (O)	Oxygen analyzers, GC
• Sulfur (S)	ICP-OES, UV-Fluorescence
• Phosphorus (P)	ICP-MS, UV-Vis
• Chlorine (Cl)	Ion Chromatography (IC), XRF
• Fluorine (F)	IC or Ion-Selective Electrodes



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Conclusion:

- AAS is not suitable for most non-metals due to their chemical nature and physical behavior in atomization processes.
- Only certain metalloids can be detected using specialized techniques like Hydride Generation AAS.
- For accurate analysis of non-metals, alternative techniques are preferred.



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Difference Between Atomic Absorption Spectroscopy (AAS) and Flame Emission Spectroscopy (FES)



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Introduction:

- Both are analytical techniques used to determine the concentration of elements, especially **metals** Involve flames to excite or atomize elements.
- Differ in principle, instrumentation, and detection method.

Principle of FES:

FES measures the emission of light from excited atoms.

The sample is introduced into a flame; atoms get excited and then emit light as they return to the ground state.

The emitted light's intensity is measured.



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Difference between AAS and FES:

• Atomic Absorption Spectroscopy

- Measures absorption of radiation.
- Required (hollow cathode lamp) as a light source.
- The energy source is Flame or graphite furnace
- Ground-state atoms absorb light.
- Their sensitivity is higher for most elements.
- Trace metal analysis in water, food, etc.

• Flame Emission Spectroscopy

- Measures *emission* of radiation.
- Not required (sample itself emits light).
- Flame is the only source.
- Excited atoms emit light.
- Lower compared to AAS.
- Mainly used for alkali and alkaline earth metals (e.g., Na, K, Ca).



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Advantages of AAS:

- **Atomic Absorption Spectroscopy (AAS)** and **Flame Emission Spectroscopy (FES)** are both analytical techniques used for the detection and quantification of metals in various samples.
- However, AAS offers several key advantages over FES, particularly in terms of sensitivity, selectivity, and precision.



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1. Higher Selectivity

- AAS measures the amount of light absorbed by ground-state atoms of an element at a specific wavelength.
- This wavelength corresponds to a unique electronic transition for each element, allowing for highly selective detection.
- In contrast, FES relies on detecting emitted light, which may have overlapping emission lines from different elements, especially in complex samples.



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2. Greater Sensitivity for Many Elements:

- AAS is often more sensitive than FES, especially for elements with low excitation energy or low emission intensity.
- Many metal ions (like lead, cadmium, and mercury) are more easily detected at lower concentrations using AAS.
- Flame emission is mainly suited for alkali and alkaline earth metals (e.g., sodium, potassium, calcium) due to their strong emission lines.



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3. Quantitative Calibration:

- AAS allows for more accurate calibration curves due to the linear relationship between absorbance and concentration (according to Beer-Lambert law).
- FES can suffer from nonlinear response due to self-absorption and changes in flame conditions.

4. Less Affected by Flame Instabilities:

Because AAS uses a **monochromatic source** (usually a hollow cathode lamp) and measures absorption, its readings are less influenced by fluctuations in flame temperature or fuel-to-oxidant ratios.



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Disadvantages of AAS:

1. **Single-element analysis:** Can only measure one element at a time, making it slow for multi-element samples.
2. **Requires separate lamps:** Each element needs a specific hollow cathode lamp, increasing cost and setup time.
3. **Limited to metals:** Primarily detects metal elements, not suitable for non-metals or many metalloids.
4. **Narrow concentration range:** Accurate only over a limited range of concentrations; often requires dilution.
5. **Matrix interferences:** Chemical or physical interferences can affect results; sample prep may be needed.



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Single-Beam vs Double-Beam Atomic Absorption Spectrometer



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Introduction:

- AAS instruments can be classified based on how the light beam is processed.
- Single-beam AAS
- Double-beam AAS
- Both measure the absorption of light by atoms, but differ in how they correct for background noise, lamp drift, and source intensity variations.



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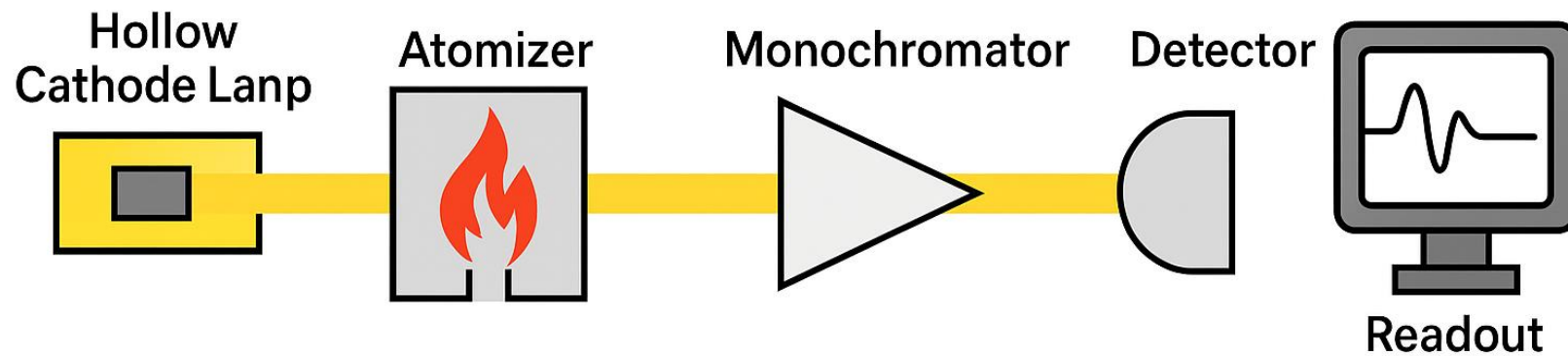
Single-Beam AAS:

- Only one light path from the lamp to the detector.
- The lamp's beam passes through the atomized sample directly into the detector.
- Blank (reference) and sample measurements are taken separately.
- Simpler and less expensive, but more prone to lamp intensity fluctuations.



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Single-Beam Atomic Absorption Spectrometer



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Double-Beam AAS:

- It uses two light paths – one passes through the sample, the other through a reference.
- A beam splitter or rotating mirror alternates the lamp beam between:

The sample path

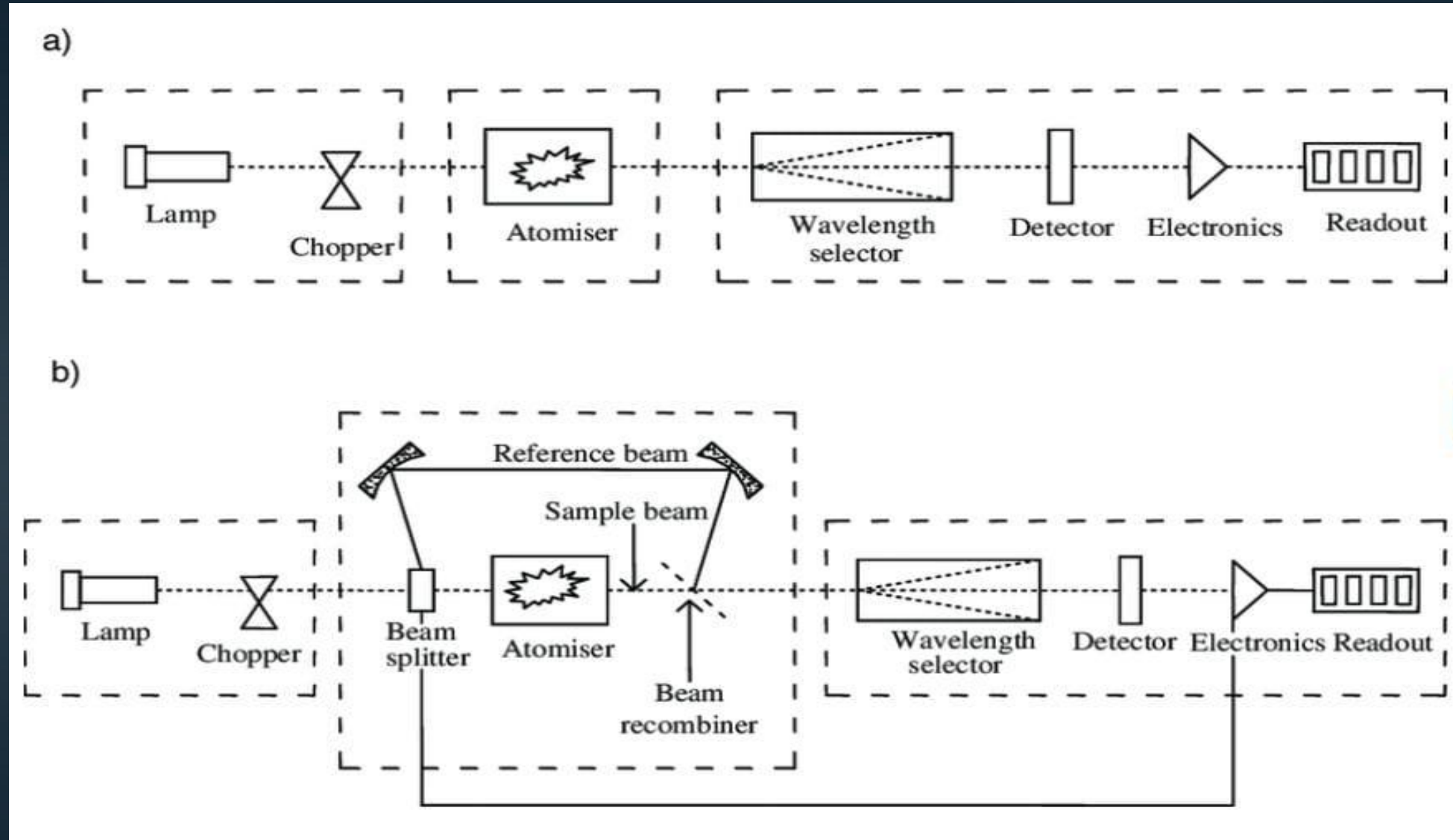
The reference path (by passing the sample)

- More complex but offers better stability and accuracy.



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Comparison Table:

• Single –Beam AAS

- Only one light path is present here, which is a sample only.
- It is less stable.
- Its accuracy is moderate.
- The cost is lower.
- The baseline correction is manual or separate blanking.
- It is typically used in routine and educational labs.

• Double- Beam AAS

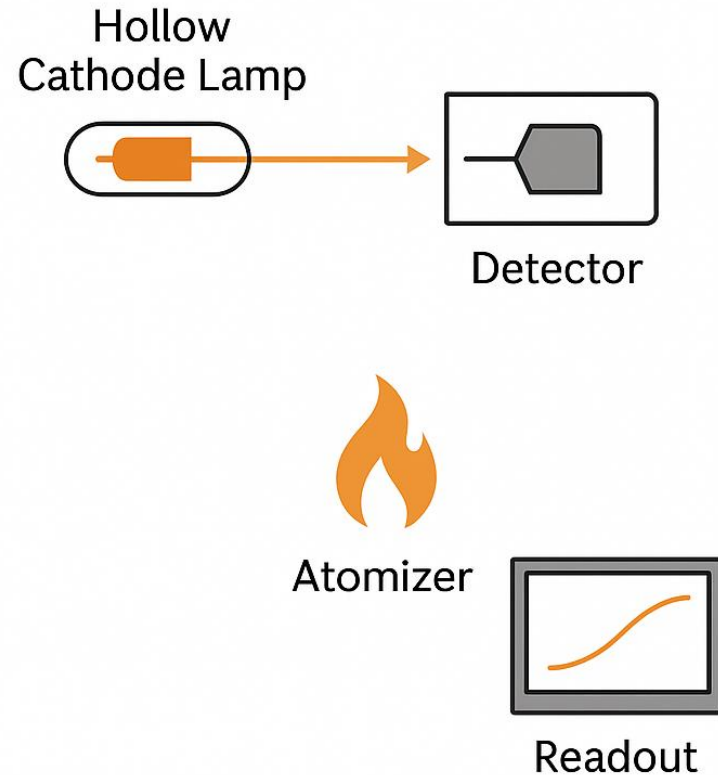
- Two light paths are there: the sample and the reference.
- It is more stable.
- Its accuracy is high.
- Cost is also higher.
- The baseline correction is automatic.
- It is typically used in research, clinical, and industrial labs.



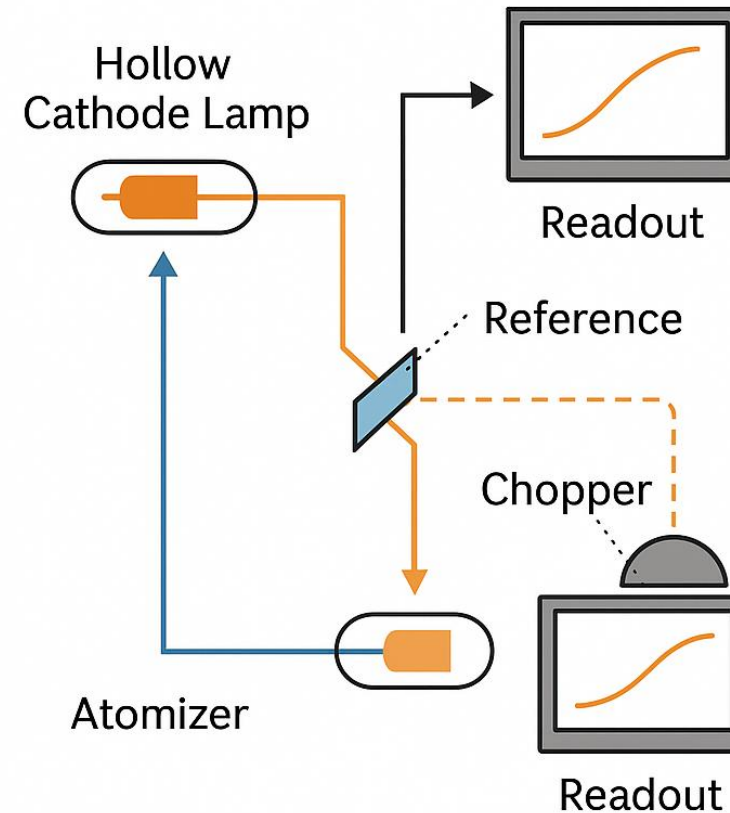
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Single-Beam



Double-Beam



Applications of AAS:

Environmental Analysis

- Water Quality Testing:
- It detects trace metals like lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), and chromium (Cr) in drinking water, wastewater, and natural water bodies.
- Soil Analysis:
- It determines the concentration of heavy metals in soil, which is crucial for environmental pollution studies.
- Air Pollution Monitoring:
- Analyzes metal particulates in air samples collected on filters.



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2. Clinical and Biomedical Applications:

- **Biological Fluids:**

Measures trace elements like zinc (Zn), copper (Cu), iron (Fe), and magnesium (Mg) in blood, urine, or tissues.

- **Diagnosis of Diseases:**

Helps detect metal poisoning (e.g., lead poisoning) or deficiencies of essential minerals.



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3. Food and Agriculture:

- **Food Safety:**

Quantifies toxic metals in food items such as lead in baby food or arsenic in rice.

- **Nutrient Analysis:**

Determines essential micronutrients in fertilizers and agricultural products.

- **Animal Feed Testing:**

- Ensures proper mineral content in feed for livestock.



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