

# Introduction to Analytical Chemistry

## Introduction to Analytical Chemistry Techniques

Key concepts, major categories, and representative methods

### 1. What Is Analytical Chemistry?

| Aspect   | Description                                                                                                      |
|----------|------------------------------------------------------------------------------------------------------------------|
| Goal     | Identify (qualitative) and quantify (quantitative) chemical species in a sample.                                 |
| Scope    | Environmental monitoring, pharmaceuticals, food safety, forensics, materials science, clinical diagnostics, etc. |
| Approach | Combine sample preparation, separation, detection, and data interpretation.                                      |

### 2. Major Categories of Techniques

| Category                 | Primary Purpose                                                                               | Typical Examples                                                                                                               |
|--------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Spectroscopy             | Interaction of electromagnetic radiation with matter ? provides structural/quantitative info. | UV-Vis, IR, Raman, Fluorescence, Atomic Absorption (AAS), ICP-OES, NMR                                                         |
| Chromatography           | Separate components based on differential partitioning/mobility.                              | Gas Chromatography (GC), Liquid Chromatography (LC), Supercritical Fluid Chromatography (SFC), Thin-layer Chromatography (TLC) |
| Mass Spectrometry (MS)   | Measure mass-to-charge ratios of ions; often coupled to a separation step.                    | GC-MS, LC-MS, MALDI-TOF, ICP-MS                                                                                                |
| Electrochemical Methods  | Measure electrical properties (current, potential) related to redox processes.                | Potentiometry, Polarography, Voltammetry, Amperometry, Conductometry                                                           |
| Thermal/Physical Methods | Detect changes in physical properties with temperature or pressure.                           | Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), X-ray Diffraction (XRD)                             |

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| Category                            | Primary Purpose                                                      | Typical Examples                                                  |
|-------------------------------------|----------------------------------------------------------------------|-------------------------------------------------------------------|
| <b>Hybrid/Multimodal Techniques</b> | Combine two or more principles for enhanced selectivity/sensitivity. | MS/MS, GC?FID?MS, ICP?OES?                                        |
|                                     |                                                                      | MS, Raman?Microscopy, Surface? Enhanced Raman Spectroscopy (SERS) |

## 3. Fundamental Steps in an Analytical Workflow

### 1. Sampling & Sample Preparation

- Homogenization, filtration, extraction, digestion, derivatization.
- Goal: Convert the real matrix into a form compatible with the chosen technique while preserving analyte integrity.

### 2. Separation (if required)

- Removes interferences and resolves complex mixtures.
- Choice depends on volatility, polarity, molecular weight, and required resolution.

### 3. Detection & Quantification

- Converts the chemical information into a measurable signal (absorbance, intensity, current, mass).
- Calibration (external, internal standards, standard addition) links signal to concentration.

### 4. Data Processing & Validation

- Baseline correction, peak integration, spectral deconvolution.
- Validation parameters: accuracy, precision, limit of detection (LOD), limit of quantification (LOQ), linearity, robustness.

## 4. Representative Techniques – Core Principles & Typical Applications

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## 4.1 UV-Visible Spectroscopy

### Techniques

- **Principle:** Electronic transitions absorb light in the 200–800 nm range.
- **Key Metric:** Beer-Lambert law,  $A = \epsilon \cdot b \cdot c$ .
- **Uses:** Determining concentrations of colored compounds, monitoring reaction kinetics, protein quantification (260/280 nm).

## 4.2 Infrared (IR) & Raman Spectroscopy

- **IR:** Vibrational transitions absorb IR radiation; provides functional group fingerprints.
- **Raman:** Inelastic scattering of monochromatic light; complementary to IR, works well