

Overview of Analytical Chemistry

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Key concepts, techniques, and applications

1. Definition & Scope

Aspect	Description
Analytical Chemistry	The branch of chemistry concerned with the qualitative and quantitative determination of chemical components in substances.
Primary Goals	1. Identify what substances are present (qualitative analysis). 2. Measure how much of each substance is present (quantitative analysis).
Fields of Application	Environmental monitoring, pharmaceuticals, food safety, forensics, clinical diagnostics, materials science, industrial process control.

2. Classical vs. Modern Approaches

Category	Classical Techniques	Modern (Instrumental) Techniques
Qualitative	Spot tests, flame tests, precipitation reactions	Mass spectrometry (MS), infrared spectroscopy (IR), nuclear magnetic resonance (NMR)
Quantitative	Gravimetry, titrimetry (acid? base, redox, complexometric)	Atomic absorption spectroscopy (AAS), inductively coupled plasma (ICP?OES/MS), chromatography (GC, HPLC), electrochemical sensors
Data Handling	Manual calculations, tables	Computer?aided data acquisition, chemometrics, statistical software

3. Core Analytical Techniques

3.1 Spectroscopy

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UV-Vis	Absorption of ultraviolet/visible light by electrons	Determining concentration of colored compounds, nucleic acids, transition metal complexes
IR	Molecular vibrations absorb IR radiation	Identifying functional groups, polymer analysis
Raman	Inelastic scattering of monochromatic light	Complementary to IR, useful for aqueous samples
Fluorescence	Emission of light from excited molecules	Trace analysis of fluorescent tags, environmental pollutants
Atomic Spectroscopy (AAS, ICP-OES/MS)	Excitation of atoms ? emission/absorption of characteristic wavelengths	Metal ion determination in water, soils, biological fluids

3.2 Chromatography

Technique	Separation Mechanism	Detector Options
Gas Chromatography (GC)	Volatility & interaction with stationary phase (gas-liquid)	FID, TCD, MS
High-Performance Liquid Chromatography (HPLC)	Partition/adsorption on a packed column (liquid-liquid)	UV-Vis, PDA, FLD, MS
Thin-Layer Chromatography (TLC)	Capillary action on a coated plate	Visual staining, UV illumination
Supercritical Fluid Chromatography (SFC)	Supercritical CO ₂ as mobile phase	UV, MS

3.3 Electrochemical Methods

Method	Principle	Applications
Potentiometry (e.g., pH meter, ion-selective electrodes)	Measure potential difference at zero current	pH, ion concentration in environmental/water samples
Voltammetry (e.g., cyclic voltammetry)	Current response to applied potential	Redox-active species, trace metal detection

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Method	Principle	Applications
Amperometry	Current at fixed potential proportional to analyte concentration	Glucose sensors, environmental monitoring

3.4 Mass Spectrometry (MS)

Variant	Ionization Technique	Typical Use
GC-MS	Electron impact (EI), chemical ionization (CI)	Volatile organics, drug metabolites
LC-MS/MS	Elect	