

Introduction to Analytical Chemistry

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Key concepts, objectives, and foundational tools

1. What Is Analytical Chemistry?

Aspect	Description
Definition	The branch of chemistry concerned with the qualitative and quantitative determination of chemical components in a sample.
Goal	Identify <i>what</i> substances are present (qualitative) and <i>how much</i> of each is present (quantitative).
Scope	Environmental monitoring, pharmaceuticals, food safety, forensics, materials science, clinical diagnostics, and more.
Relation to Other Fields	Bridges chemistry with physics, biology, engineering, and data science; often the “interface” between the laboratory and real-world applications.

2. Core Concepts

Concept	Why It Matters	Typical Example
Selectivity	Ability of a method to respond to a specific analyte in the presence of others.	Using ion-selective electrodes for Na ⁺ in seawater.
Sensitivity	Small changes in analyte concentration produce measurable signal changes.	Detecting trace heavy metals by atomic absorption spectroscopy (AAS).
Accuracy vs. Precision	Accuracy = closeness to true value; Precision = repeatability.	Replicate measurements of glucose in blood give low standard deviation (precision) but may be offset from certified reference (accuracy).
Limit of Detection (LOD) & Limit of Quantification (LOQ)	Smallest amount that can be reliably detected/quantified.	LOD of 0.1 µg/L ¹ for pesticide residues by GC-MS.

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Concept	Why It Matters	Typical Example
Calibration	Relating instrument response to known concentrations.	Constructing a calibration curve for lead using ICP-OES.
Matrix Effects	Sample components that alter the analytical signal.	Proteins in serum suppress ionization in LC-MS.
Quality Assurance (QA) & Quality Control (QC)	Procedures that ensure reliable, reproducible data.	Use of blanks, spikes, and certified reference materials (CRMs).

3. Main Branches of Analytical Chemistry

Branch	Primary Techniques	Typical Applications
Classical (Wet) Chemistry	Gravimetry, titration, precipitation, colorimetry	Determining water hardness, acidity, chloride content.
Instrumental (Physical) Chemistry	Spectroscopy, chromatography, electrochemical methods, mass spectrometry	Environmental pollutant monitoring, drug analysis.
Chemometrics	Multivariate statistics, pattern recognition, machine learning	Spectral deconvolution, fingerprinting of complex mixtures.
Surface/Interface Analysis	X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), atomic force microscopy (AFM)	Material surface composition, thin-film characterization.
Bioanalytical Chemistry	Immunoassays, ELISA, biosensors, LC-MS/MS for metabolites	Clinical diagnostics, therapeutic drug monitoring.

4. Typical Workflow of an Analytical Investigation

1. Define the Problem

- Identify the analyte(s), required detection limits, and sample matrix.

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2. Select an Appropriate Method

- Consider selectivity, sensitivity, speed, cost, and regulatory requirements.

3. Sample Collection & Preservation

- Use proper containers, temperature control, and preservatives to prevent degradation or contamination.

4. Sample Preparation

- **Pre-treatment:** Filtration, centrifugation, digestion, extraction (solid-phase, liquid-phase, SPE).
- **Derivatization** (if