

Introduction to Analytical Chemistry

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Key concepts, objectives, and common techniques

1. What Is Analytical Chemistry?

Aspect	Description
Definition	The branch of chemistry concerned with the qualitative and quantitative determination of chemical components in natural and synthetic materials.
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, forensic science, materials research, clinical diagnostics, and industrial process control.
Two Main Subfields	Qualitative Analysis – detection and identification of species. Quantitative Analysis – measurement of concentration, amount, or purity.

2. Core Principles

1. **Selectivity** – Ability of a method to discriminate the analyte of interest from other components.
 2. **Sensitivity** – Minimum amount of analyte that can be reliably measured (limit of detection, LOD).
 3. **Accuracy** – Closeness of the measured value to the true value.
 4. **Precision** – Reproducibility of repeated measurements (repeatability & reproducibility).
 5. **Linearity** – Proportional response of the detector over a defined concentration range.
 6. **Robustness** – Tolerance of the method to small variations in experimental conditions.
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3. General Workflow of an Analytical Procedure

1. **Define the problem** – What needs to be measured and why?
2. **Select the appropriate technique** – Based on matrix, required detection limits, speed, cost.

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3. **Sample collection & preservation** – Prevent changes in composition (e.g., oxidation, evaporation).
 4. **Sample preparation** – Filtration, digestion, extraction, derivatization, dilution, etc.
 5. **Calibration** – Build a calibration curve using standards (external, internal, or standard addition).
 6. **Measurement** – Run the sample under controlled conditions.
 7. **Data processing** – Apply calibration, correct for blanks, calculate concentrations, assess uncertainties.
 8. **Validation & quality control** – Use controls, replicate analyses, recovery studies, and proficiency testing.
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4. Major Analytical Techniques

Technique	Principle	Typical Analytes	Strengths	Limitations
Gravimetry	Mass of a precipitate or residue	Ions, metals	Simple, high accuracy	Time-consuming, limited to species that form weighable solids
Titrimetry	Stoichiometric reaction with a titrant	Acids, bases, redox species, complexing agents	Direct, inexpensive	Requires suitable indicator, limited to relatively high concentrations
Spectroscopy	Interaction of light with matter (absorption, emission, scattering)	Metals, organics, pigments	Fast, non-destructive, adaptable to many matrices	Interferences, matrix effects
• UV-Vis	Electronic transitions	Transition metal ions, organic chromophores	Simple instrumentation	Overlap of spectra
• Atomic Absorption (AAS)	Atom-vapour absorption	Metals	Element-specific, low detection limits	Single-element analysis per run

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Technique	Principle	Typical Analytes	Strengths	Limitations
• Fluorescence	Emission after excitation	Trace organics, biologics	Very high sensitivity	Quenching, requires fluorophore
Chromatography	Separation of components before detection	Complex mixtures (drugs, pollutants)	High resolution, coupled with many detectors	Requires skilled operation, solvent consumption
• Gas Chromatography (GC)	Volatile compounds on a stationary			