

Introduction to Environmental Chemistry

Introduction to Environmental Chemistry

Key concepts, scope, and relevance for students and professionals

1. What Is Environmental Chemistry?

Aspect	Description
Definition	The branch of chemistry that studies the chemical and biochemical phenomena that occur in the natural environment.
Goal	Understand how chemicals behave in air, water, soil, and living organisms, and how human activities alter these processes.
Interdisciplinary Links	Ecology, toxicology, atmospheric science, geology, public health, engineering, policy.

2. Major Environmental Compartments

Compartment	Typical Chemical Species	Important Processes
Atmosphere	Gases (CO ₂ , NO _x , SO ₂ , O ₃), aerosols, volatile organic compounds (VOCs)	Photochemical reactions, gas-phase diffusion, wet/dry deposition
Hydrosphere (freshwater & oceans)	Dissolved ions (Ca ²⁺ , Mg ²⁺ , Na ⁺), nutrients (N, P), metals (Hg, Pb), organic pollutants (PCBs, pesticides)	Solubility equilibria, redox reactions, biogeochemical cycling, adsorption onto sediments
Lithosphere (soil & rocks)	Minerals (silicates, carbonates), metals, organic matter	Sorption/desorption, precipitation/dissolution, microbial transformation
Biosphere (living organisms)	Biomolecules, metabolites, bioaccumulative toxins	Metabolism, bioaccumulation, biomagnification, enzymatic detoxification

3. Fundamental Chemical Principles

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Principle

Environmental Relevance

Equilibrium & Le Chatelier's Principle	Predicts how changes (e.g., pH, temperature) shift solubility of contaminants.
Acid–Base Chemistry	Controls speciation of metals (e.g., Fe^{3+} vs. $\text{Fe}(\text{OH})_3$) and buffering capacity of water bodies.
Redox Reactions	Governs oxidation of pollutants (e.g., O_2 formation) and reduction of metals (e.g., $\text{Cr}(\text{VI}) \rightarrow \text{Cr}(\text{III})$).
Sorption & Partitioning	Describes distribution of chemicals between phases (air–water, water–soil).
Kinetics	Determines rates of degradation (photolysis, hydrolysis, microbial metabolism).
Thermodynamics	Predicts spontaneity of reactions (ΔG) and phase stability (e.g., mineral precipitation).

4. Sources of Environmental Contaminants

Source Type	Examples	Typical Pathways
Natural	Volcanic gases, weathering of rocks, forest fire emissions	Direct release to air, water, soil
Anthropogenic – Point	Industrial discharge, wastewater treatment plant effluent, oil spills	Localized, often high concentration
Anthropogenic – Non-point	Agricultural runoff (fertilizers, pesticides), urban stormwater, atmospheric deposition from combustion	Diffuse, widespread distribution

5. Fate and Transport Mechanisms

1. **Advection** – Bulk movement with water or air currents.
2. **Diffusion** – Molecular spreading from high to low concentration.
3. **Dispersion** – Mixing caused by turbulence or heterogeneities.
4. **Sorption/Desorption** – Attachment to/ release from solids (soil, sediments).
5. **Volatilization** – Transfer from liquid/solid to gas phase.
6. **Deposition**