

KARACHI EDU • ADVANCED COACHING NOTES

Environmental Chemistry II

Advanced chemical dynamics of the hydrosphere, photochemical smog mechanisms, wastewater engineering, and green chemistry.

Photochemical Smog Mechanisms

Complex secondary pollutant formation driven by solar radiation in urban environments.



Primary Reactants

Nitrogen oxides (NO_x) and Volatile Organic Compounds (VOCs) emitted from vehicular exhaust react under high ultraviolet intensity.



Peroxyacetyl Nitrate (PAN)

Formation of secondary oxidants including ozone (O_3) and PAN, leading to eye irritation, respiratory damage, and reduced visibility.

Stratospheric Ozone Catalysis

Detailed kinetic breakdown of ozone depletion by chlorine free radicals.

1. Photolysis of CFCs

$CF_2Cl_2 + h\nu \rightarrow CF_2Cl^\bullet + Cl^\bullet$. UV radiation cleaves chlorofluorocarbons releasing active chlorine radicals.

2. Chain Propagation

$Cl^\bullet + O_3 \rightarrow ClO^\bullet + O_2$
 $ClO^\bullet + O^\bullet \rightarrow Cl^\bullet + O_2$. A single Cl atom destroys thousands of O_3 molecules.

3. Ecological Hazard

Loss of UV shield increases biological mutation risks, skin cancers, and damages aquatic phytoplankton populations.

Water Quality Dynamics (BOD & COD)

Quantitative chemical indicators of organic pollution in aquatic ecosystems.

Biochemical Oxygen Demand (BOD)

Amount of dissolved oxygen consumed by aerobic microorganisms to biodegrade organic matter in water over 5 days at 20°C.

High BOD $\rightarrow$ Severe organic pollution

Chemical Oxygen Demand (COD)

Total oxygen required to chemically oxidize all organic and inorganic compounds using a strong oxidizing agent ($K_2Cr_2O_7$ in acidic medium).

Always greater than or equal to BOD

Municipal Wastewater Treatment Plant

Multi-stage purification sequence ensuring safe effluent discharge.

Primary & Secondary Treatment

- **Primary:** Physical screening and sedimentation of suspended solids and grit.
- **Secondary:** Biological activated sludge process where aerobic bacteria consume dissolved organics.

Tertiary Treatment & Disinfection

Advanced chemical precipitation to remove residual phosphates/nitrates, followed by chlorination, ozonation, or UV irradiation to eliminate pathogens.

Produces potable or irrigation-grade water

Soil Pollution & Heavy Metals

Accumulation of persistent toxic pollutants in pedosphere and food chains.

Heavy Metal Toxicity

Cadmium (\$Cd\$), Lead (\$Pb\$), Mercury (\$Hg\$), and Arsenic (\$As\$) enter soil via industrial sludge, electronic waste, and agrochemicals, causing bioaccumulation in crops.

Biomagnification Effect

Concentration of non-biodegradable toxins multiplies exponentially at higher trophic levels in food webs, endangering apex predators and human consumers.

Green Chemistry Principles

Designing chemical products and processes to minimize hazardous waste generation.

Atom Economy

Maximizing incorporation of all starting materials into final desired products, minimizing byproduct waste.

Safer Solvents & Catalysis

Using water or supercritical CO_2 instead of toxic volatile organic solvents; employing catalysts over stoichiometric reagents.

Key Takeaways

- **Photochemical Smog:** Driven by NO_x and VOCs producing ozone and PAN under solar radiation.
- **Stratospheric Chemistry:** Free radical chlorine chain reactions catalyze ozone depletion.
- **Water Parameters:** BOD and COD quantify organic pollution load in aquatic systems.
- **Green Chemistry:** Focuses on atom economy, safer solvents, and minimal waste generation.