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Chemical Reactions in the Atmosphere

1. Introduction

The Earth's atmosphere is a dynamic chemical system. Reactions in the atmosphere:

- Transform pollutants
- Produce ozone and secondary compounds
- Affect air quality and climate

Main categories of chemical reactions:

1. Photochemical reactions
2. Oxidation reactions
3. Gas-phase reactions
4. Heterogeneous reactions

2. Photochemical Reactions

Definition: Reactions driven by sunlight, especially UV radiation.

Examples:

- Ozone formation (stratosphere): Oxygen molecules absorb UV → split into O atoms → combine with O₂ → O₃
- Tropospheric ozone (smog): NO₂ absorbs sunlight → breaks into NO + O → O reacts with O₂ → ozone forms

Diagram 1: Ozone Formation Cycle

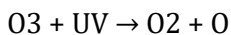


Table 1: Photochemical Reactions Examples

Reaction Type	Reactants	Products	Importance
Stratospheric ozone	O ₂ + UV	O + O ₂ → O ₃	Protects from UV
Urban smog	NO ₂ + sunlight	NO + O → O ₃	Air pollution

3. Oxidation Reactions

Definition: Molecules lose electrons or react with radicals (e.g., OH).

Examples:

- Methane oxidation: $\text{CH}_4 + \text{OH} \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
- Sulfur dioxide oxidation: $\text{SO}_2 + \text{OH} \rightarrow \text{H}_2\text{SO}_4$ (acid rain)

Diagram 2: Oxidation of Methane & SO_2

(Visual: arrows showing $\text{CH}_4 + \text{OH} \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ and $\text{SO}_2 + \text{OH} \rightarrow \text{H}_2\text{SO}_4$)

Table 2: Oxidation Reactions and Environmental Impact

Reactant	Radical/Agent	Product	Effect
CH_4	OH	$\text{CO}_2 + \text{H}_2\text{O}$	Greenhouse gas removal
SO_2	OH/ H_2O_2	H_2SO_4	Acid rain formation

4. Gas-Phase Reactions

Definition: Reactions in the air without involving surfaces.

Examples:

- $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$
- $\text{NO}_2 + \text{sunlight} \rightarrow \text{NO} + \text{O}$
- VOCs + OH \rightarrow secondary aerosols

Diagram 3: Tropospheric Ozone Formation

(Visual: arrows showing NOx and O_3 interactions in urban air)

5. Heterogeneous & Multiphase Reactions

Definition: Reactions on surfaces of aerosols, droplets, or ice.

Examples:

- $\text{N}_2\text{O}_5 + \text{H}_2\text{O}$ (on droplets) $\rightarrow 2\text{HNO}_3$
- $\text{SO}_2 + \text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4$
- $\text{ClONO}_2 + \text{HCl}$ (on polar stratospheric clouds) $\rightarrow \text{Cl}_2 + \text{HNO}_3 \rightarrow$ Cl radicals destroy O_3

Diagram 4: Surface Reactions Leading to Acid Rain and Ozone Depletion

(Visual: cloud droplet + chemical arrows showing transformations)

Table 3: Heterogeneous Reactions

Reaction	Surface	Product	Environmental Impact
$\text{N}_2\text{O}_5 + \text{H}_2\text{O}$	Aerosol	HNO_3	Acid rain
$\text{SO}_2 + \text{H}_2\text{O}_2$	Droplet	H_2SO_4	Acid rain
$\text{ClONO}_2 + \text{HCl}$	Polar cloud	Cl radicals	Ozone depletion

6. Summary

- Photochemical reactions: sunlight drives ozone formation
- Oxidation reactions: remove pollutants, produce acids and aerosols
- Gas-phase reactions: form tropospheric ozone and secondary aerosols
- Heterogeneous reactions: occur on particles/droplets, key in acid rain and ozone depletion

Diagram 5: Overview of Atmospheric Chemical Reactions

(Visual: flowchart connecting photochemical, oxidation, gas-phase, and heterogeneous reactions with products and environmental effects)