Dr. Nadia Mohammed

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 O_2 → O_3
- Tropospheric ozone (smog): NO_2 absorbs sunlight → breaks into NO + O → O reacts with O_2 → ozone forms

Diagram 1: Ozone Formation Cycle

O2 + UV → 2O
O + O2 → O3
O3 + UV → O2 + O

Table 1: Photochemical Reactions Examples

Reaction Type	Reactants	Products	Importance
Stratospheric ozone	O_2 + UV	$O + O_2 \rightarrow O_3$	Protects from UV
Urban smog	NO_2 + sunlight	$NO + O \rightarrow O_3$	Air pollution

3. Oxidation Reactions

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

Examples:
- Methane oxidation: $CH_4 + OH \rightarrow CO_2 + H_2O$
- Sulfur dioxide oxidation: $SO_2 + OH \rightarrow H_2SO_4$ (acid rain)

Diagram 2: Oxidation of Methane & SO_2
(Visual: arrows showing $CH_4 + OH \rightarrow CO_2 + H_2O$ and $SO_2 + OH \rightarrow H_2SO_4$)

Table 2: Oxidation Reactions and Environmental Impact

Reactant	Radical/Agent	Product	Effect
CH_4	OH	$CO_2 + H_2O$	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:
- $NO + O_3 \rightarrow NO_2 + O_2$
- NO_2 + sunlight $\rightarrow NO + O$
- 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:
- $N_2O_5 + H_2O$ (on droplets) $\rightarrow 2HNO_3$
- $SO_2 + H_2O_2 \rightarrow H_2SO_4$
- $ClONO_2$ + HCl (on polar stratospheric clouds) $\rightarrow Cl_2 + HNO_3 \rightarrow$ 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
$N_2O_5 + H_2O$	Aerosol	HNO_3	Acid rain
$SO_2 + H_2O_2$	Droplet	H_2SO_4	Acid rain
$ClONO_2 + HCl$	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)