Structure and Chemistry of the Atmosphere

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The Structure of the Atmosphere

The Atmosphere:
1.8 x 10^{20} mole gas

Exosphere
- 400 km altitude

Thermosphere
- 300 km

Mesosphere
- 50 km

Stratosphere
- 40 km

Troposphere
- 10 km

http://www.chs.k12.nf.ca/science/b3201/WebCT-Copy/images/lesson-images/lesson01/atmosphere.gif
A Mole of Gas:
6.023 x 10^{23} \text{ atoms/molecules}

Source: Chemistry by Cheng
## Composition of Dry Air at Sea Level

<table>
<thead>
<tr>
<th>Gas</th>
<th>Composition (%) by Volume</th>
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<tbody>
<tr>
<td>N\textsubscript{2}</td>
<td>78.03</td>
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<tr>
<td>O\textsubscript{2}</td>
<td>20.99</td>
</tr>
<tr>
<td>Ar</td>
<td>0.94</td>
</tr>
<tr>
<td>CO\textsubscript{2}</td>
<td>0.039204*</td>
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<td>Ne</td>
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* ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_mm_mlo.txt

Source: *Chemistry* by Chang
Adiabatic Cooling

Source: *Earth Under Siege* by Turco
Adiabatic Cooling

Adiabatic Law:

\[ P_1 V_1^\gamma = P_2 V_2^\gamma \]

\[ \gamma = \frac{C_P}{C_V} \]
Adiabatic Lapse Rate:
- 10 K per 1 km for dry air
- 4 K per 1 km for air saturated with H₂O
- 6.5 K per 1 km global average
Temperature versus Altitude

Source: *Earth Under Siege* by Turco
Solar Radiation
Photolytic Cleavage and Ionization

\[ \text{O}_2 + \text{hv (} \lambda < 242 \text{ nm)} \rightarrow \text{O}^* + \text{O}^* \]

and

\[ \text{O}^* + \text{hv (} \lambda < 92 \text{ nm)} \rightarrow \text{O}^+ + \text{e}^- \]
Temperature versus Altitude

Source: Earth Under Siege by Turco
In the unperturbed stratosphere ozone is produced by

\[ O_2 + hv (\lambda < 242 \text{ nm}) \rightarrow O^* + O^* \]  \hspace{1cm} (I)

\[ O^* + M + O_2 \rightarrow O_3 + M + \text{energy} \] \hspace{1cm} (II)

and then subsequently destroyed by

\[ O_3 + hv (200 \text{ nm} < \lambda < 300 \text{ nm}) \rightarrow O + O_2 \] \hspace{1cm} (III)

\[ O + O_3 \rightarrow O_2 + O_2 + \text{energy} \] \hspace{1cm} (IV)
Temperature versus Altitude

Source: *Earth Under Siege* by Turco
1D Radiative Convective Model

Manabe & Wetherald 1967
The global mean radiative forcing of the climate system for the year 2000, relative to 1750

Radiative forcing (Watts per square metre)

- Halocarbons
- N$_2$O
- CH$_4$
- CO$_2$
- Tropospheric ozone
- Black carbon from fossil fuel burning
- Mineral Dust
- Aviation-induced
  - Contrails
  - Cirrus
- Aerosol indirect effect
- Land-use (albedo) only
- Stratospheric ozone
- Sulphate
- Organic carbon from fossil fuel burning
- Biomass burning
- Very Low

Level of Scientific Understanding:
- High
- Medium
- Medium
- Low
- Very Low
- Very Low
- Very Low
- Very Low
- Very Low
- Very Low
- Very Low
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- Very Low
- Very Low
- Very Low

Source: IPCC TAR
The global mean radiative forcing for the year 2000, relative to 1850. The chart illustrates the contributions of various greenhouse gases and aerosols to global warming. CO₂ is the largest contributor, with 55%. Other significant contributors include CH₄ (15%), CFCs (24%), and halocarbons. The level of scientific understanding for each factor is indicated by the length of the bars, with longer bars indicating higher confidence.

Source: Chemistry by Chang
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Source: *Chemistry* by Chang
Vibrational Modes

$v_1$ Symmetrical stretch

$v_3$ Antisymmetrical stretch

$v_2$ Bend

(b) $\text{CO}_2$

Source: *Chemical Principles* by Atkins and Jones
$A = \varepsilon l c$

Incoming solar radiation

CO$_2$

Outgoing terrestrial radiation

Source: Chemistry by Chang
Vibrations...

H₂O

http://webbook.nist.gov/
METHANE
INFRARED SPECTRUM

Absorbance

Micrometers

CH₄

http://webbook.nist.gov/
Temperature versus Altitude

Source: *Earth Under Siege* by Turco
Trends in CO₂

http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo
$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$