Ozone

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Outline of Lecture

- ☐ Molecular Structure
- ☐ Properties of Light
- ☐ Ozone in the Atmosphere
- ☐ Ozone Hole and Consequences

Ozone Structure

Forms of Oxygen in our atmosphere. Remember that oxygen normally wants to have exactly two bonds.
O - Single atom. Very reactive

O_3 - Ozone. No "ideal" bonding pattern. Reactive

O=O–O ↔ O–O=O

(Central O has 3 bonds. One end O has only 1)

Chapman Cycle

(1) $O_2 \xrightarrow[\text{High Energy UV}]{h\nu} 2\,O$ Destruction of O

(2) $O_2 + O \longrightarrow O_3$ *Formation of ozon*

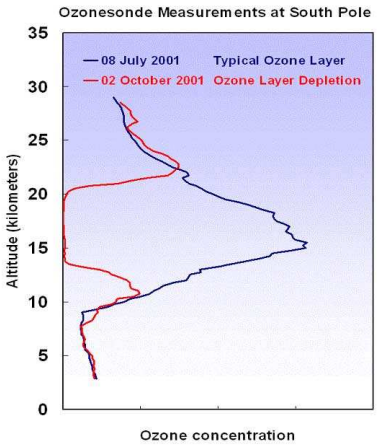
(3) $O_3 \xrightarrow[\text{Low Energy UV}]{h\nu} O_2 + O$ *Reverse of #2*

(4) $O_3 + O \longrightarrow 2\,O_2$ *Destruction of ozon*

Ozone Layer

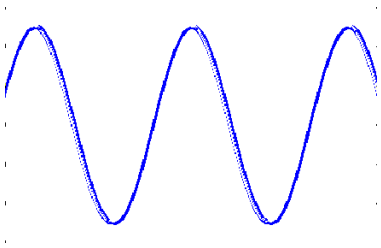
Definition
Concentration of ozone in upper atmosphere varies with altitude. The concentration of ozone peaks around 20 km (˜12 miles) above the earth's surface. The ozone layer is considered to be between 15-30 kilometers.
Role in Environment
Ozone is responsible for absorption of high energy ultraviolet light. Loss of ozone in the upper atmosphere results in an increase in UV rays, which can be harmful t life on earth.

Ozone Layer



Light

Energy of light based on two characteristics:
Amplitude - Height of wave. Intensity. Number of photons.
Frequency - # of oscillations. Energy of each photon



Light - Equations

The energy of light is directly proportional to the frequency (ν).

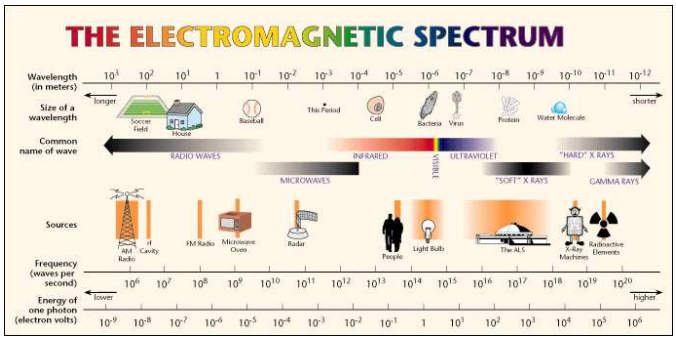
$$E = h\nu$$

The energy is also inversely proportional to the wavelength (λ).

$$E = \frac{hc}{\lambda}$$

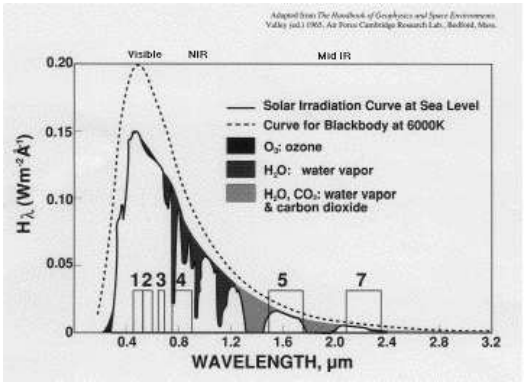
These equations for single photon of light.

Electromagnetic Spectrum



Taken from Berkeley Lab web site.

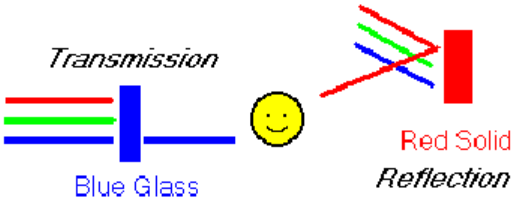
Solar Radiation



For more information, see NASA site.

Color

The color of an object is due to the color(s) NOT absorbed by that object.



Sunscreen

The gases present in our atmosphere protect us from harmful radiation. These gases absorb the UV light in the upper atmosphere, preventing them from hitting the earth's surface.

- $<$ 100 nm - Extremely high energy UV. Absorbed by primarily by N_2 and O_2.
- 100-210 nm - Very high energy UV. Absorbed primarily by oxygen (O_2).
- 210-310 nm - High energy UV. Absorbed primarily by ozone (O_3).

Absorption of Light

Sun				
	Ultraviolet		Visible	IR
100-210	210-310	310-380	380-760	>760
⇓	⇓	⇓	⇓	⇓
O_2	O_3	*Little absorption*		
		⇓	⇓	⇓
Earth's surface				

Radiation from sun given as wavelength in nm.

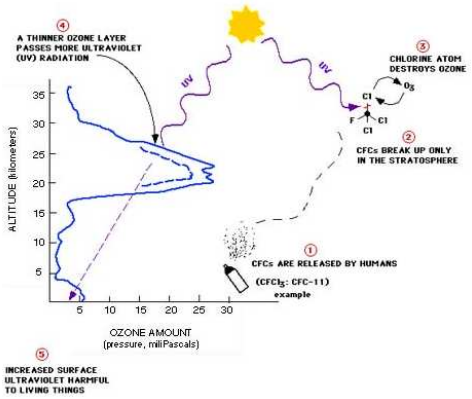
Ozone Hole

Decrease in concentration of ozone in atmosphere over Antarctica observed every fall.
June-September: Winter at South pole. Ice forms in upper atmosphere, trapping chlorine-containing compounds.
October: Spring. Ice in atmosphere melts, releasing ozone-depleting molecules.
November-May: Warmer temperatures. Chapman cycle operates as usual.

CFC's

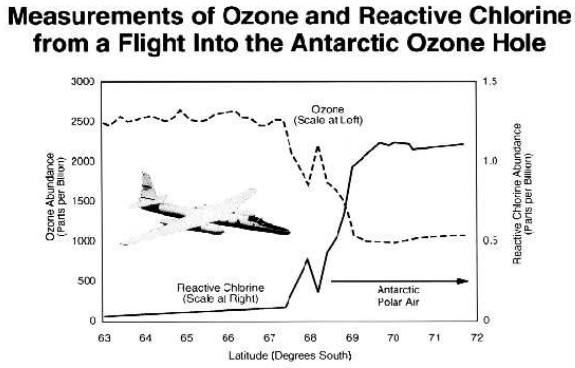
Chlorofluorocarbons (CFC's) were widely used as refrigerants (refrigerators, air conditioners, ...) and propellents (blowing agents for insulation, ...). Accumulation of these species in the atmosphere is believed to be at least partially to blame for the destruction of ozone.
CFC's are particularly bad because they are so stable. Very reactive molecules wouldn't make it into the upper atmosphere, and if they did, they would last very long.

Ozone Destruction



From NOAA site

CFC's and Ozone



From NOAA site

Montreal Protocol

- Multinational agreement to limit use of CFC's.
  - Agreed in 1987
  - Ratified by U.S. in 1989
- Credited with stopping further destruction of ozone layer
  - Ozone hole expected to be gone by ≈25-50 years

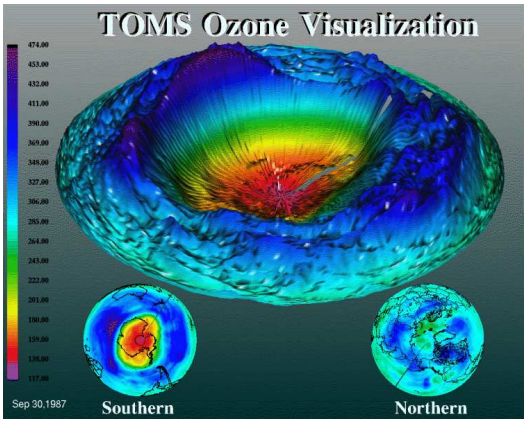
Problem

Scientists have recently reported (Pope, Hansen, Bayes, Friedl, and Sander in *J. Physical Chemistry A*, **2007**, 111(20), 4322-4332) that the UV absorption of Cl-O-O-Cl is significantly less than previously believed.

- Calculated photolysis rates are 6 times slower than previously believed.
- At least 60% of ozone destruction by some unknown mechanism.

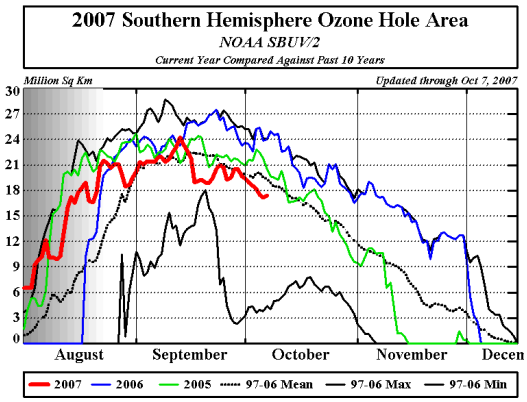
For a summary, see
http://www.nature.com/nature/journal/v449/n7161/full/449382a.html

Ozone Hole Image



From NASA site

2007 Ozone Levels

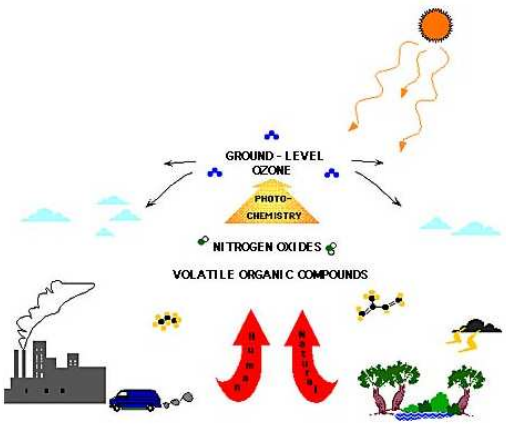


Ground-Level Ozone

Ozone is beneficial in upper atmosphere. At ground-level, it is highly reactive and can severely damage living tissue of plants and animals.
Ozone can be formed in the lower atmosphere by pollutants, in particular the combination of:

- volative organic compounds - both natural and man-made
- nitrogen oxides - primarily from man-made combustion (auto exhaust, power plants, ...)

Tropospheric Ozone Image



From NOAA site

Current Ozone Levels

It is possible to obtain recent ozone levels for much of the world over the internet.
Note that KSU-Stark is located at 40.86° longitude and -81.40° latitude.
Ozone levels reported in Dobson Units, where the average reading over the U.S. is ˜320 D.U.
A UV forcast is also available (updated daily), which attempts to assess risk of UV exposure.