NATS 101
Section 13: Lecture 6

The Greenhouse Effect and Earth-Atmosphere Energy Balance

FOUR POSSIBLE FATES OF RADIATION:

1.Transmitted

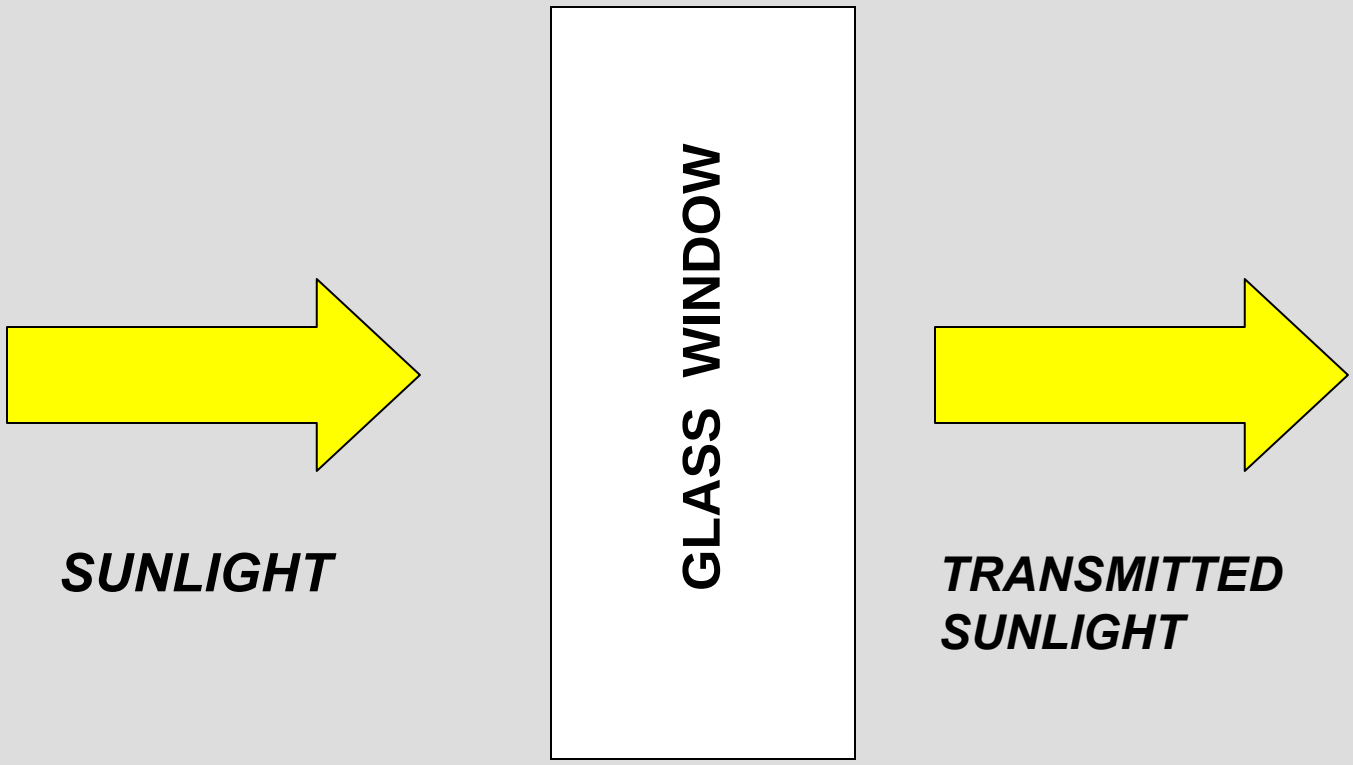
2. Reflected

3. Scattered

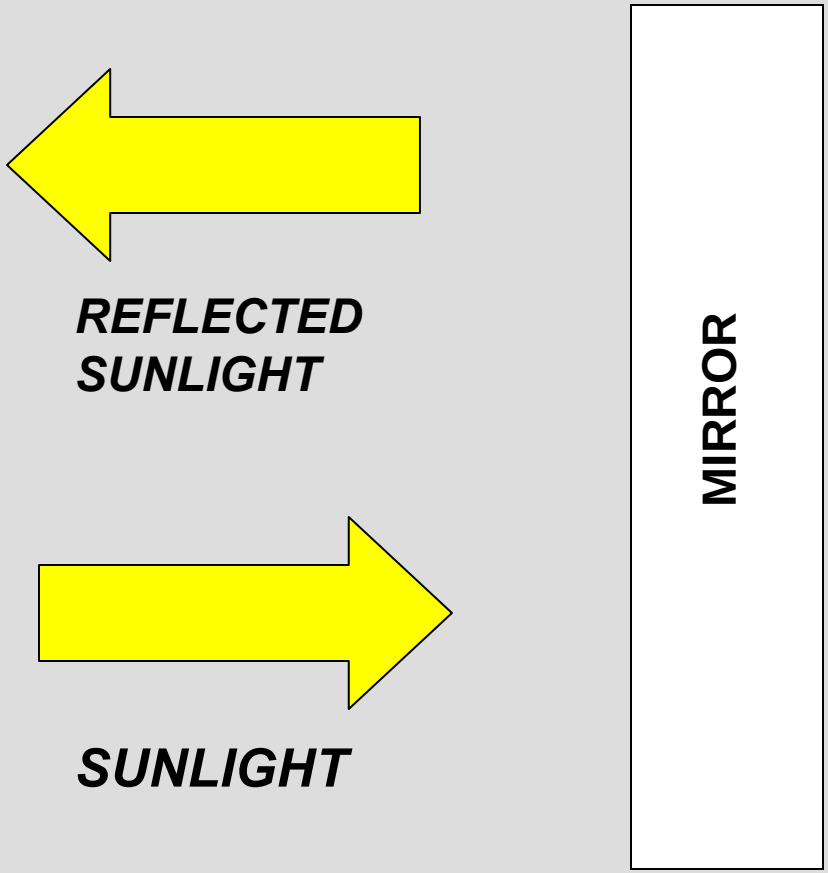
4. Absorbed

The atmosphere does ALL of these…

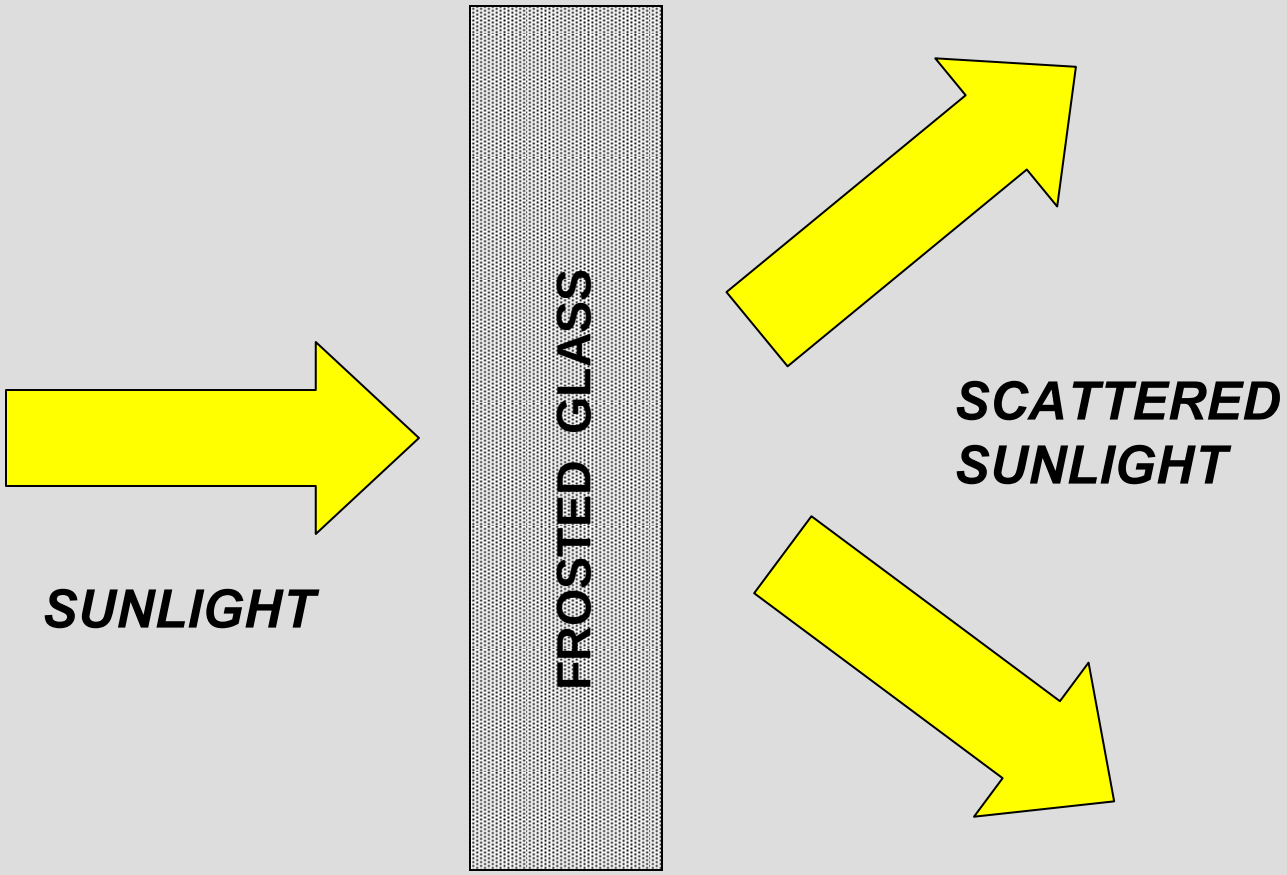
Transmitted:
Radiation passes through object



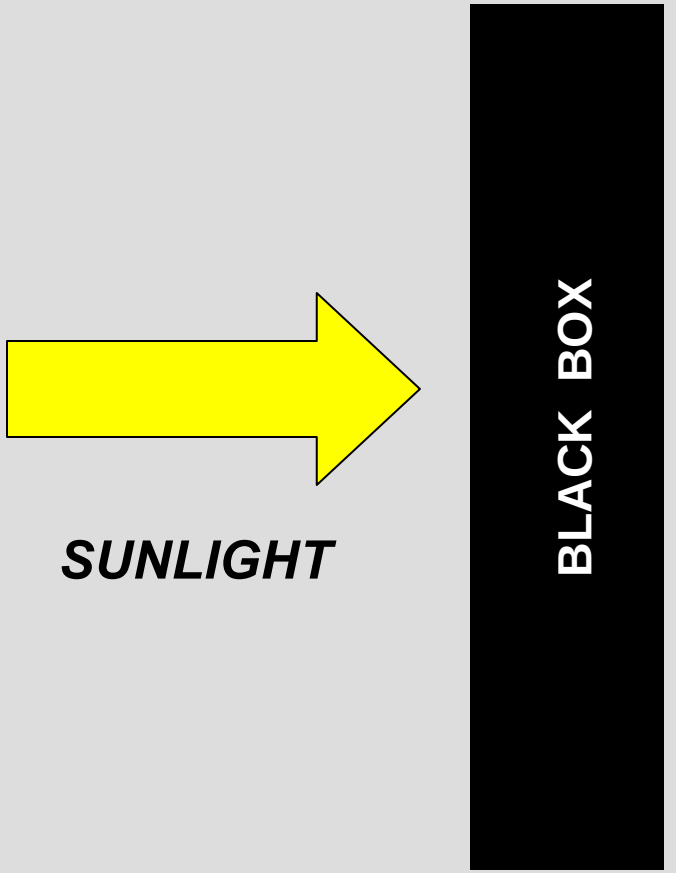
Reflected:
Radiation turned back



Scattered:
Path of radiation deflected

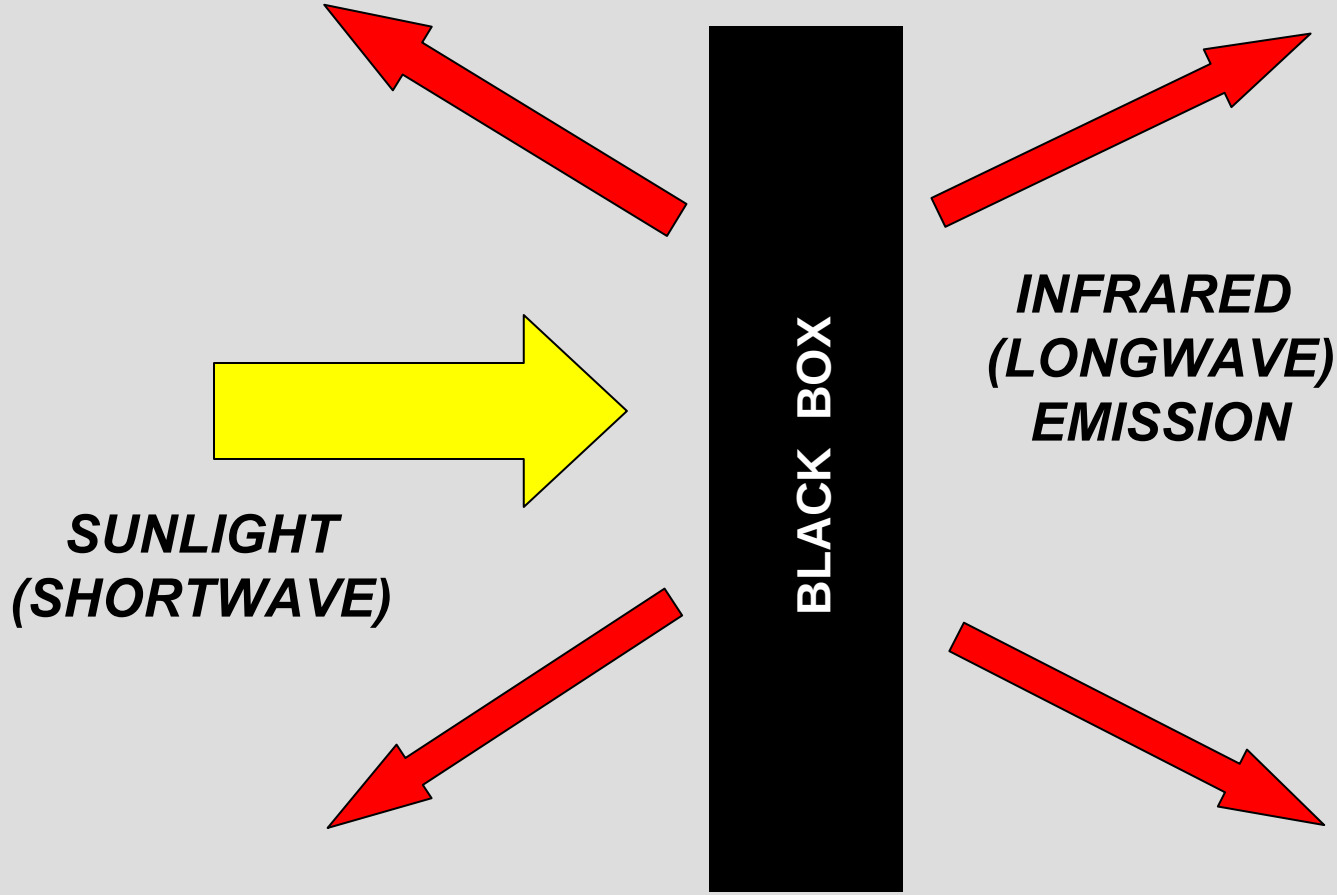


Absorbed:
Radiation transferred to object

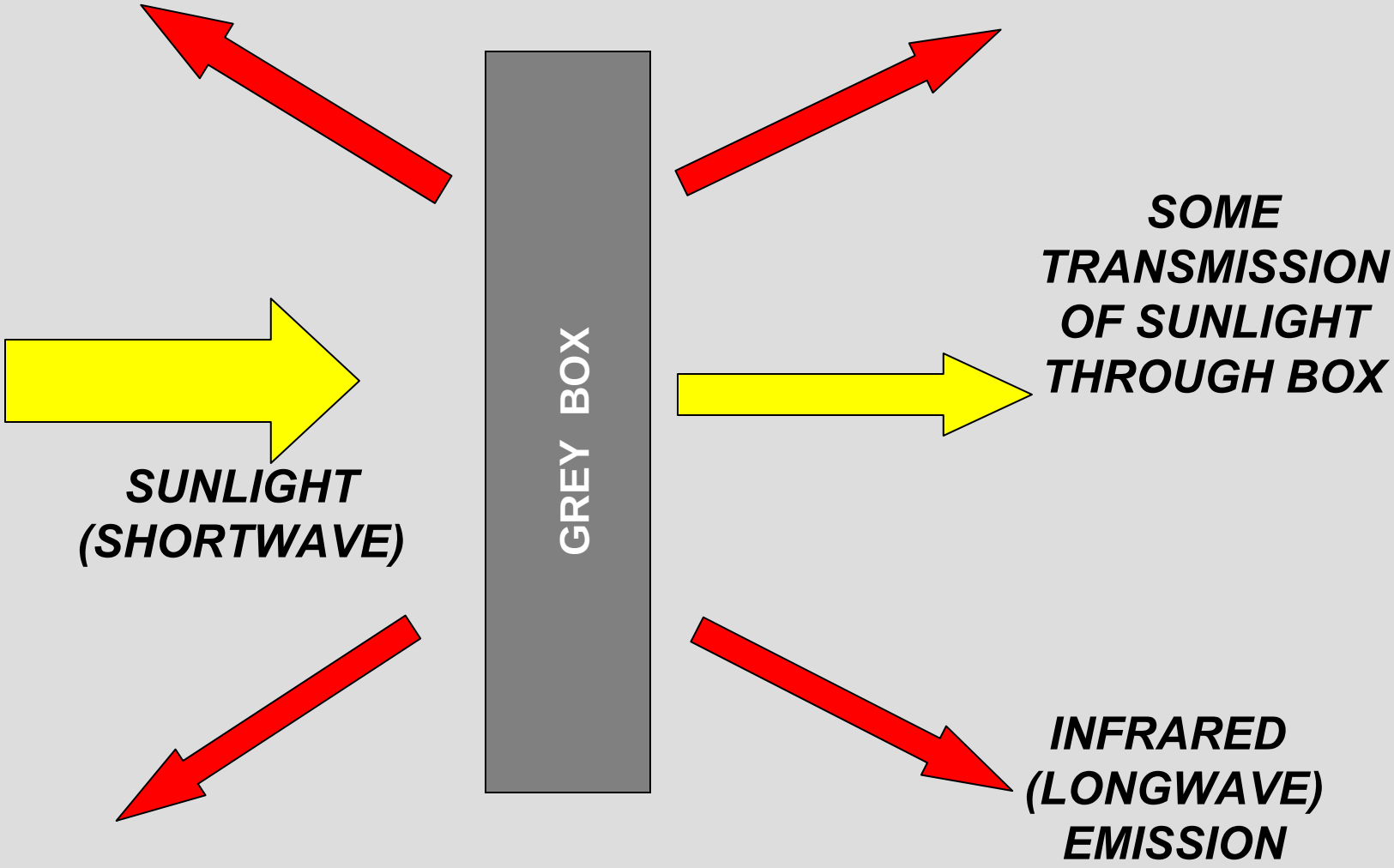


<u>Blackbody</u>: a perfect absorber and emitter of radiation in equilibrium, with no reflection or scattering.

Radiative equilibrium:
Absorption = Emission (Kirchoff's Law)



A “Grey Body” = Not all radiation absorbed
How the atmosphere behaves



What Happens When Radiation is “Absorbed”?

Internal energy increases by changes on the molecular and atomic levels

ENERGY TRANSITIONS:

Translational

Rotational

Vibrational

Electronic: molecular

Electronic: atomic

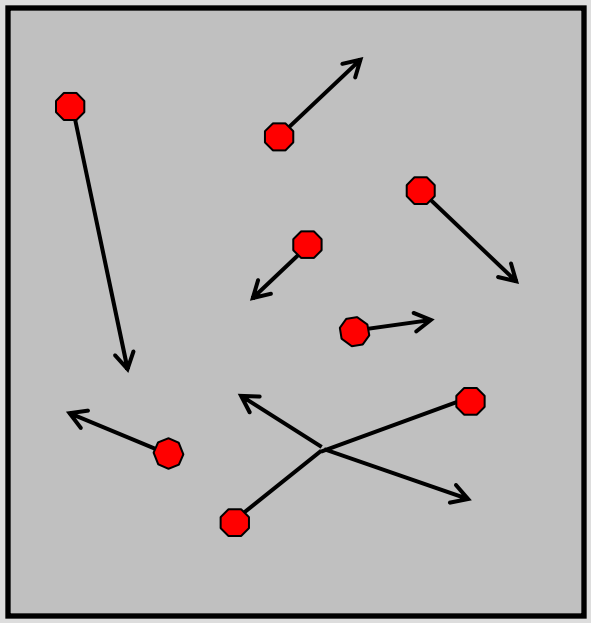
Less Energy required
Changes on molecular level
Longer wavelength of radiation

More energy required
Changes on the atomic level
Shorter wavelength of radiation

Translational Energy

Gross movement of atoms and molecules through space.

The translational energy reflects the kinetic energy—and thus the temperature.

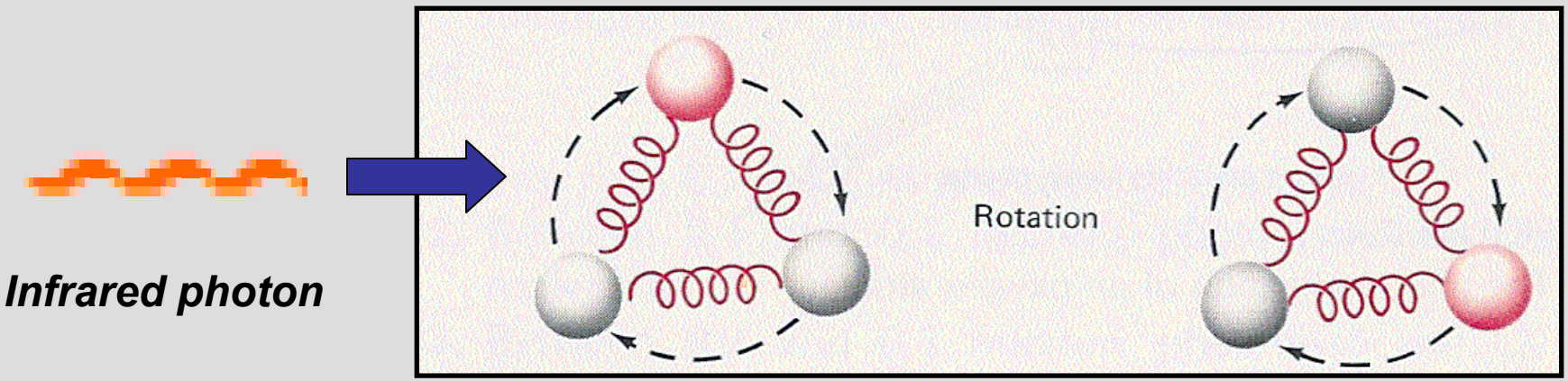


Rotational Energy

Energy associated the rotation of the molecule. Takes on discrete values (or quanta) dependent on the type of molecule.

Corresponds to energy changes shorter than 1 cm (far infrared).

Rotation of water molecules

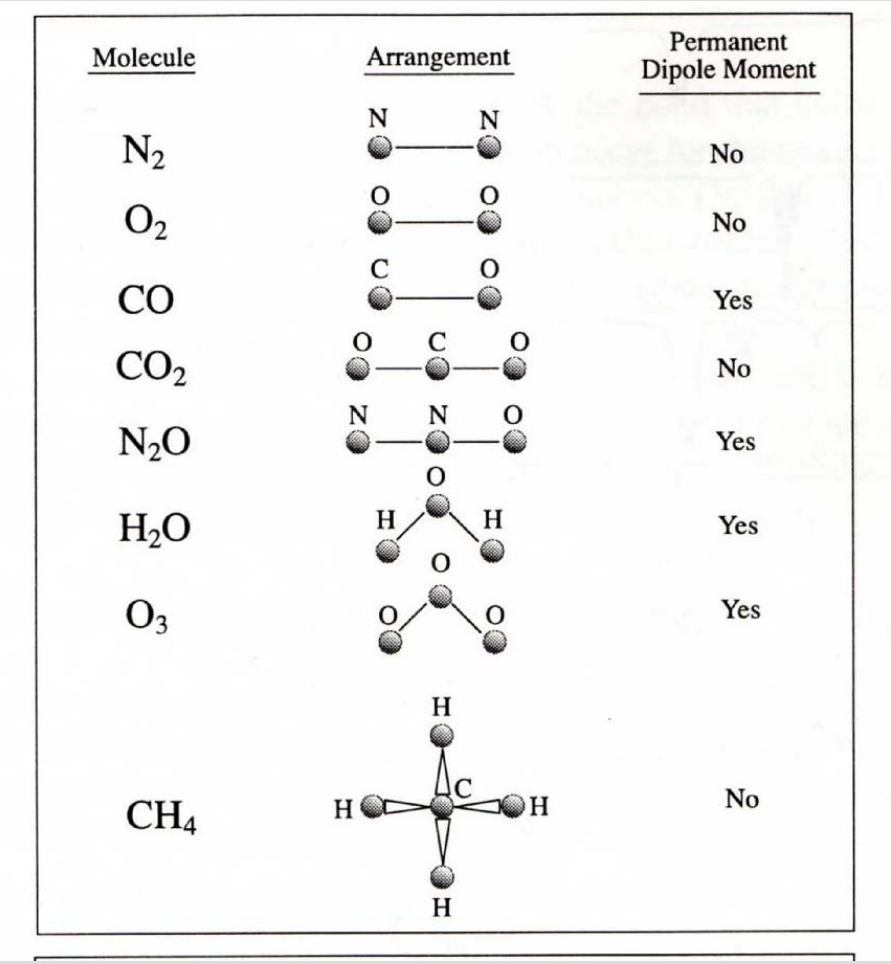


Infrared photon

(Gedzelman 1980, p 105)

Rotational Energy of Common Gases in the Atmosphere

Molecules have rotational energy only if they have a *permanent dipole moment, or asymmetric charge distribution*.



Molecule	Arrangement	Permanent Dipole Moment
N_2	N N	No
O_2	O O	No
CO	C O	Yes
CO_2	O C O	No
N_2O	N N O	Yes
H_2O	O (H H)	Yes
O_3	O (O O)	Yes
CH_4	H (H C H) H	No

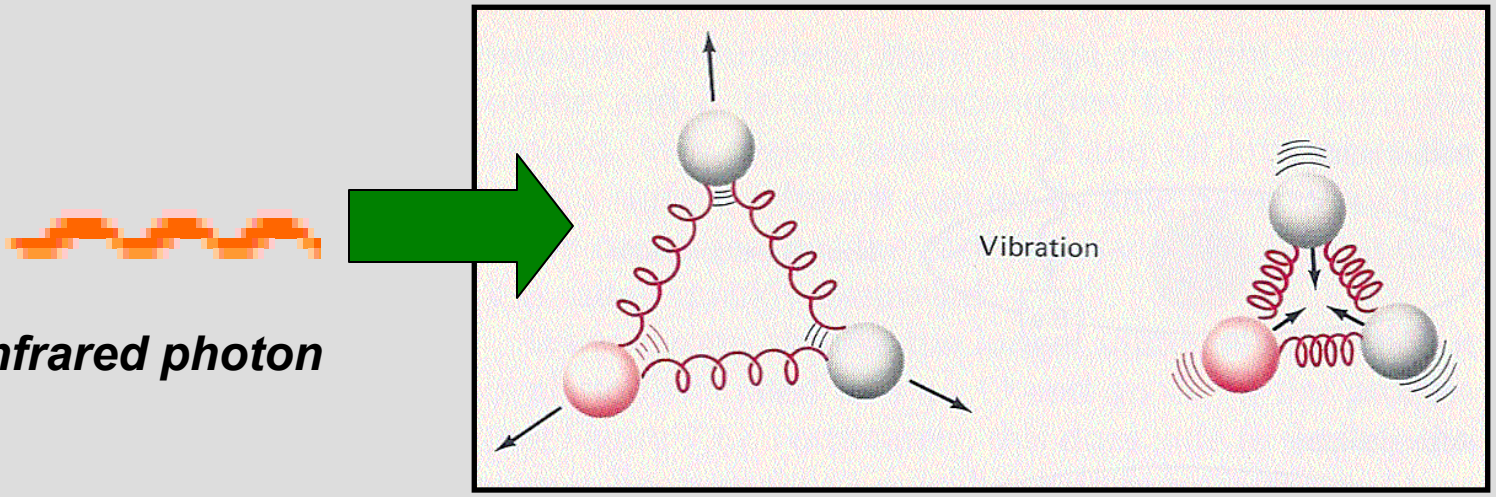
(Hartmann 1994)

Vibrational Energy

Molecular energy stored in the vibrations (or stretching and bending) of atomic bonds. Takes on discrete values (or quanta) dependent on the type of molecule.

Corresponds to energy changes in the _____ spectrum.

Vibration of water molecules



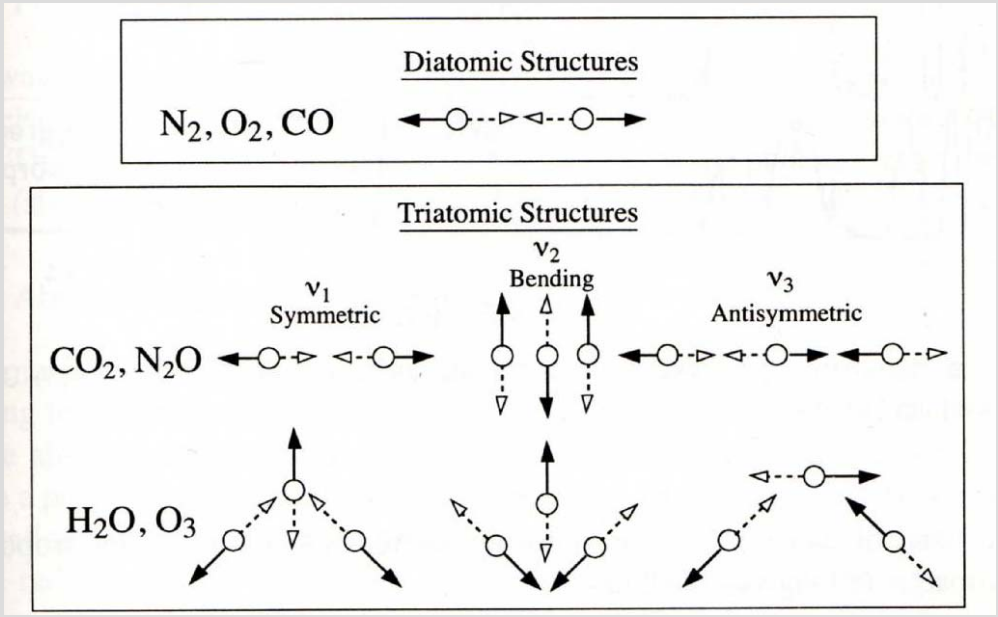
Infrared photon

(Gedzelman 1980, p 105)

Vibrational Energy for Common Gases in the Atmosphere

Most effective absorbers are molecules that have a dipole moment and/or are bent.

Carbon dioxide creates a dipole moment as a result of its vibrational transitions, so has rotational energy as well.

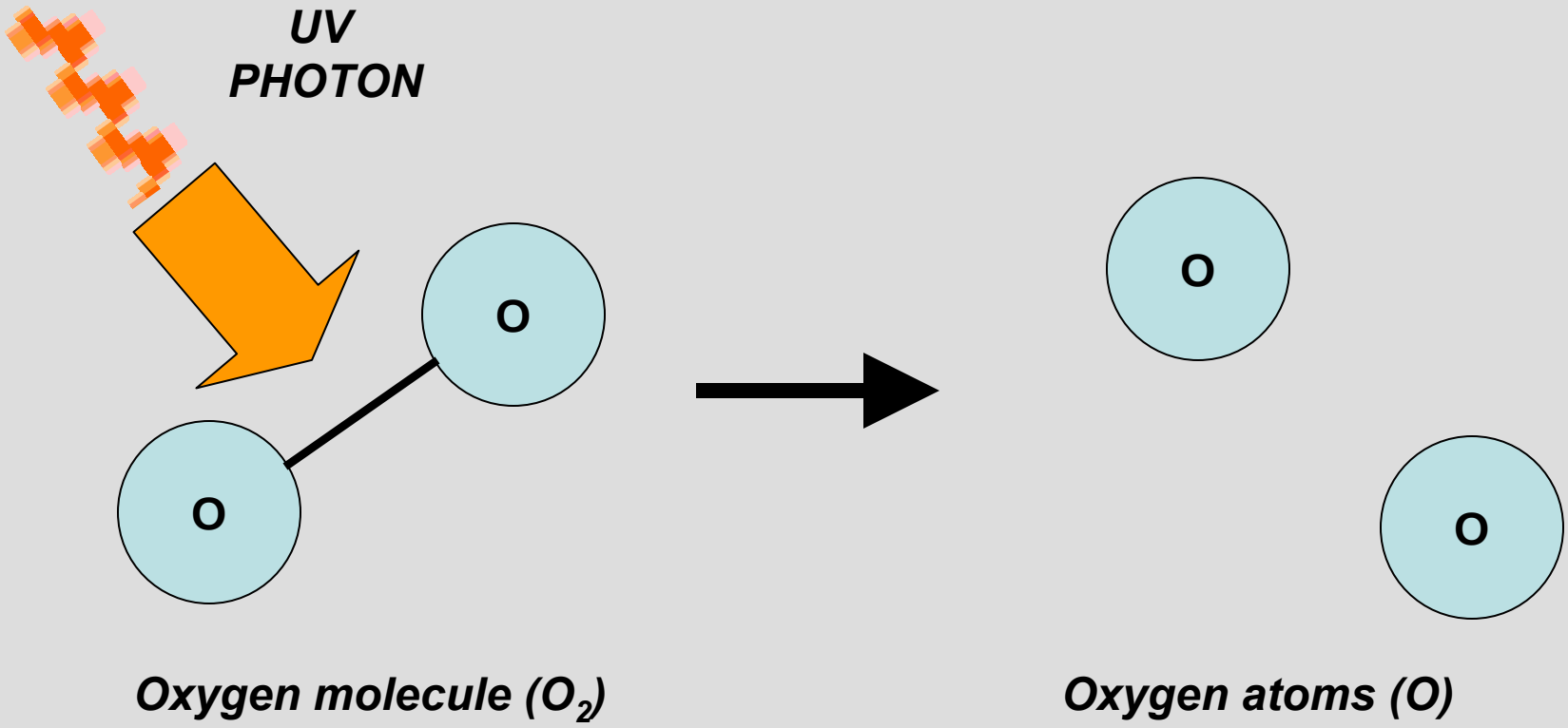


(Hartmann 1994)

Electronic energy: Photodissociation (Molecular level)

Energy associated with breaking of atomic bonds of molecules. Takes on discrete values (or quanta) dependent on the type of molecule.

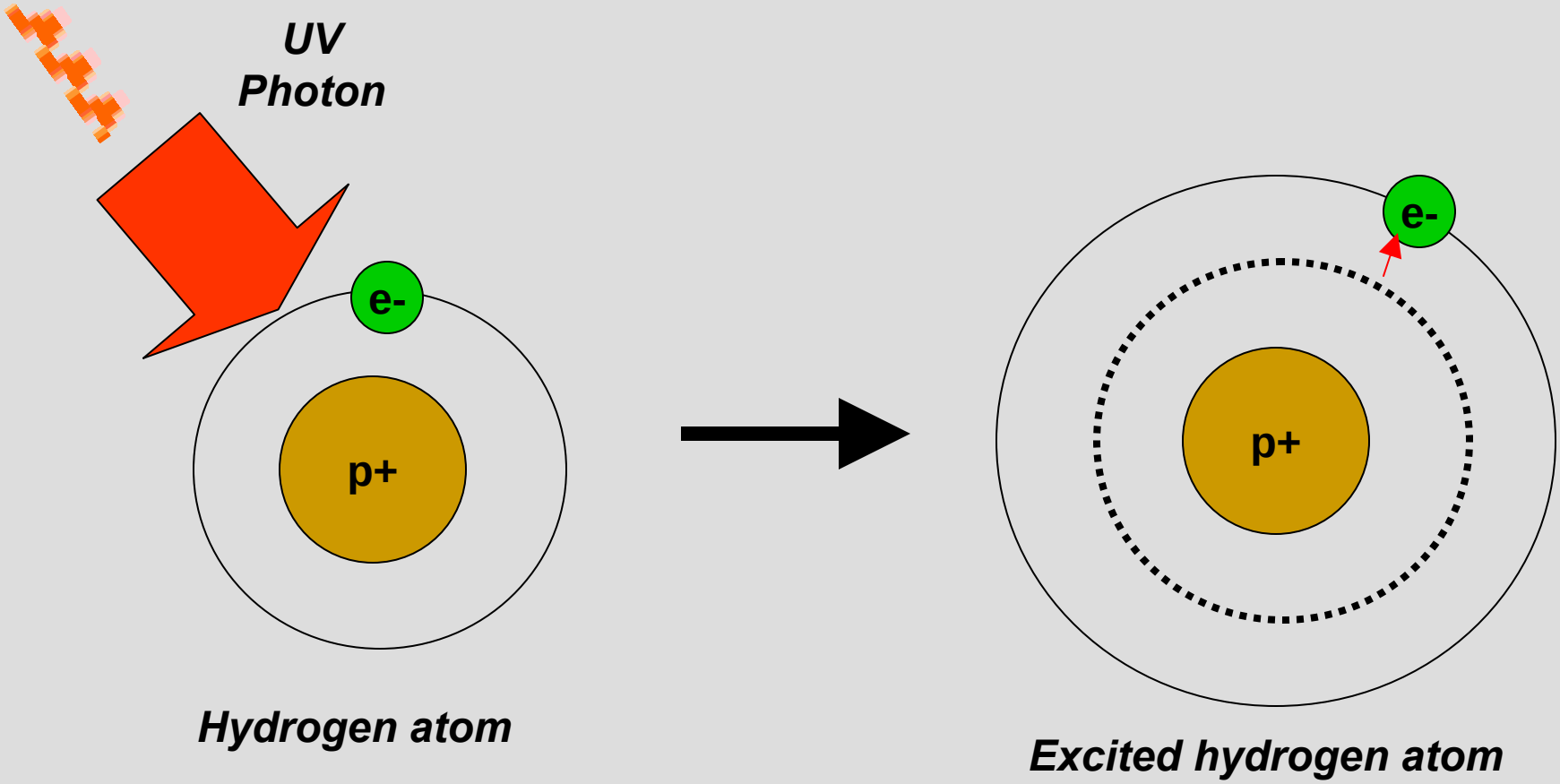
Corresponds mainly to energy changes in the _____ spectrum.



Electronic energy: Excitation (Atomic Level)

Energy associated with excitation of electrons in the outer shell of an atom. Takes on discrete values (or quanta) dependent on the type of molecule.

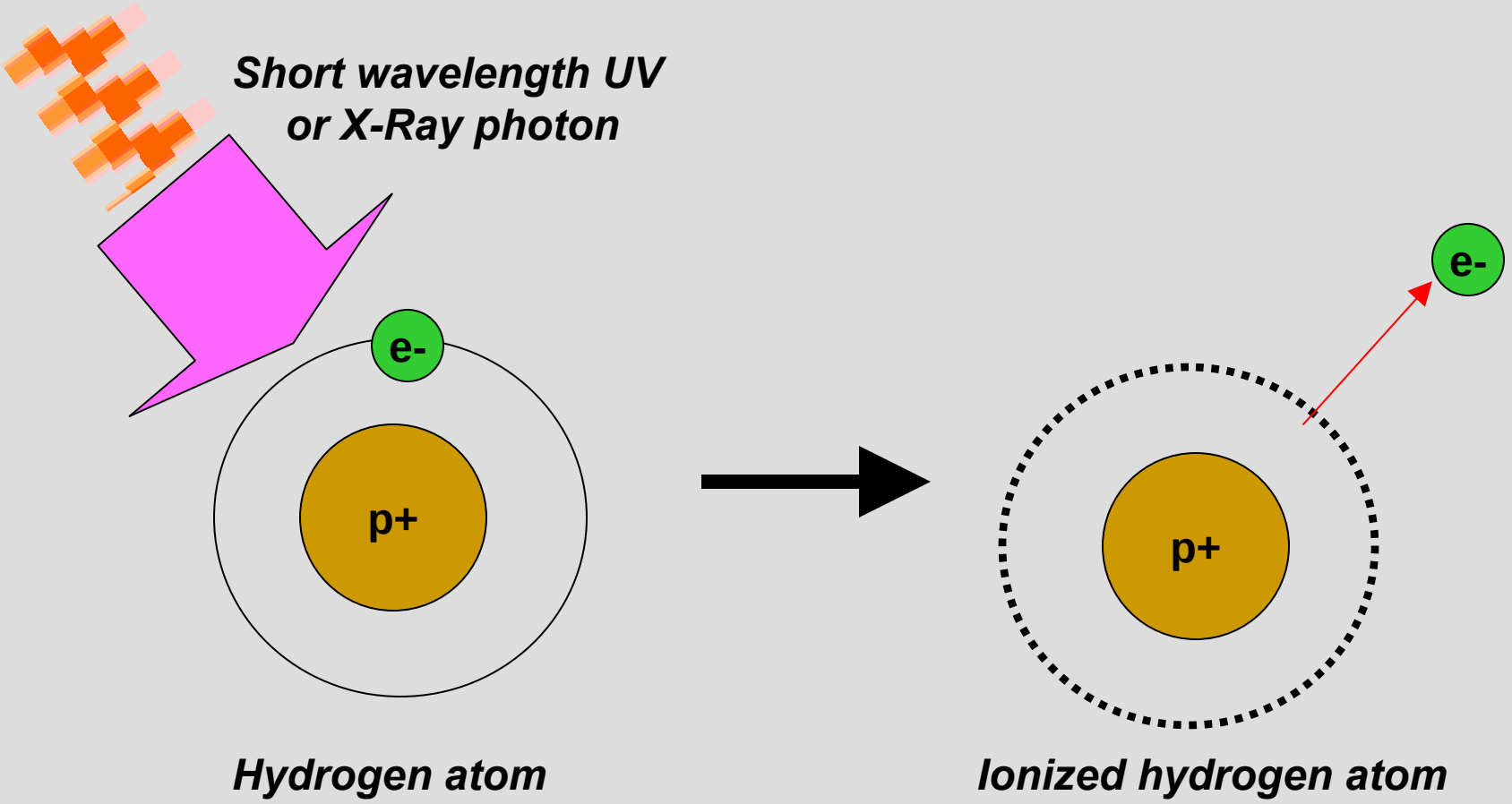
Corresponds to energy changes mainly in the _____.



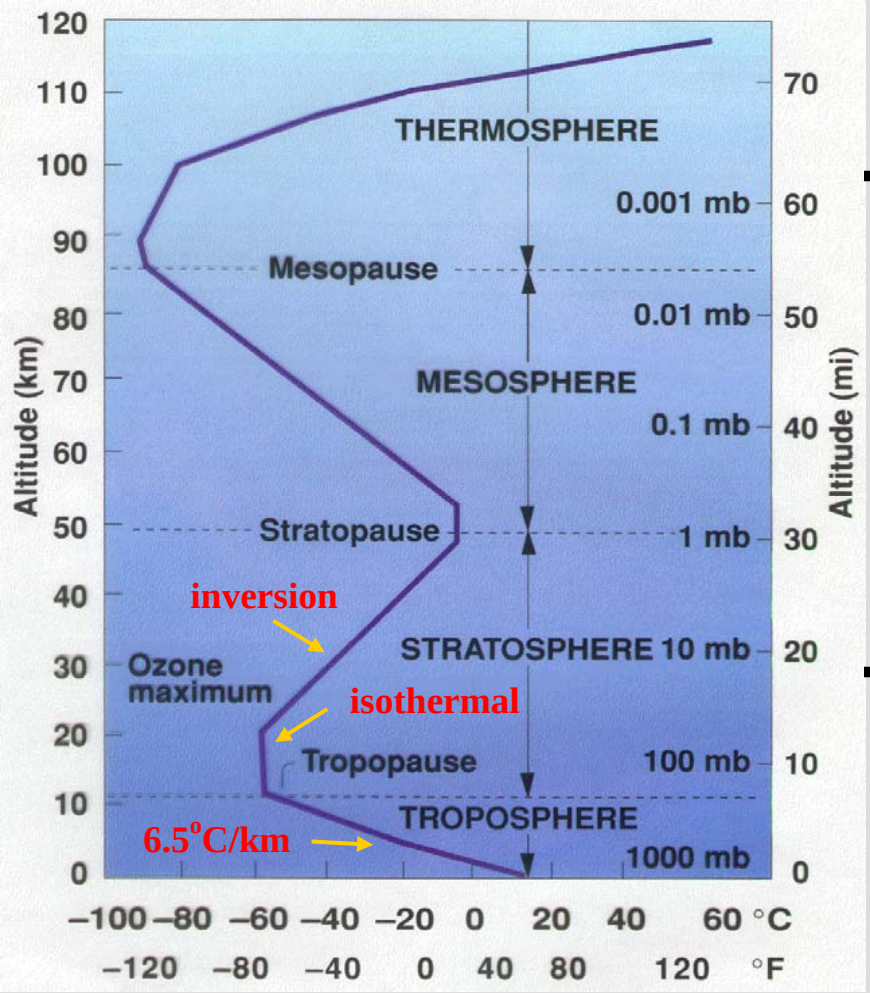
Electronic energy: Ionization (Atomic level)

Energy associated with removal of electrons from an atom. Takes on discrete values (or quanta) dependent on the type of molecule.

Corresponds to energy changes mainly higher than ultraviolet.



Flashback: Why is there warming in Thermosphere and Stratosphere?



THERMOSPHERE: Warming because of

_____

_____.

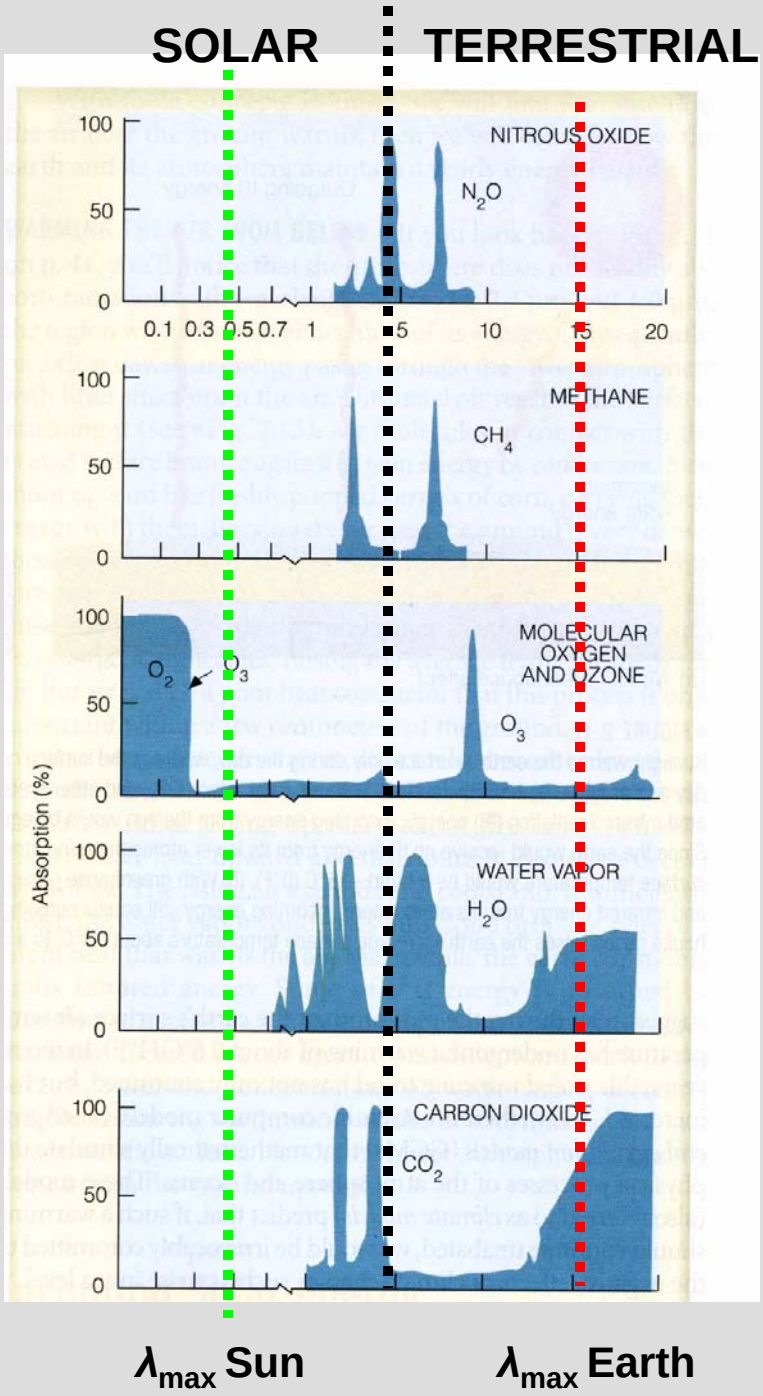
STRATOSPHERE: Warming because of photodissociation of

_____

_____.

Aurora Borealis or Aurora Australis

Caused by ionization of gases in the Earth's atmosphere from the solar wind, which appears as visible light. Occur only at the poles because of the properties Earth's magnetic field



Absorption of Radiation by Common Atmospheric "Greenhouse" Gases

The "greenhouse gases" are called such because they absorb and emit very effectively in

_____

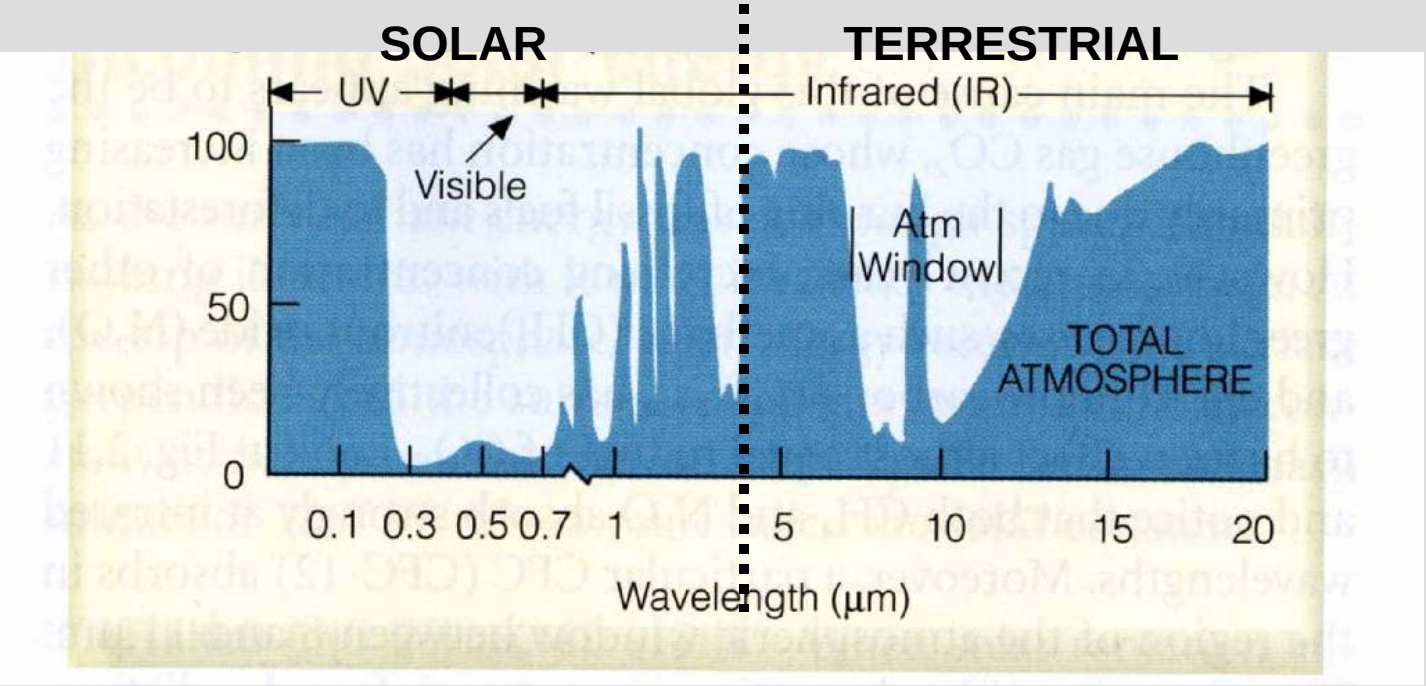
_____.

Water and CO_2 are good greenhouse gases

Oxygen (O_2) and ozone (O_3) are absorbed in the UV.

Little or no absorption in some places

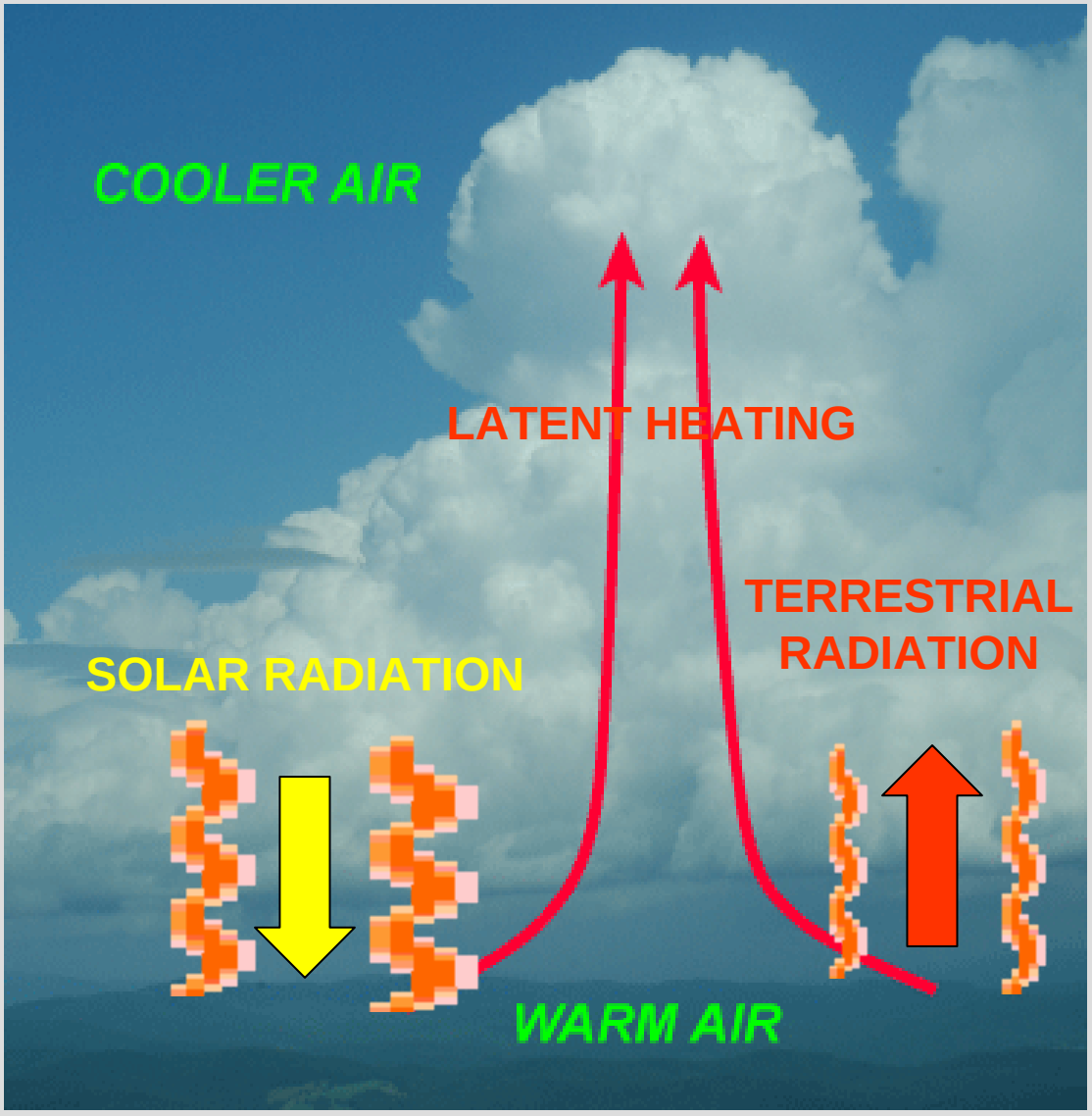
Total Radiation Absorption Spectrum by all Atmospheric Gases



Little or no absorption.

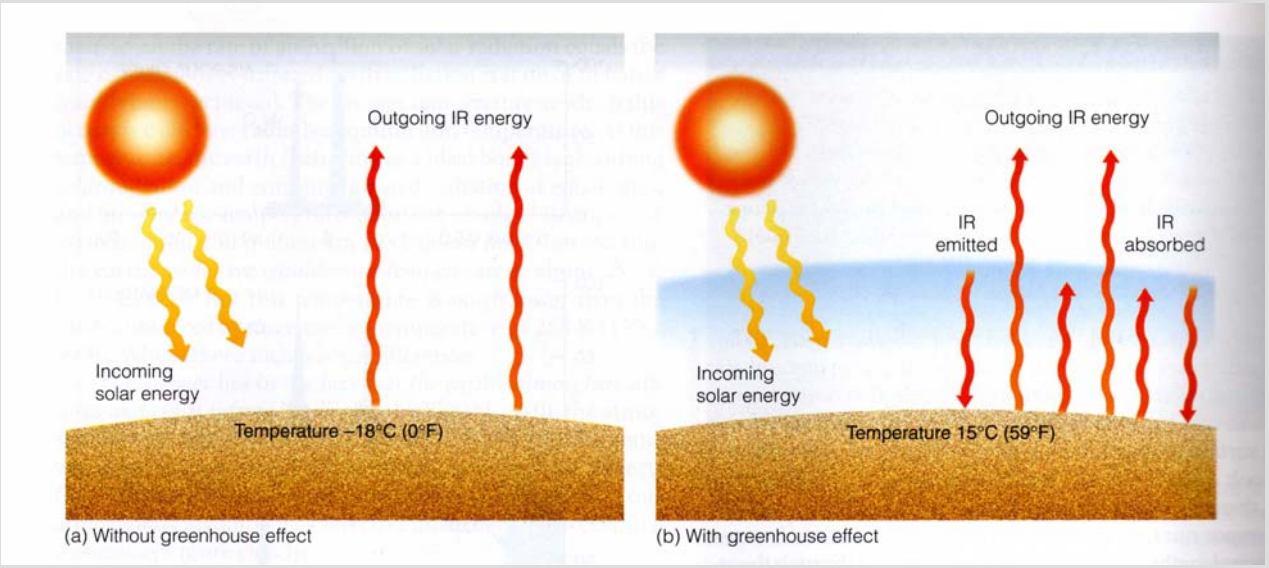
A lot of absorption because of greenhouse gases, *except in an atmospheric window of 8-11 μm.*

Atmospheric Heating From Below



Since there is little or no absorption of radiation in the most intense part of the solar radiation band, the heat supplied comes from the Earth itself.

The Importance of the Greenhouse Effect



The presence of the gases in our atmosphere that absorb and emit infrared radiation help maintain the Earth's average temperature at about 59 °F.

The Greenhouse Effect
DOES NOT EQUAL
Global Warming or Climate Change!

Global warming: **The increase in Earth's mean temperature that would result because of the increase in greenhouse gases due to human activities. This would enhance the greenhouse effect.**

Climate change: **Long-term change in global, regional, or local climate resulting from both enhanced greenhouse gases and/or other human activities.**

Greenhouse Effect: Venus, Earth, and Mars

VENUS
(Same size as Earth)

Pressure = 90 Atm.
Atmosphere composed of 96% CO_2
Temperature = 482 °C

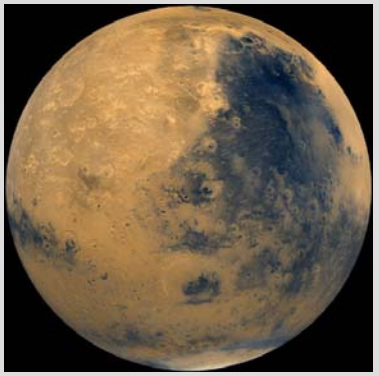
GREENHOUSE EFFECT ON STERIODS!

EARTH

Pressure = 1 Atm.
Atmosphere composed of less than 1% CO_2
Temperature = 15 °C

GREENHOUSE EFFECT JUST RIGHT

MARS
(Half size of Earth)

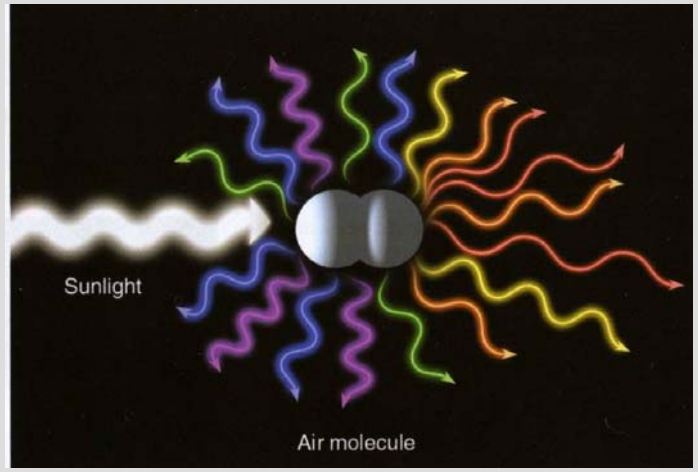


Pressure = 0.01 Atm.
Atmosphere composed of 95% CO_2
Temperature = -63 °C

VIRTUALLY NO ATMOSPHERE TO HAVE A GREENHOUSE EFFECT

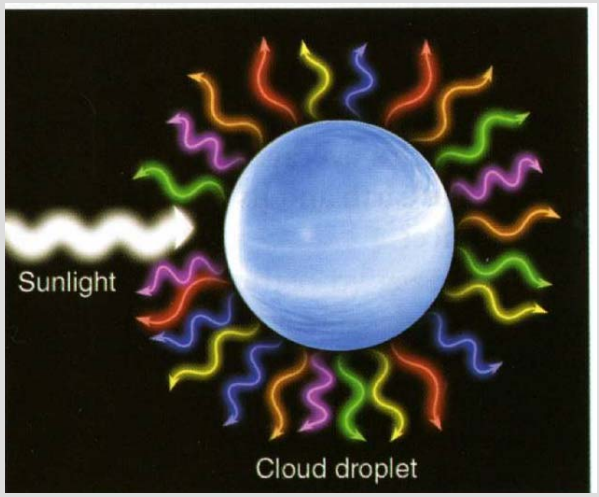
Scattering: Radiation deflected

Rayleigh Scattering



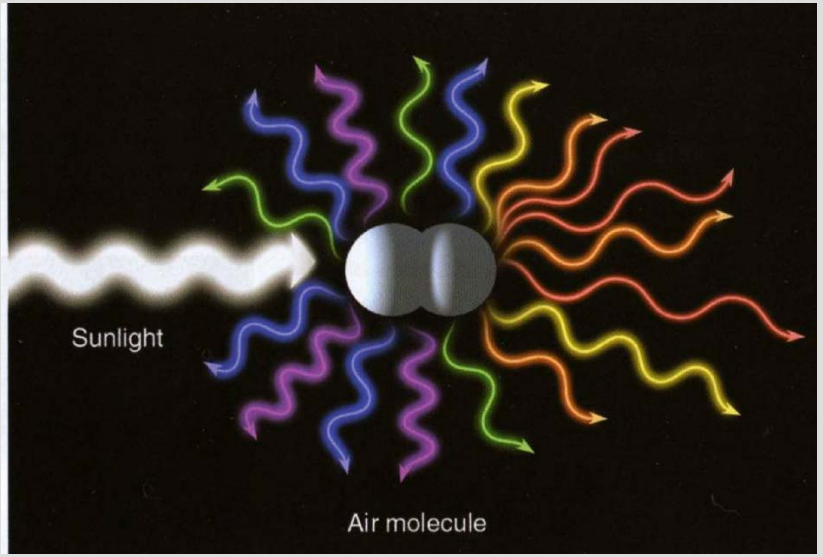
Atmospheric gases: Molecules preferentially scatter the smaller wavelengths of visible light.

Mie Scattering



Cloud drops: Scatter all wavelengths of visible light equally.

Why is the sky blue?



ANSWER:

Reflection: Radiation turned back

In meteorology the reflectivity is called the *albedo*.

Albedo = 1 → All radiation reflected

Albedo = 0 → All radiation absorbed

Snow : 0.7

Water: 0.1

Vegetation: 0.1 to 0.3

Sand: 0.15 to 0.45

Clouds: Depends on type and location

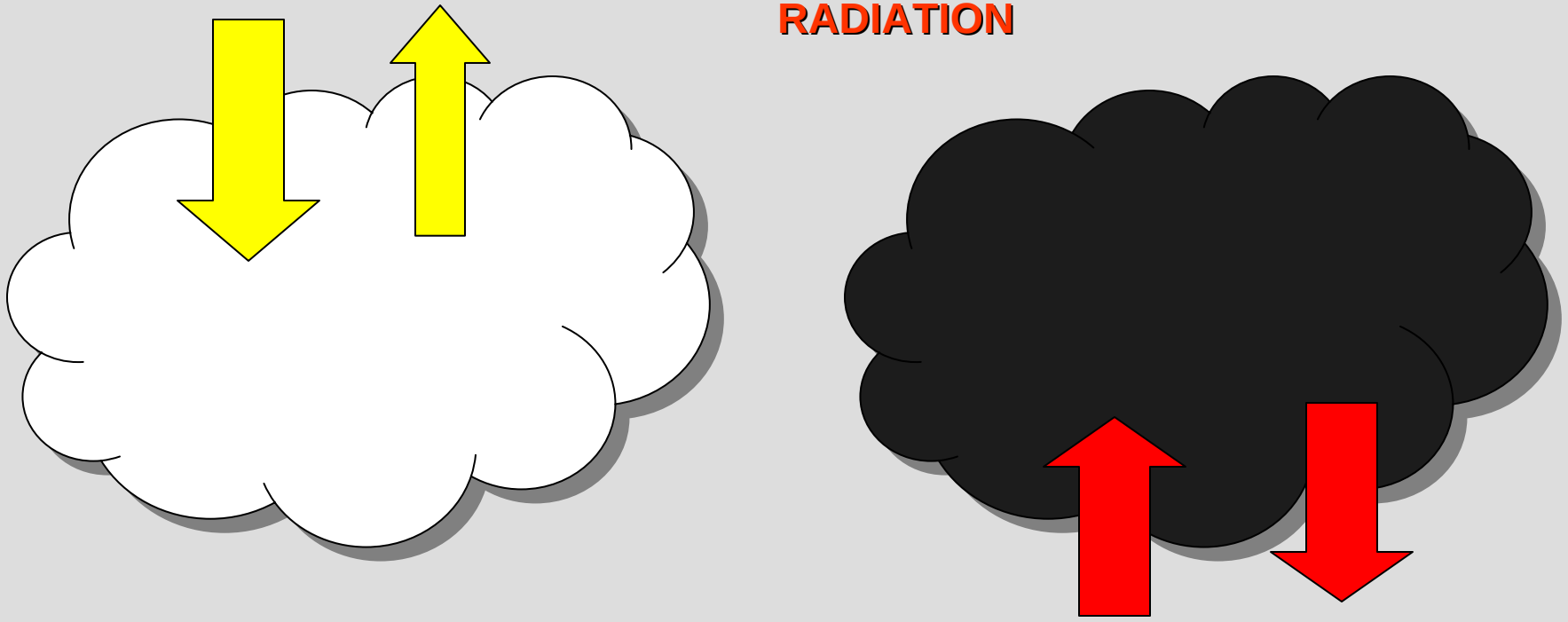
NET ALBEDO OF EARTH = 0.3

Important Aside:
Clouds are a big part of the radiation budget

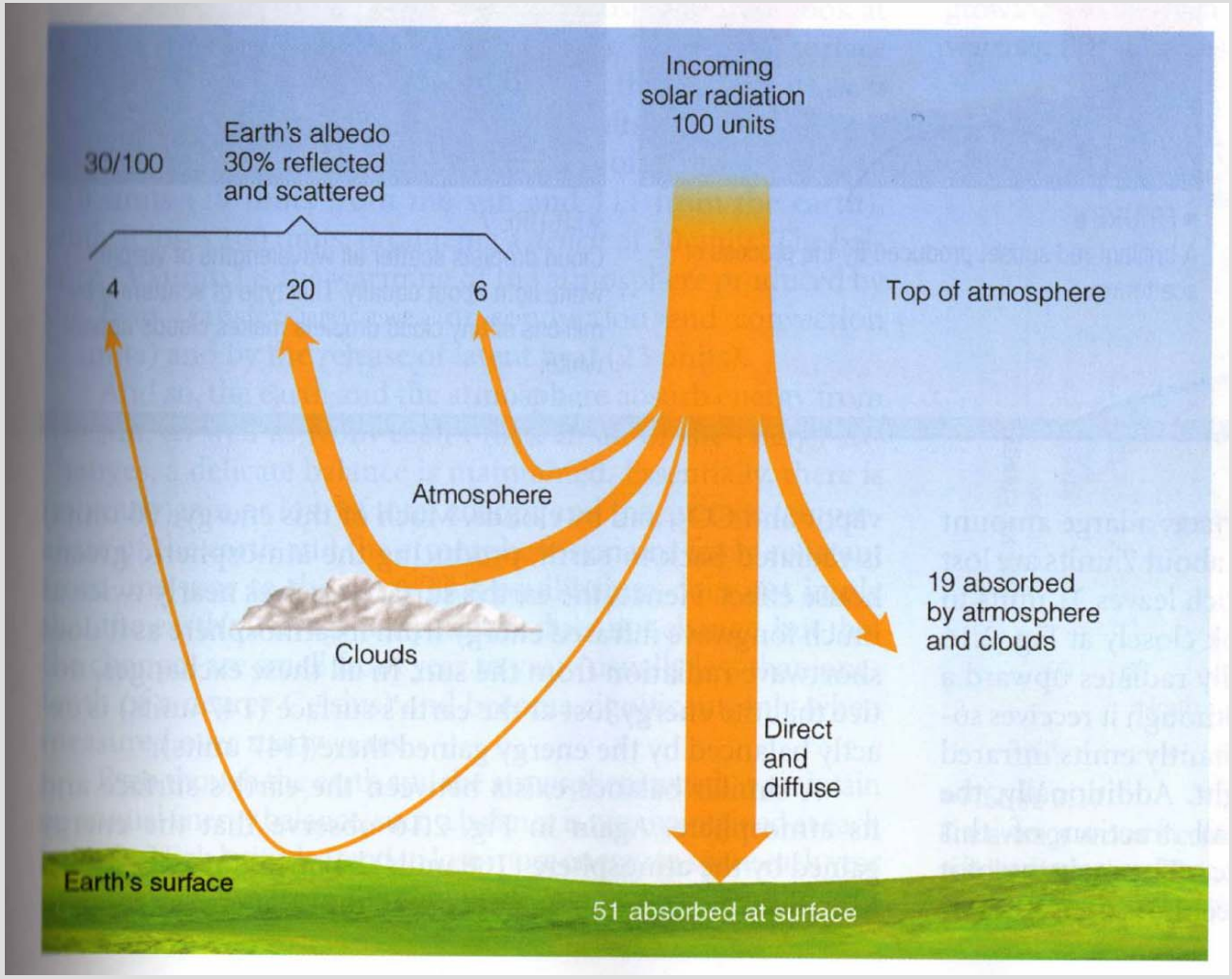
Why is the cloud black on this side?

ABSORPTION AND REFLECTION OF SOLAR RADIATION

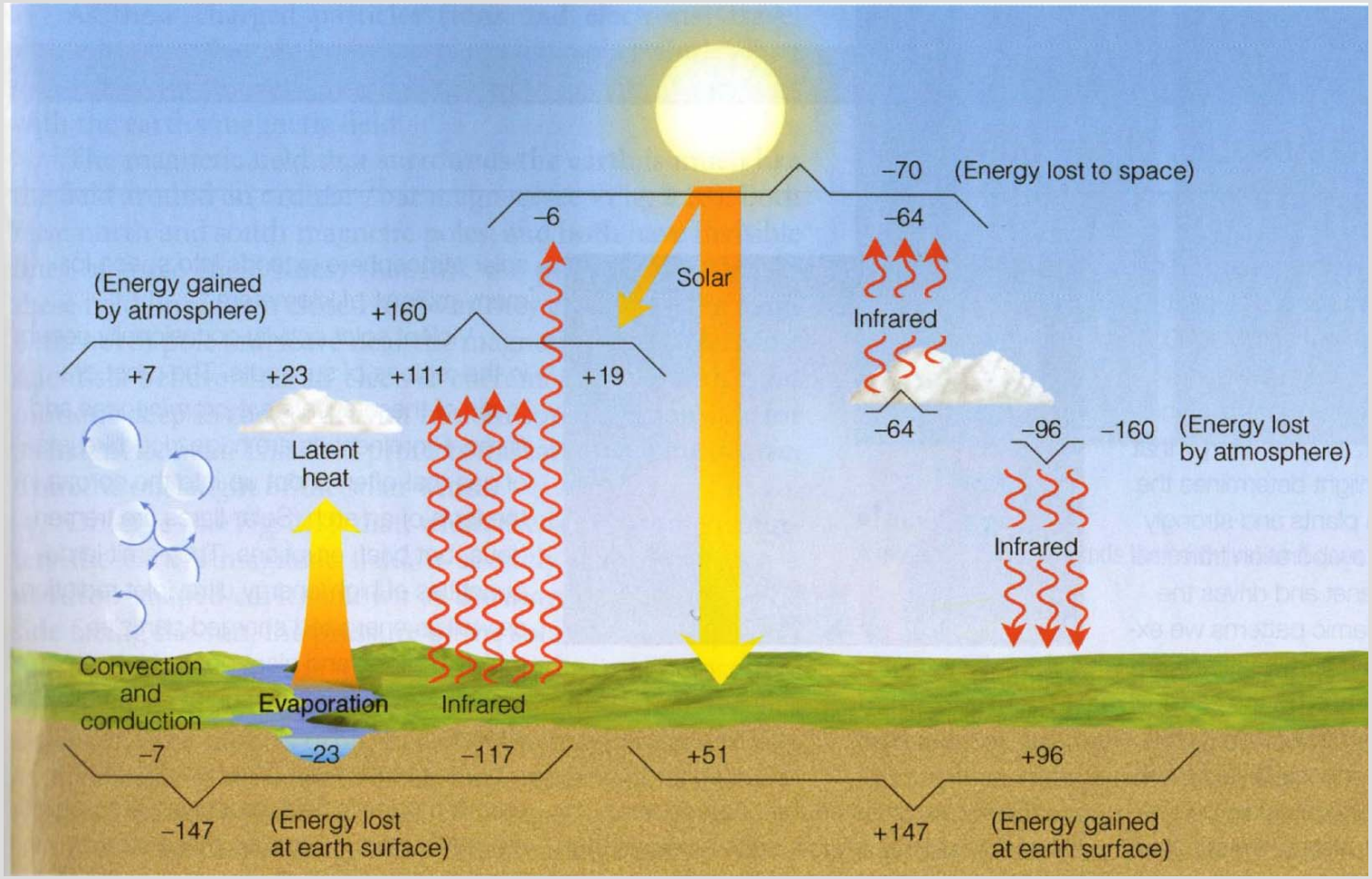
VERY EFFECTIVE ABSORBERS AND EMITTERS OF TERRESTRIAL RADIATION



Energy Budget: Shortwave Radiation



Energy Budget: Longwave radiation and Sensible and Latent Heating



Summary of Lecture 6

Radiation in the atmosphere has four possible fates: *transmitted*, *reflected*, *scattered*, or *absorbed*. A perfect absorber and emitter of radiation is called a *blackbody*.

The atmosphere selectively reflects, scatters and absorbs radiation at certain wavelengths, which depend on the specific gas constituents.

Absorbed radiation increases the internal energy by changes on the molecular and atomic level. Terrestrial radiation is associated with *translational*, *rotational*, and *vibrational* energy transitions on the molecular level. Solar radiation is associated with *electronic* energy transitions on the atomic level.

Greenhouse gases are those which absorb and emit very effectively in the infrared, like water and CO_2. Because of them the atmosphere is very *opaque* to terrestrial radiation and the Earth's surface temperature is maintained. Reviewed the atmospheric energy budget to prove the point.

Though the atmosphere is fairly *transparent* to solar radiation, *scattering* and *reflection* of solar radiation is important. Scattering of visible light is why the sky is blue!

Reading Assignment and Review Questions

Ahrens, Chapter 3, pp. 55-63 (8th ed.)

pp. 57- 65 (9th ed.)