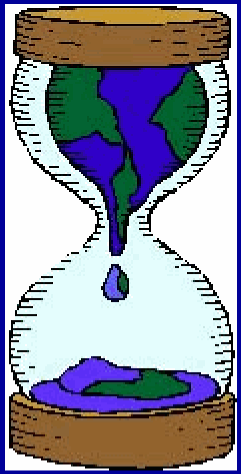
TODAY we'll START with :

THE SUSTAINABILITY SEGMENT

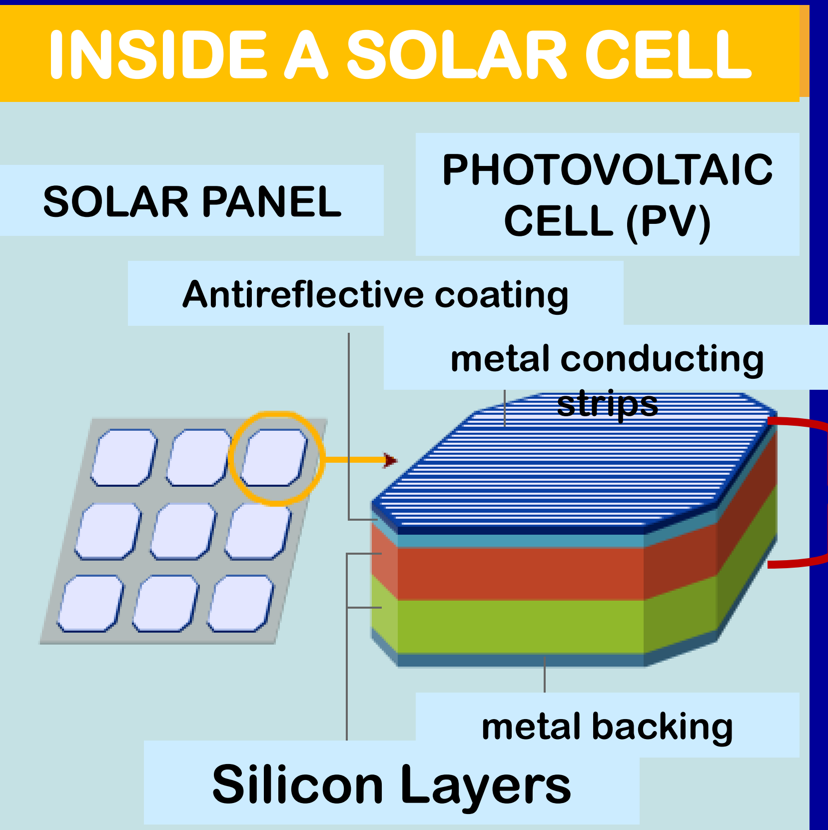


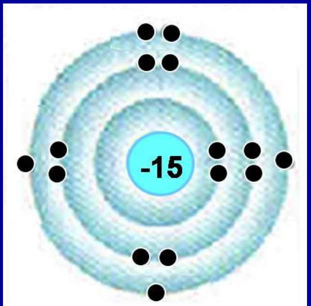
The next segment of:

"SAVED BY THE SUN"

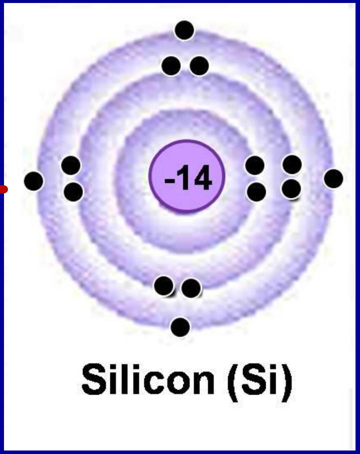
More lecture & clicker points to follow the next 10 minutes of the film . . .

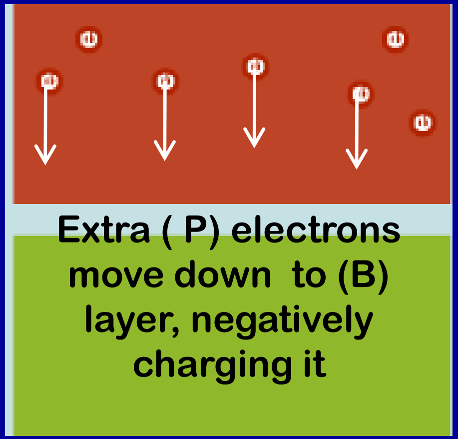
Review of an earlier part of the film:



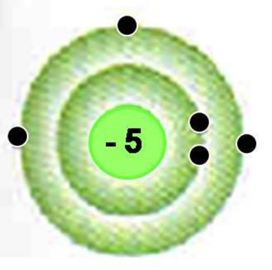


Phosphorus (P) “doped” Si layer





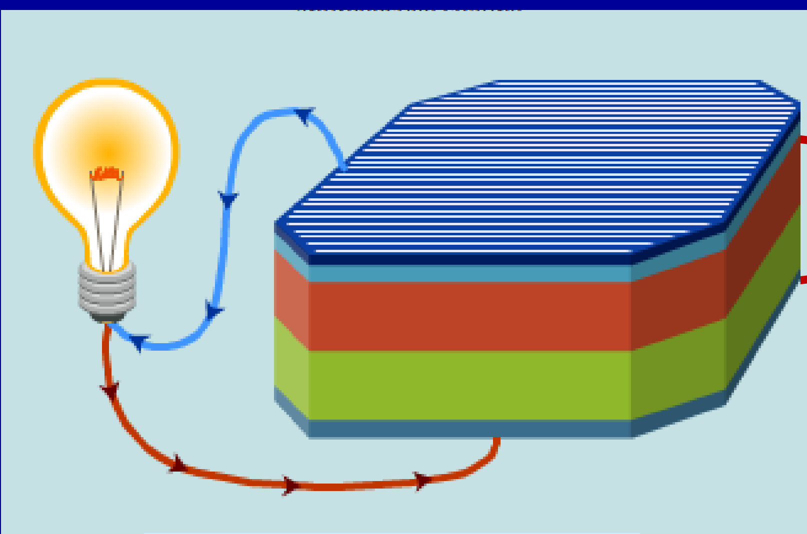
Boron (B) “doped” Si layer

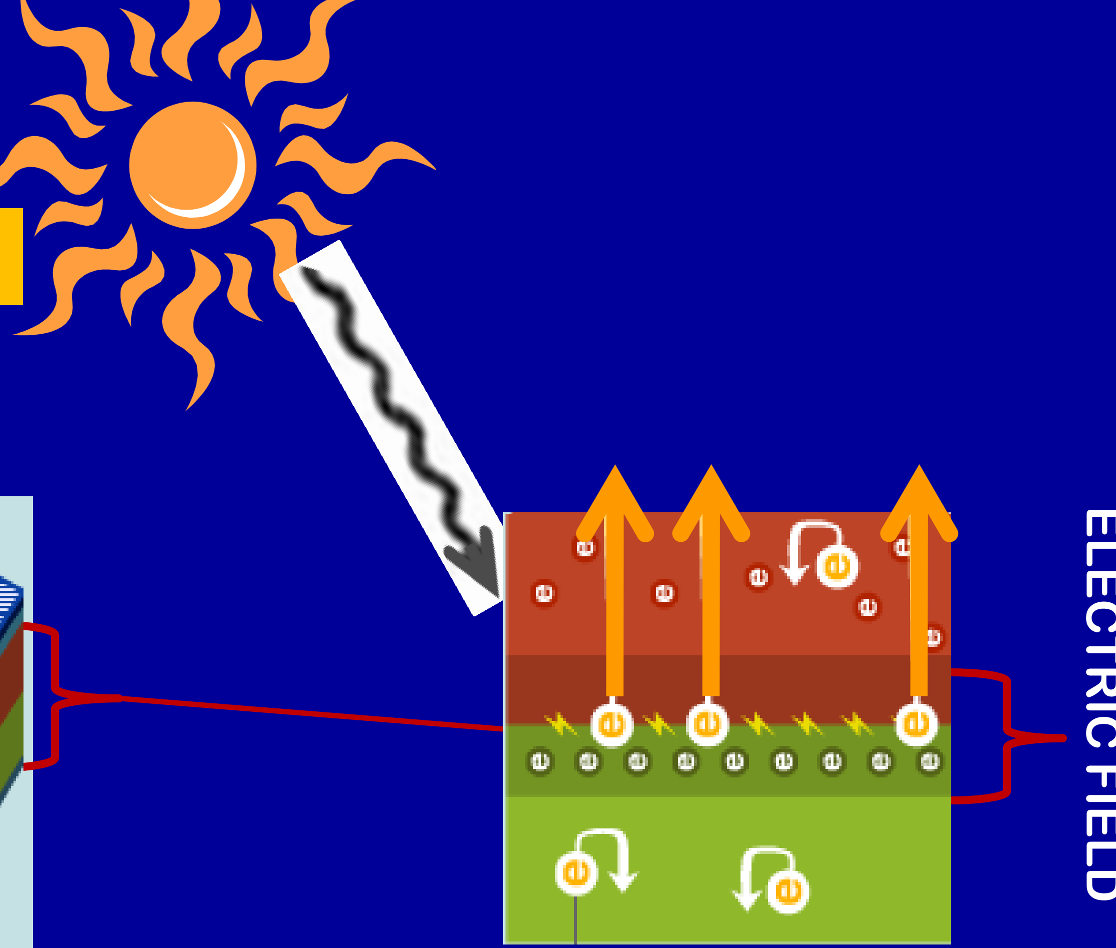


Read this explanation at:

http://www.pbs.org/wgbh/nova/solar/

INSIDE A SOLAR CELL





Now . . . To the film:

GERMANY vs. UNITED STATES
What's happening here??

http://www.pbs.org/wgbh/nova/solar/

Topic #6
THE RADIATION LAWS(cont.):

APPLYING THE RADIATION LAWS

#1Emission of radiation

All substances emit radiation as long as their temperature is above absolute zero

Review pp 33 - 35

#2 Planck Function: $E = hc/\lambda$

"SHORTER wavelengths have HIGHER intensity radiation than LONGER wavelengths"

3 Stefan-Boltzmann Law: $E = \sigma T^4$

"The hotter the body, the (much) greater the amount of energy flux or radiation"

4 Wein's Law: $\lambda_m = a / T$

"The <u>hotter</u> the body, the <u>shorter</u> the wavelength"
The <u>cooler</u> the body, the <u>longer</u> the wavelength"

review

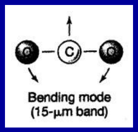
#5: Radiation & distance: inverse-square law

$$E_{flux} \approx (1/d^2)$$

"Energy flux decreases with increasing distance from source such that small changes in distance → large changes in energy received."


#6: Selective emission and absorption

"Some substances, especially gases, emit and absorb radiation at certain wavelengths only due to quantum behavior of electrons & molecules"



review

Electromagnetic energy does not NEED matter to be transferred, but when it DOES **react with matter,** it can be:

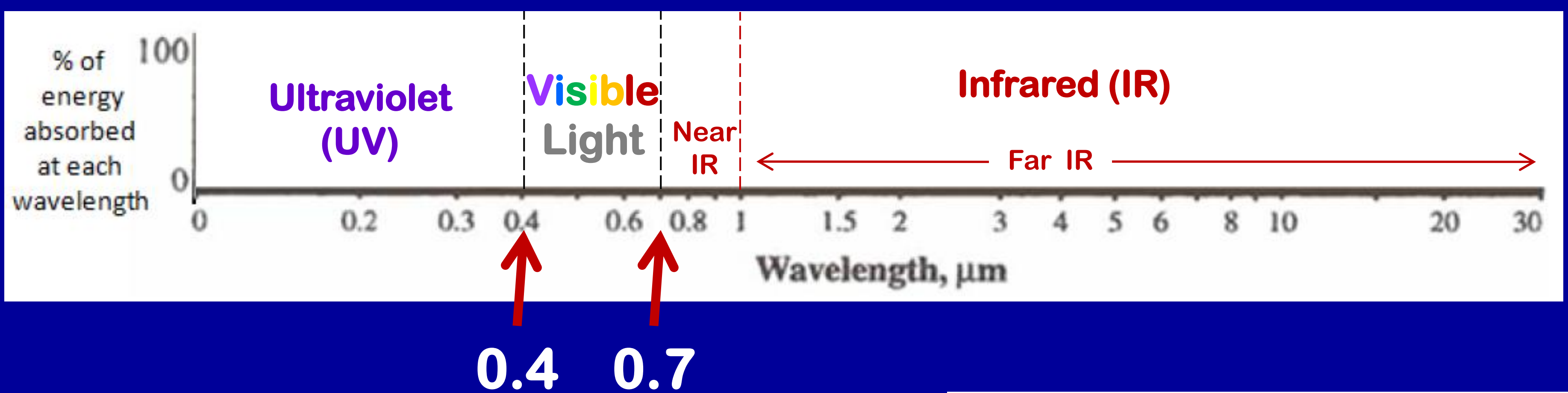
- **ABSORBED (and EMITTED)**
- **TRANSMITTED**
- **SCATTERED**, or
- **REFLECTED . . .**

. . . . through -- or by -- the matter

More about these 4 processes in upcoming lectures . . . .

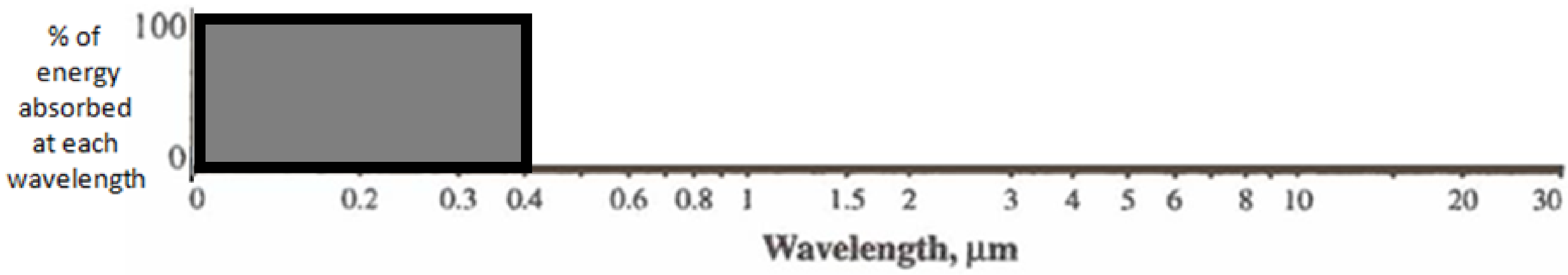
ABSORPTION CURVES

Graph the relationship between <u>wavelength</u> and <u>% of energy absorbed</u> (at a given wavelength)

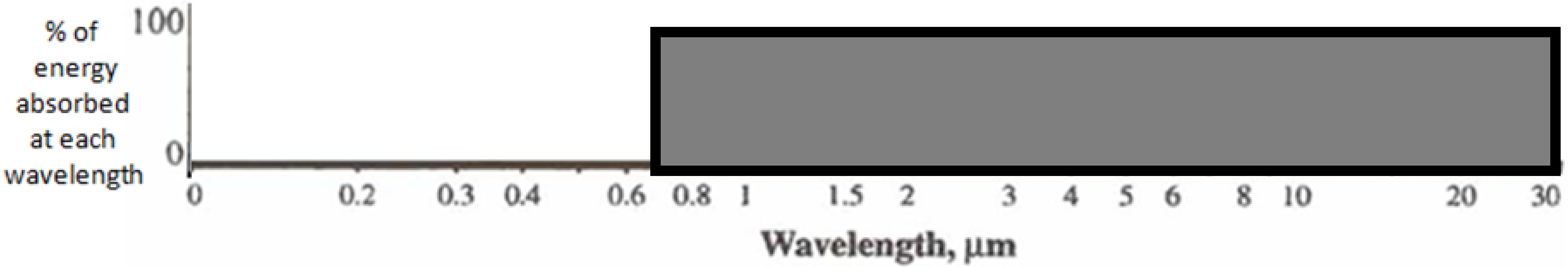


G-1 review p 36

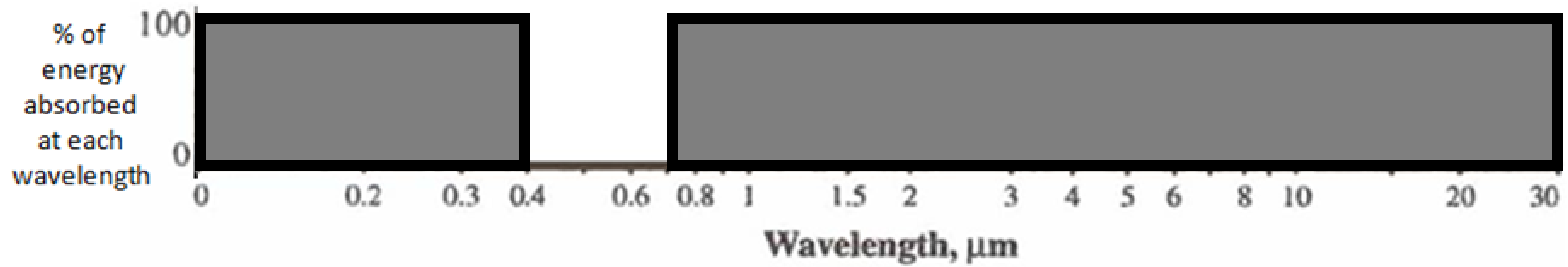
Q1. *Draw an absorption curve for a hypothetical gas that can absorb ALL UV radiation but zero visible light and IR radiation. Then* ***shade in the area under your curve*** *in this and subsequent questions.*



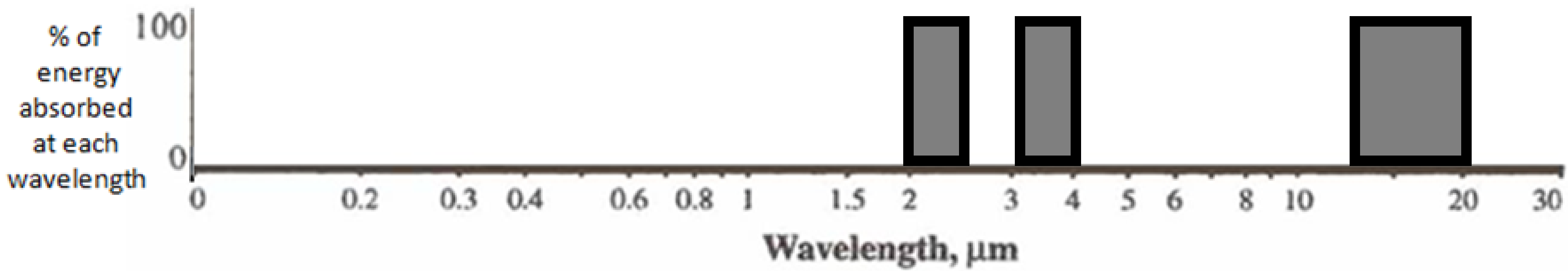
Q2. *Draw an absorption curve for a "perfect" greenhouse gas that absorbs ALL IR radiation, but no visible or UV:*



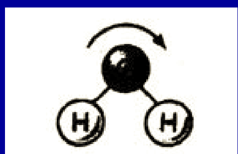
Q3. *Draw an absorption curve for a hypothetical gas that absorbs ALL UV radiation and ALL IR radiation, but leaves a "WINDOW" open for visible light, allowing the visible light wavelengths to pass through the gas unimpeded* ***without*** *being absorbed:*

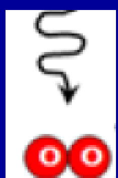


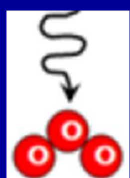
Q4. *Draw an absorption curve for a hypothetical gas that can absorb 100% of the IR radiation in these three wavelength bands*: band from 2 to 2.5 µm band from 3 to 4 µm band from 13 to 20 µm

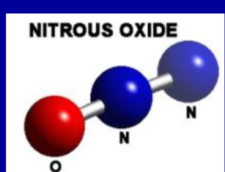


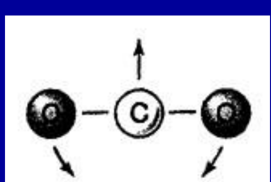
Skip to p 38:











Gas	Primary absorption wavelengths *(in micrometers)*
Water vapor (H_2O)	0.8 1 1.5 2 to 3.5 4 to 7 9 to 10 11 to 20
Molecular oxygen (O_2) and Ozone (O_3)	0.0001 to 0.280 8.5 to 10
Nitrous oxide (N_2O)	4 to 5 7 to 7.5
Carbon dioxide (CO_2)	2 to 2.5 3 to 4 13 to 20

In SGC E-Text Chapt 3:

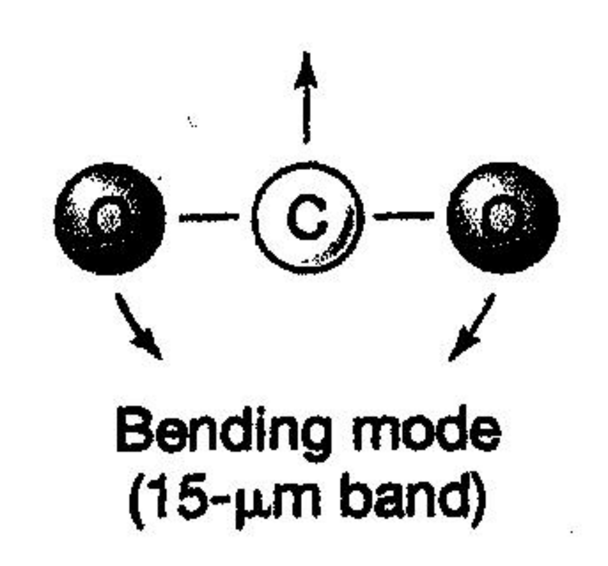


FIGURE 3-14

As a triatomic molecule, one way that CO_2 vibrates is in a "bending mode" that has a frequency that allows CO_2 to absorb IR radiation at a wavelength of about 15 micrometers

What about another triatomic molecule: N_2O (Nitrous oxide)?

DANCE YOUR PhD !!

N_2O acts as a greenhouse gas through the absorption of radiation in 3 vibrational modes.

With one hand as a nitrogen atom, torso as central nitrogen, and the other hand as an oxygen atom, the dancers exhibit the three specific movements of N_2O's vibrational modes.

http://www.youtube.com/watch?v=L5j6BS3XoLc

☺

The N_2O starts in the soil where it is produced by microbial activity and "moves on up" into the atmosphere.

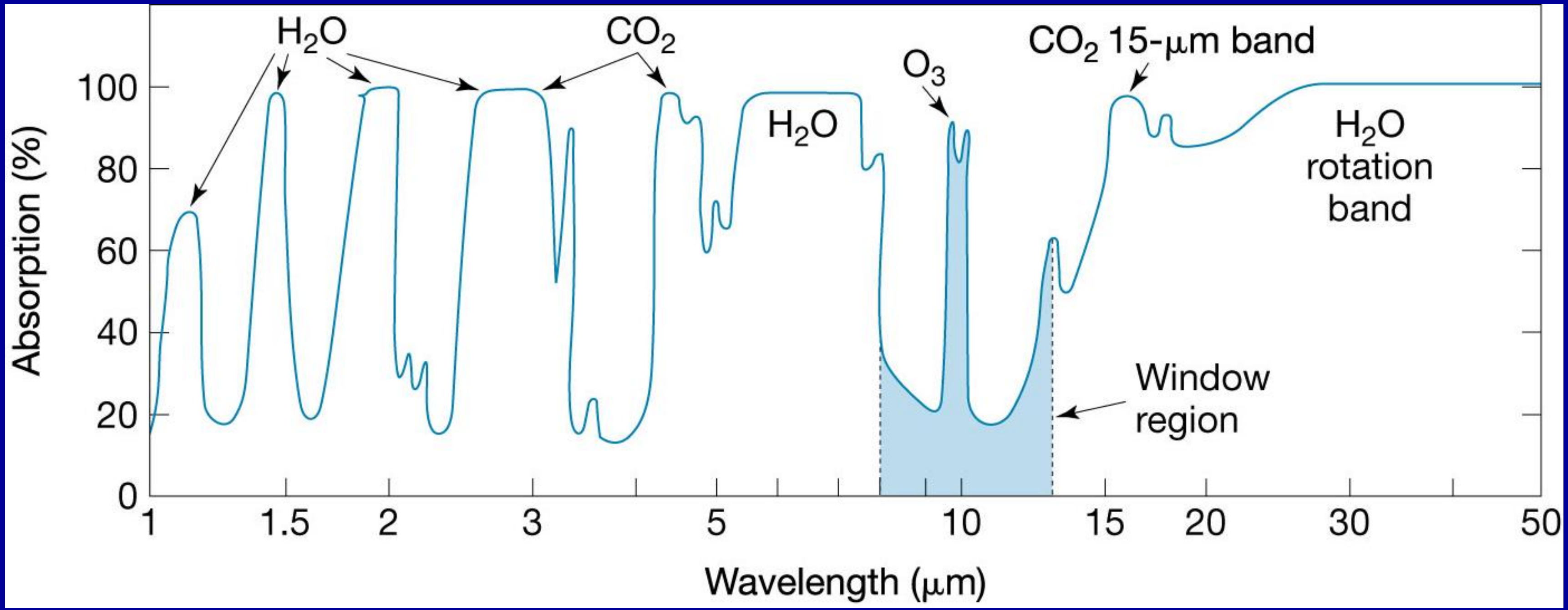
☺

Stepping onto the chairs represents the progression of N_2O to higher levels in the atmosphere (the stratosphere) where it is subject to intense Ultraviolet (UV) radiation from the sun.

This high energy from the bombarding UV radiation is shown in the dancers' high energy, more spastic dancing.

The high intensity UV radiation leads to the destruction of N_2O -- seen as jumping from the chair at the end ➔

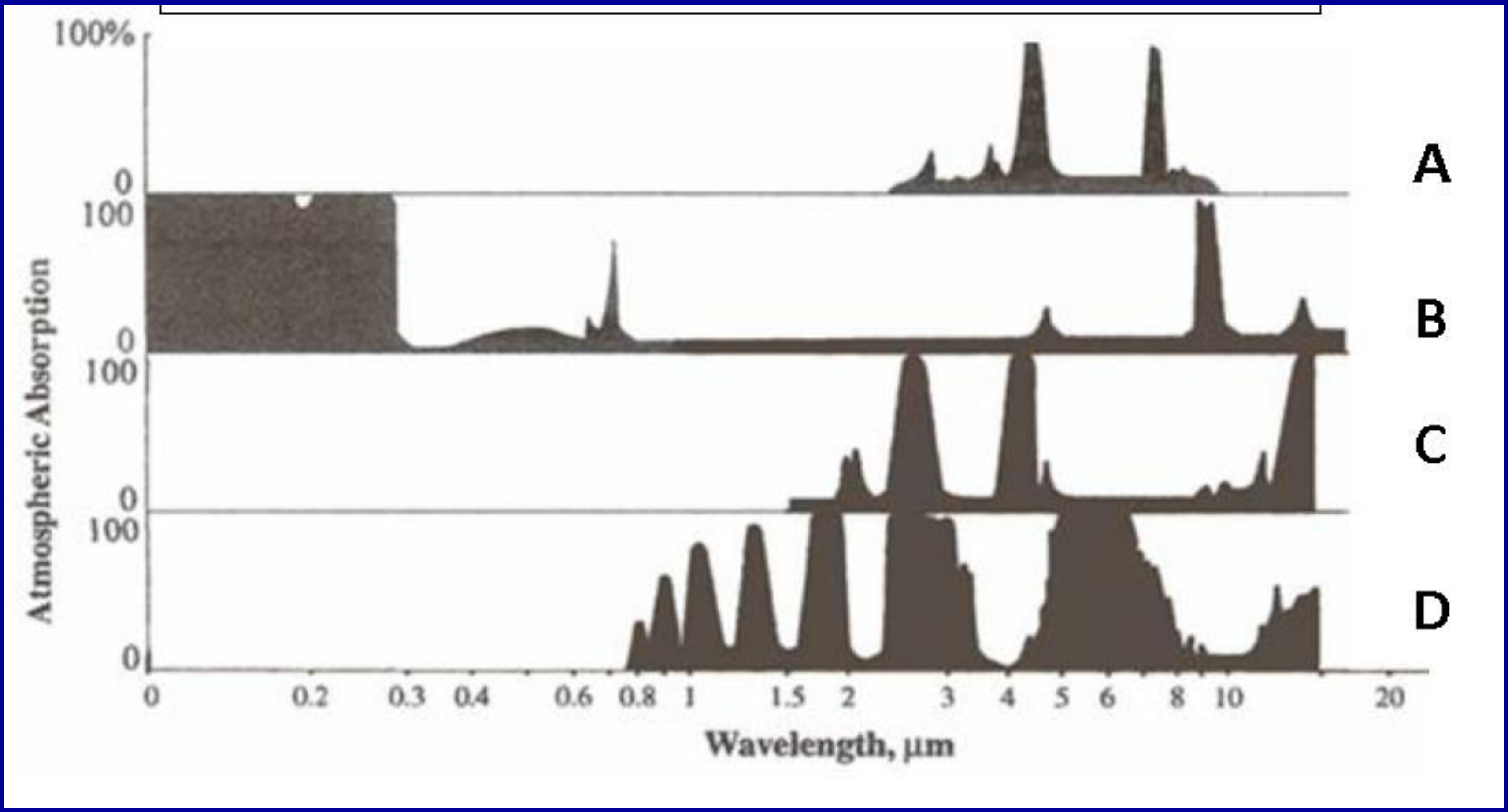
Close up view of absorption of IR wavelengths by different GHG's:



SGC E-Text Fig 3-13

Match the GAS with the Absorption Curve #:

CHOICES: CO_2 H_2O O_2/O_3 N_2O & ??



CLICKERS – Channel 41

CHOICES:

1) CO_2
2) H_2O
3) O_2/O_3
4) N_2O

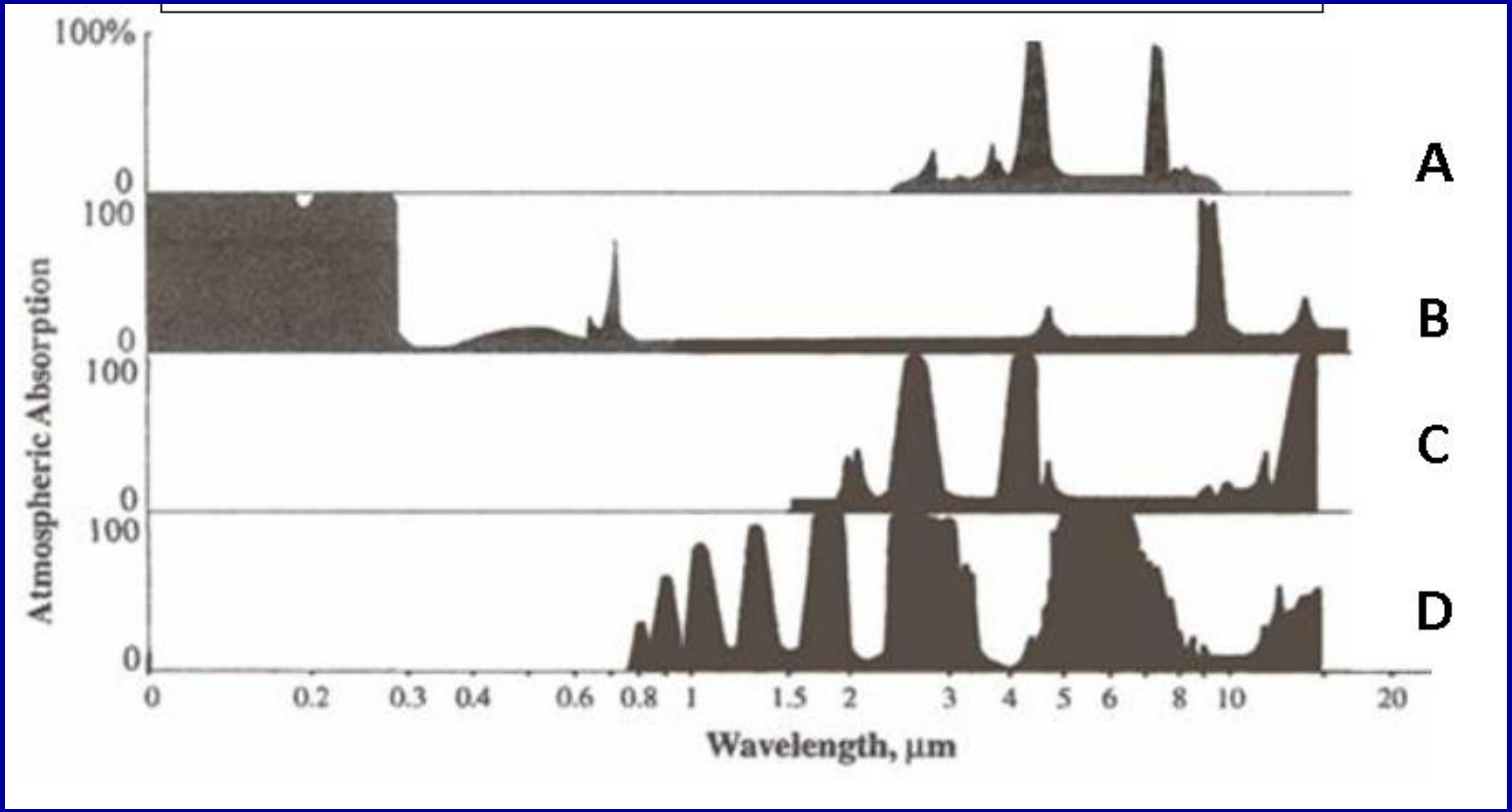
Q. Four separate CLICKER questions:

A =

B =

C =

D =



CHOICES:

1) CO_2
2) H_2O
3) O_2/O_3
4) N_2O

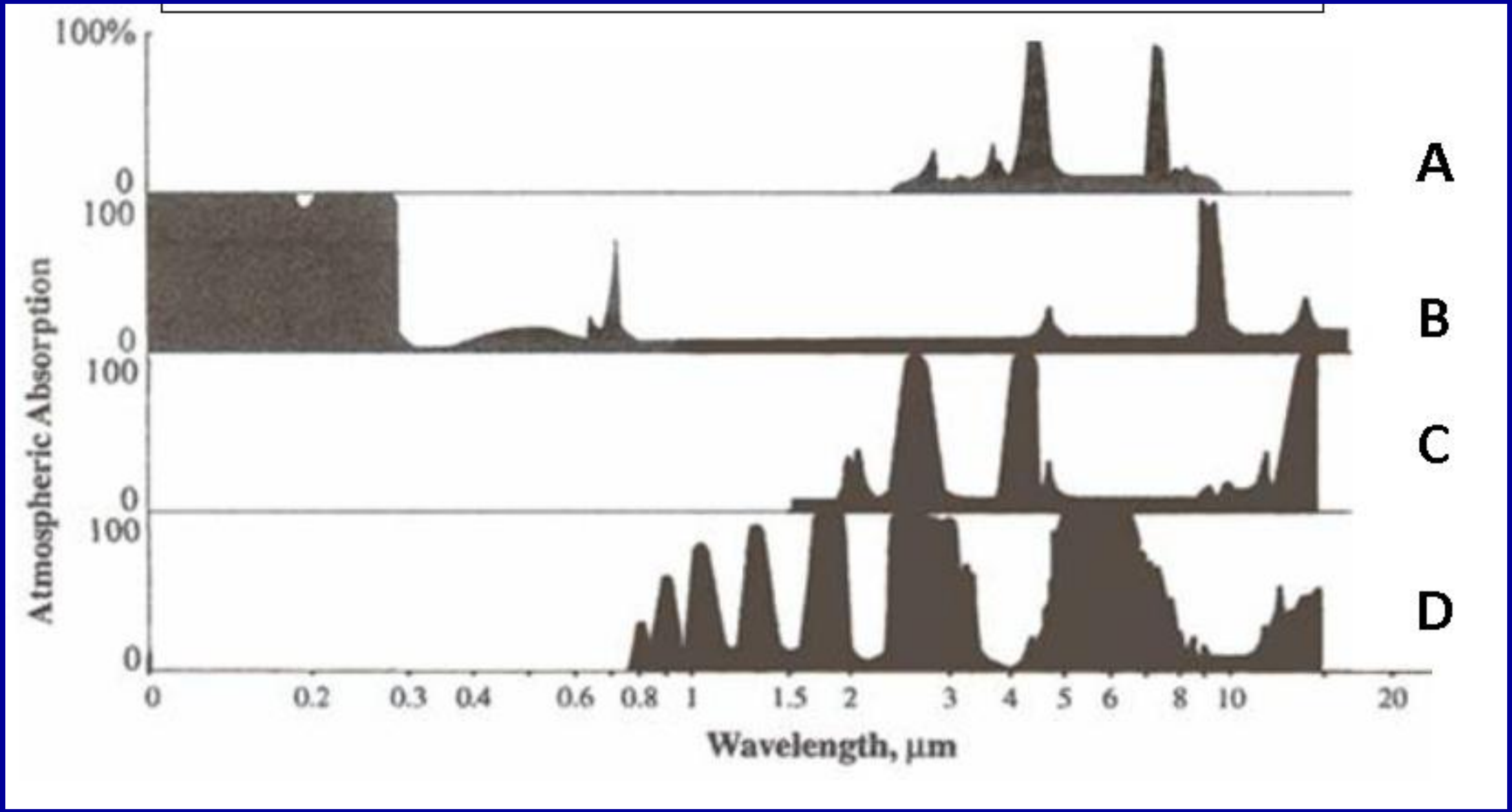
Q. ANSWERS:

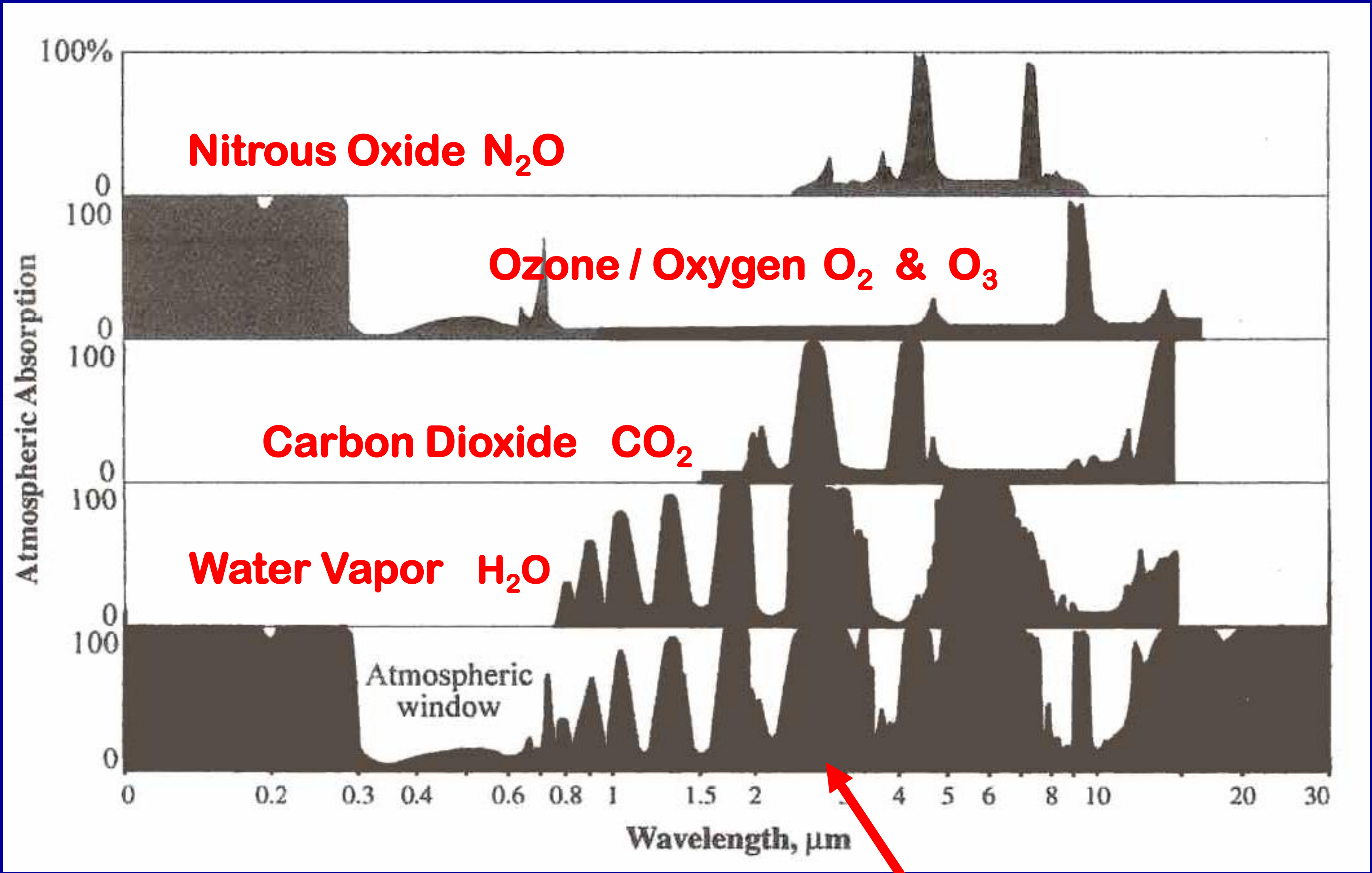
A = 4

B = 3

C = 1

D = 2

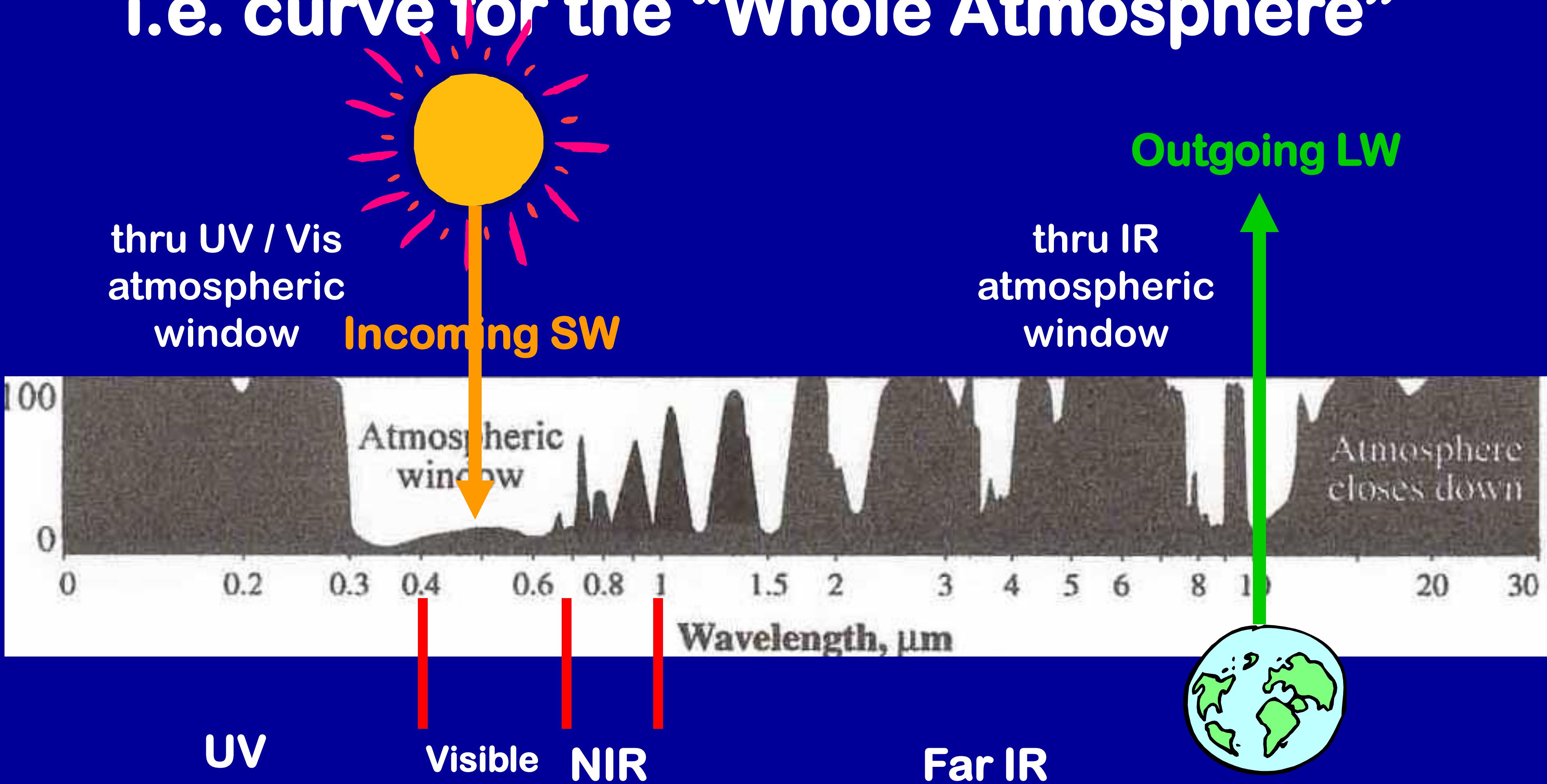




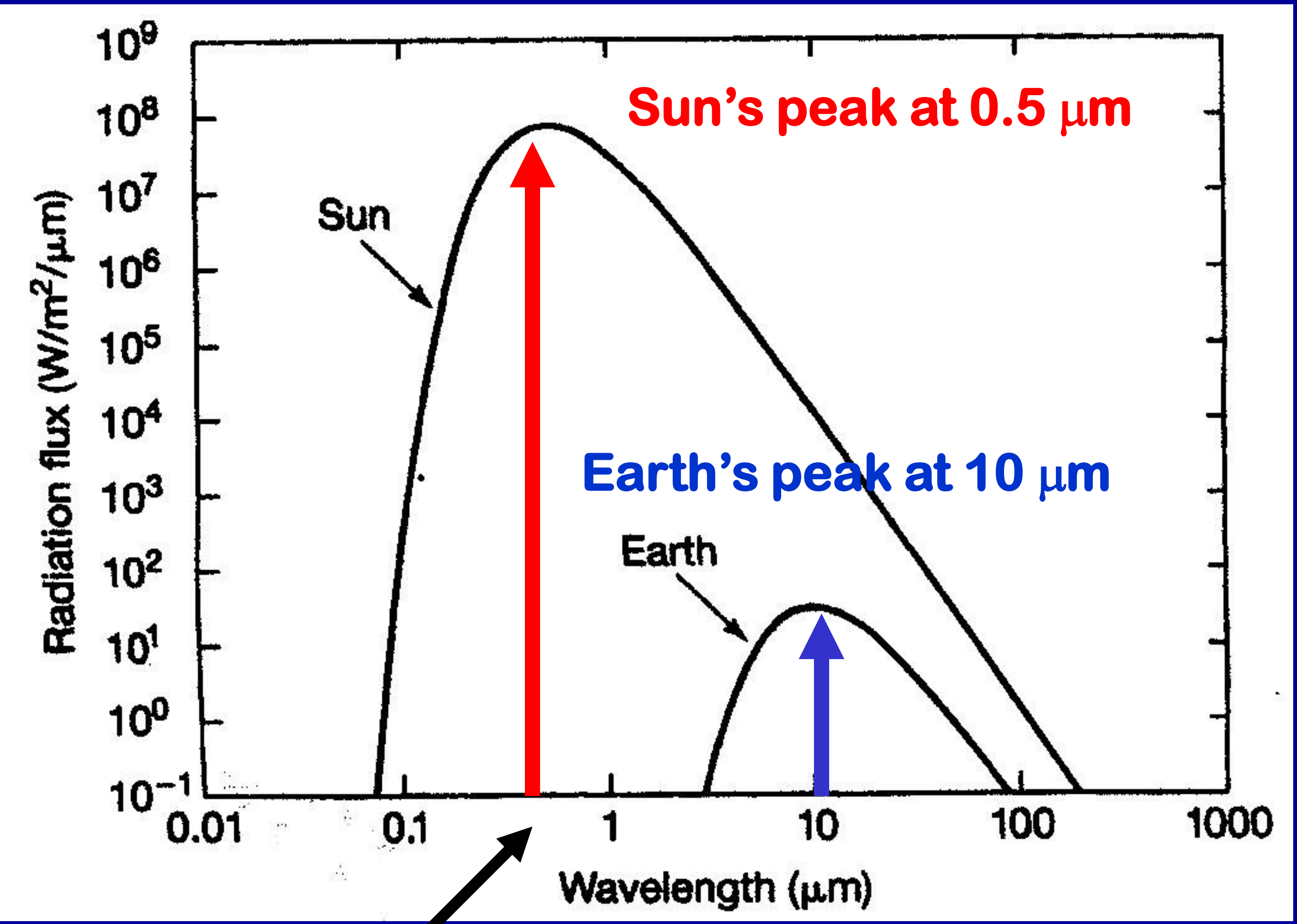
All gases in the atmosphere together!

Absorption by ALL the gases in the atmosphere put together –

i.e. curve for the "Whole Atmosphere"



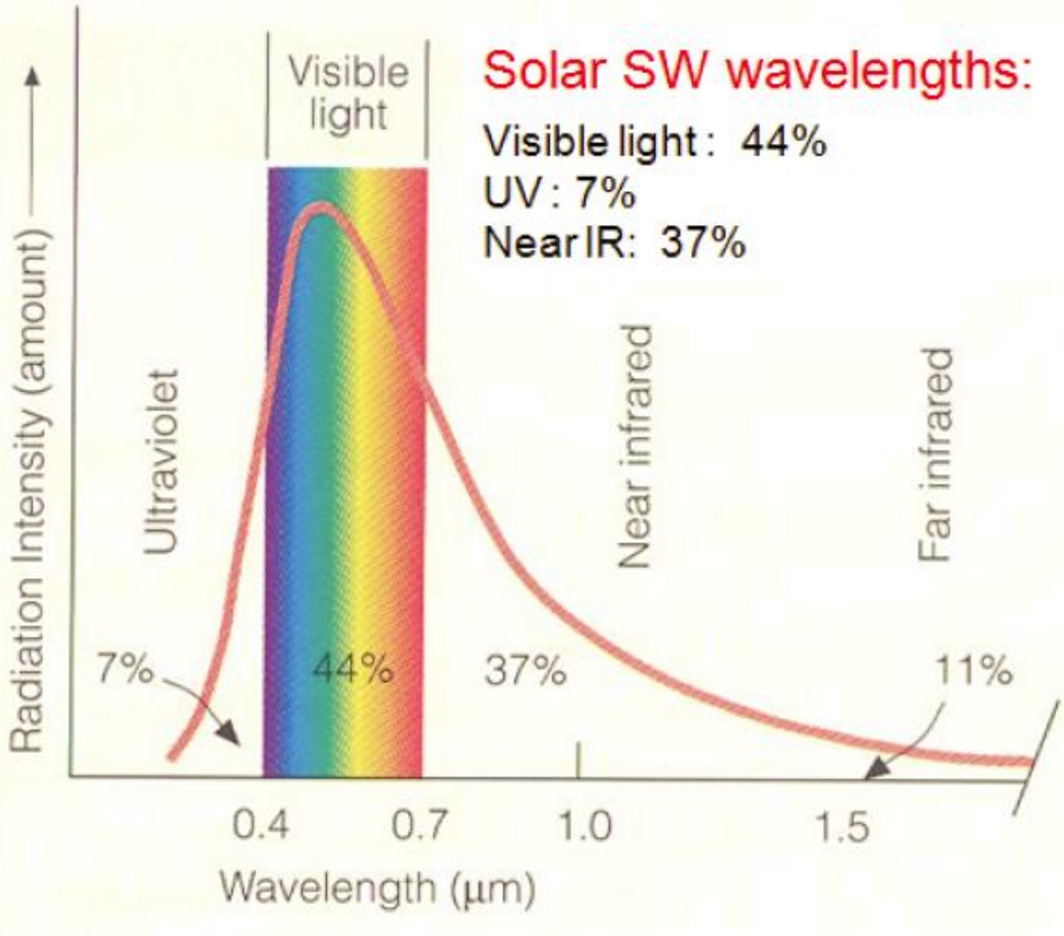
Bottom row p 38



NOTE: this is a logarithmic scale -- values increase exponentially to the right

Shortwave SOLAR radiation
(SW) = UV + VIS + Near IR

TERRESTRIAL radiation
(LW) = Far IR

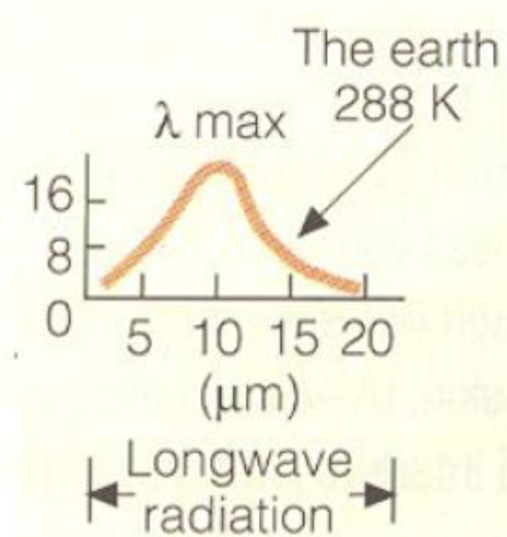


Solar SW wavelengths:

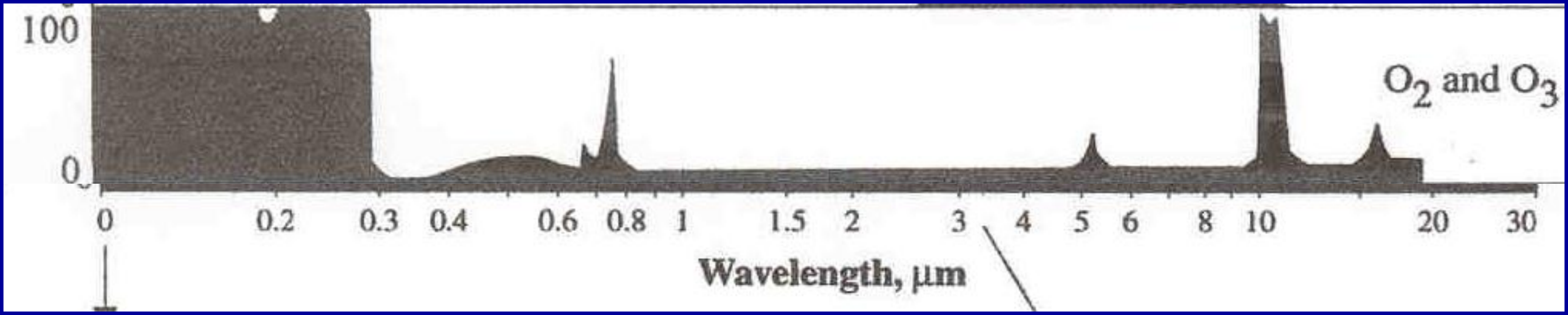
Visible light : 44%
UV : 7%
Near IR: 37%

Terrestrial (Earth) radiation wavelengths:

Far IR, with a maximum at ~ 10 μm



HOW IS OZONE (actually O_3 & O_2) unique???



IMPLICATIONS SUMMARY:

a) The frequency & wavelength of a photon absorbed by a given electron, atom, molecule will be the same as the frequency/wavelength with which it is emitted.

b) O_3 (ozone) selectively absorbs ultraviolet (UV) radiation at wavelengths < ~ 0.3 µm
This is how the ozone layer in the stratosphere protects us from harmful, high energy radiation.

c) GREENHOUSE GASES both absorb and emit electromagnetic radiation in the infrared (IR) part of the spectrum – once IR is absorbed by the greenhouse gases in the atmosphere, it can be emitted back to the Earth's surface to heat it all over again!!

This is called the GREENHOUSE EFFECT!

d) The IR absorbed in the atmosphere by the GHG's can also be emitted upward to outer space, where it will be lost from the Earth-Atmosphere system altogether.

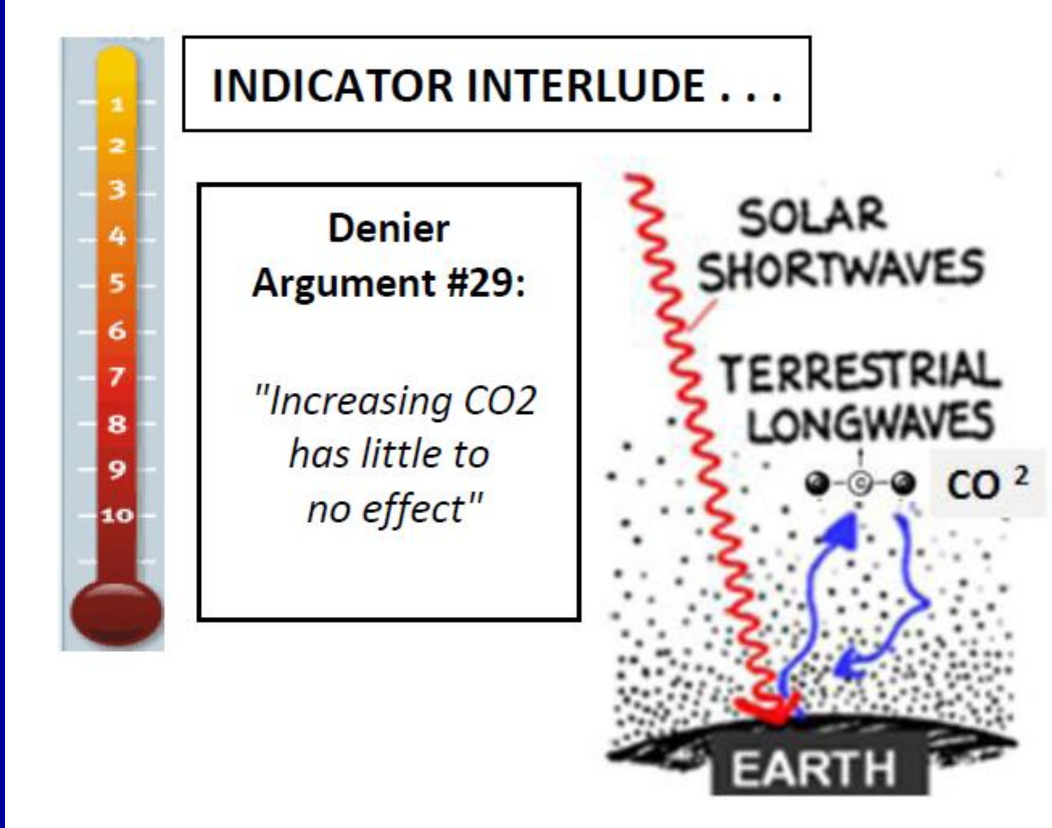
e) CO_2 is a triatomic molecule, and one way that CO_2 vibrates is in a "bending mode" that has a frequency that allows CO_2 to absorb IR radiation at wavelengths of 2.5 - 3.0 µm, at ~ 4 µm, and especially at a wavelength of about 15 µm. (the "15 µm CO_2 band")

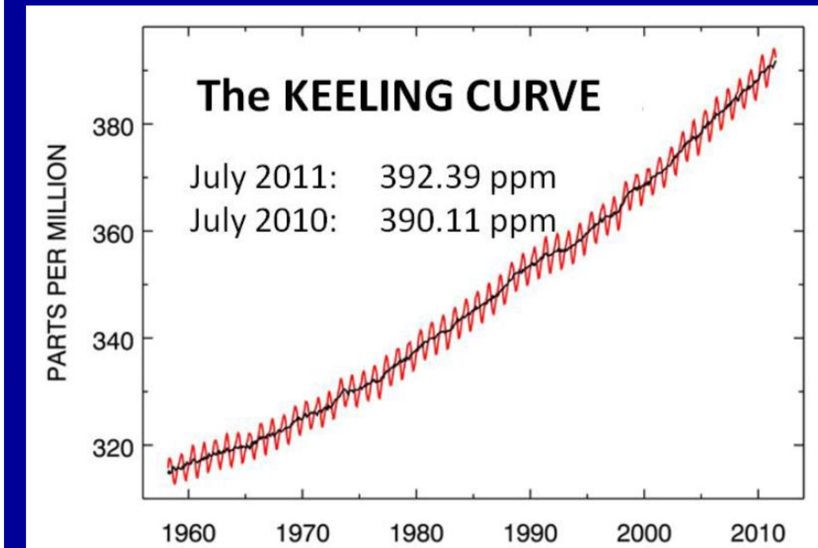
f) Since 15 µm is close to the peak of Earth's outgoing radiation, (10 µm), this absorption band keeps a lot of Earth's longwave radiation from escaping to space.

g) If a gas absorbs radiation of any wavelength, the amount absorbed will be proportional to:

(a) the number of molecules of gas &

(b) the intensity of radiation of that wavelength.





For Wednesday: can you come up with a good response to this argument???

What evidence do we have that increasing CO2 <u>does</u> have a large effect??

A possible hint:

➔**A gas has the <u>most effect</u> if it absorbs in a "window" of wavelengths where the atmosphere is fairly transparent.**