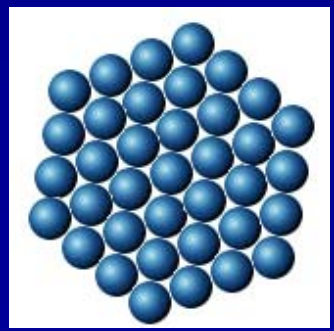
The RADIATION LAWS

Quick Review

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



Remember vibrating molecules . . . .

#2 Planck Function:
Energy & wavelength

$$E = h\,c\,/\,\lambda$$

"SHORTER wavelengths have HIGHER intensity radiation than LONGER wavelengths"

#3 Stefan-Boltzmann Law:
Energy & temperature

$$E = \sigma T^4$$

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

#4 Wein's Law:
temperature & wavelength

$$\lambda_m = a\,/\,T$$

"The hotter the body, the shorter the wavelength"
"The cooler the body, the longer the wavelength"

#5 INVERSE SQUARE LAW =

The amount of radiation passing through a particular unit area is:

INVERSELY PROPORTIONAL
to the
SQUARE of the distance
of that unit area from the source

$(1/d^2)$

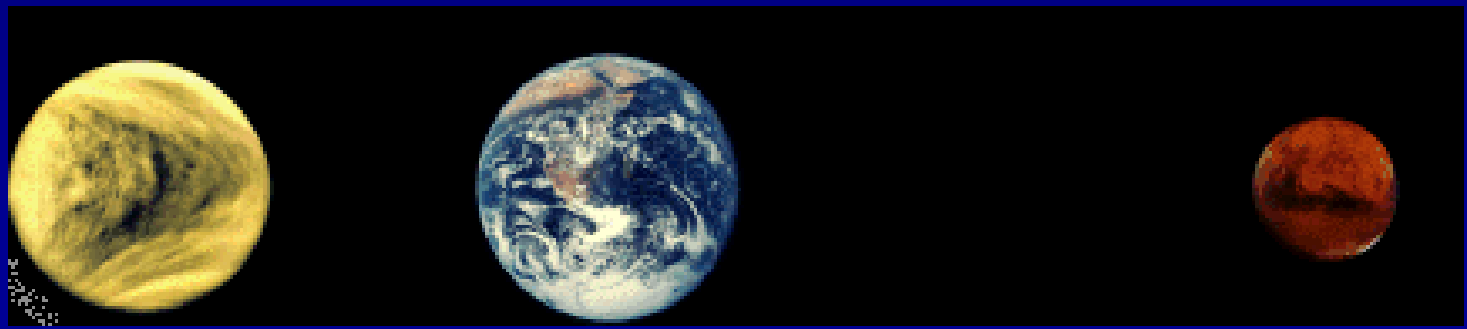
Why is this concept important?

Because it means that relatively SMALL changes in distance from the source of energy (e.g., the Sun)

can result in LARGE changes in the amount of energy received by a planet's surface.

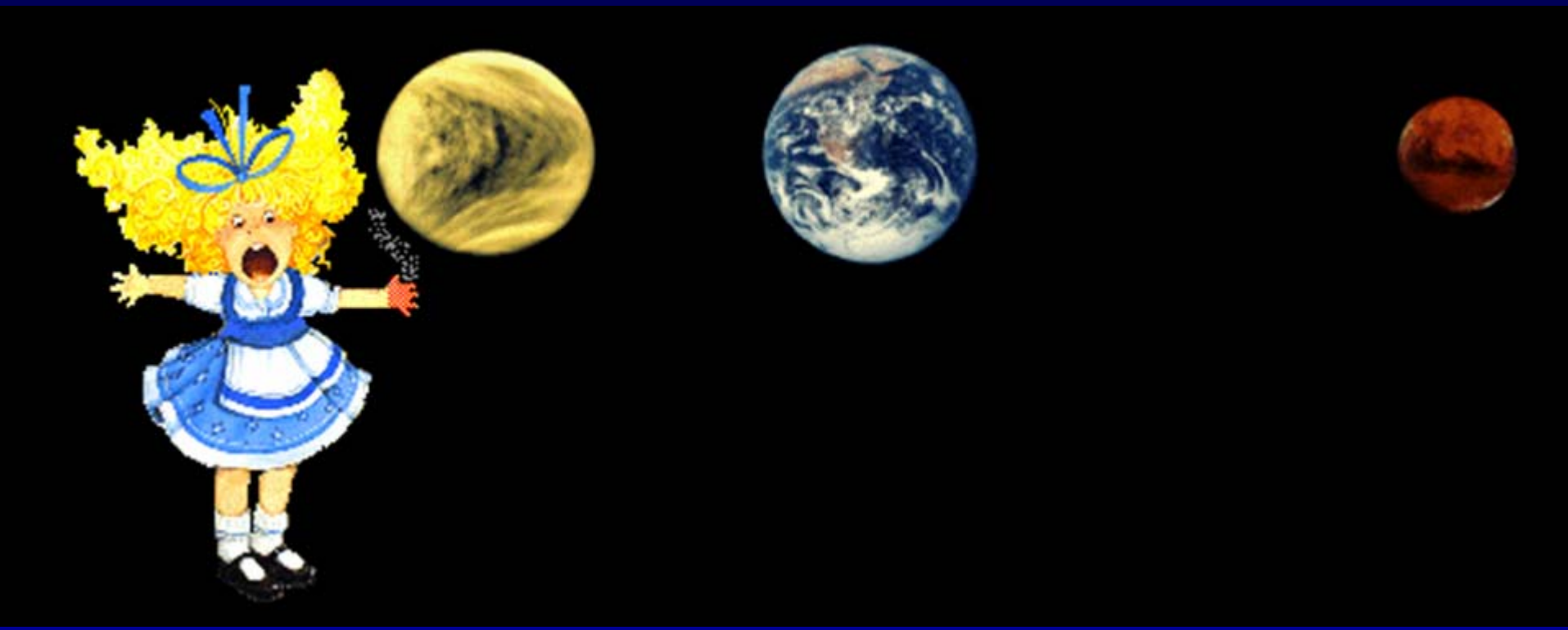
GOLDILOCKS & THE 3 PLANETS

← to Sun



VENUS EARTH MARS

GOLDILOCKS & THE 3 PLANETS



Yikes! Venus is too HOT!

GOLDILOCKS & THE 3 PLANETS

Brrrrrrrrrr, Mars is too COLD!!

GOLDILOCKS & THE 3 PLANETS

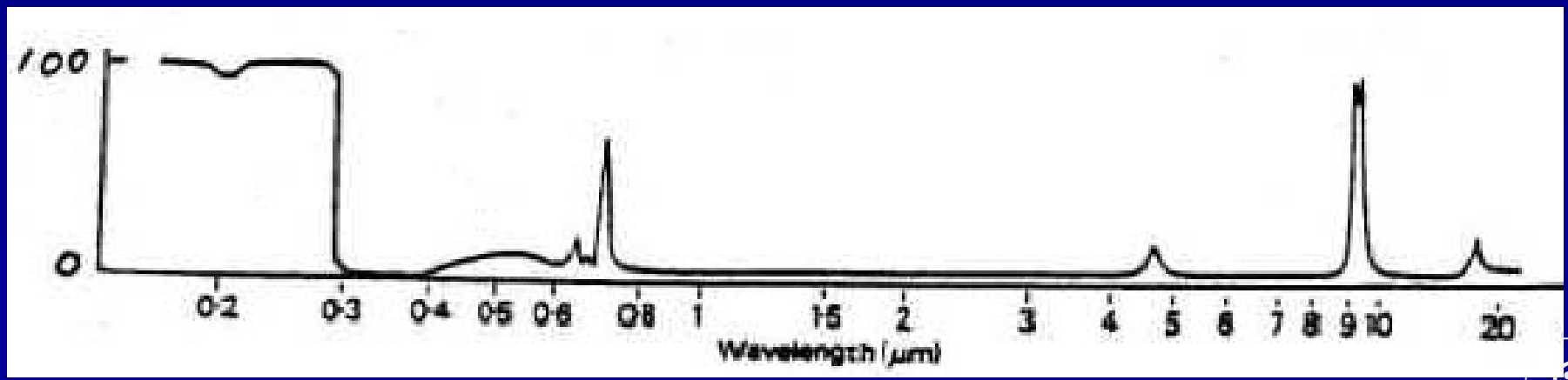
Ahhhh! Earth is JUST RIGHT!

Law # 6:

Different gases absorb & emit radiation at different wavelengths

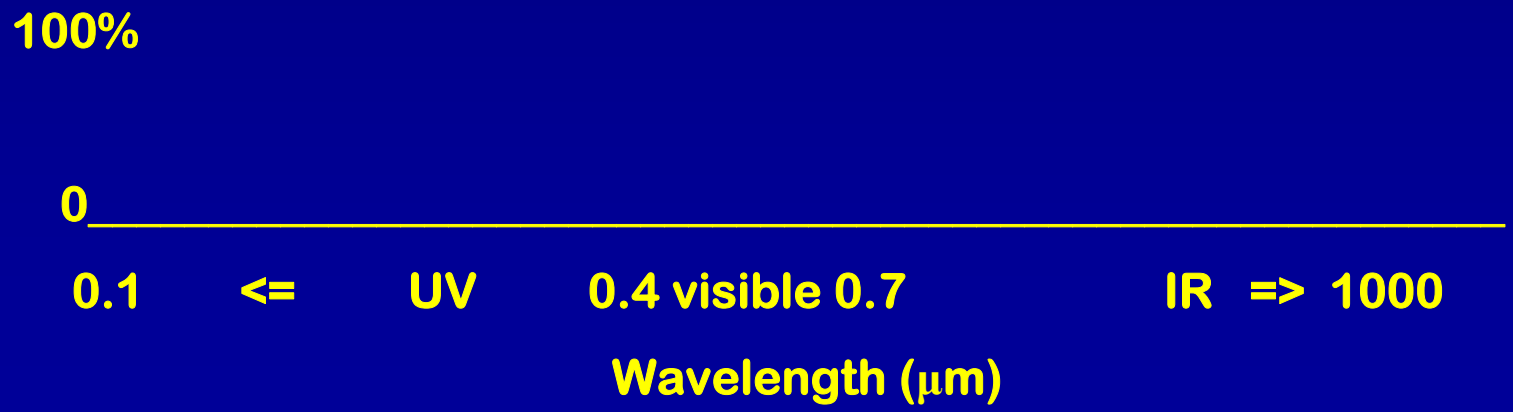
How do we know which wavelengths are absorbed/emitted by different gases?

By looking at the Gas's ABSORPTION CURVE:

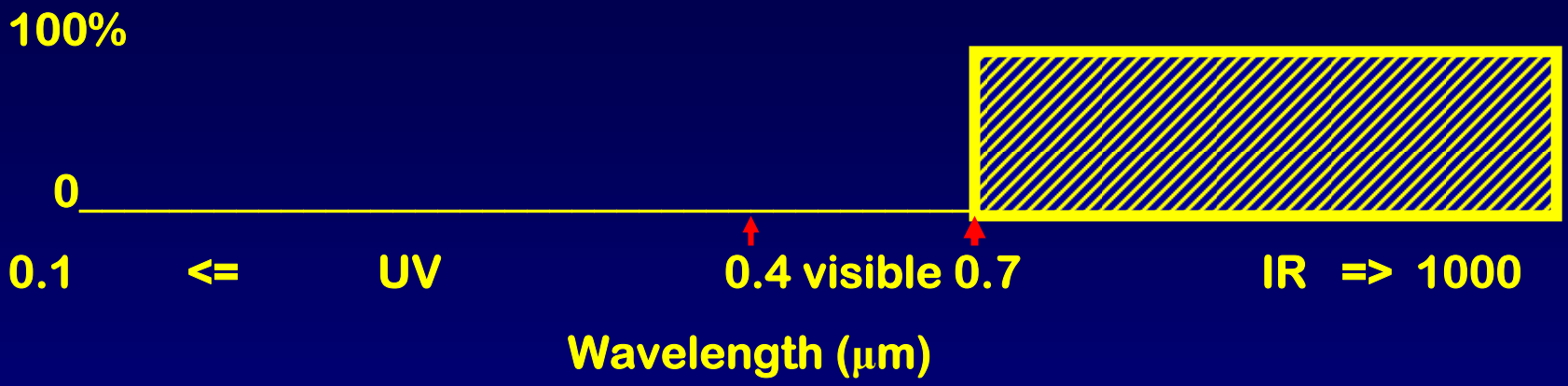


ABSORPTION CURVES

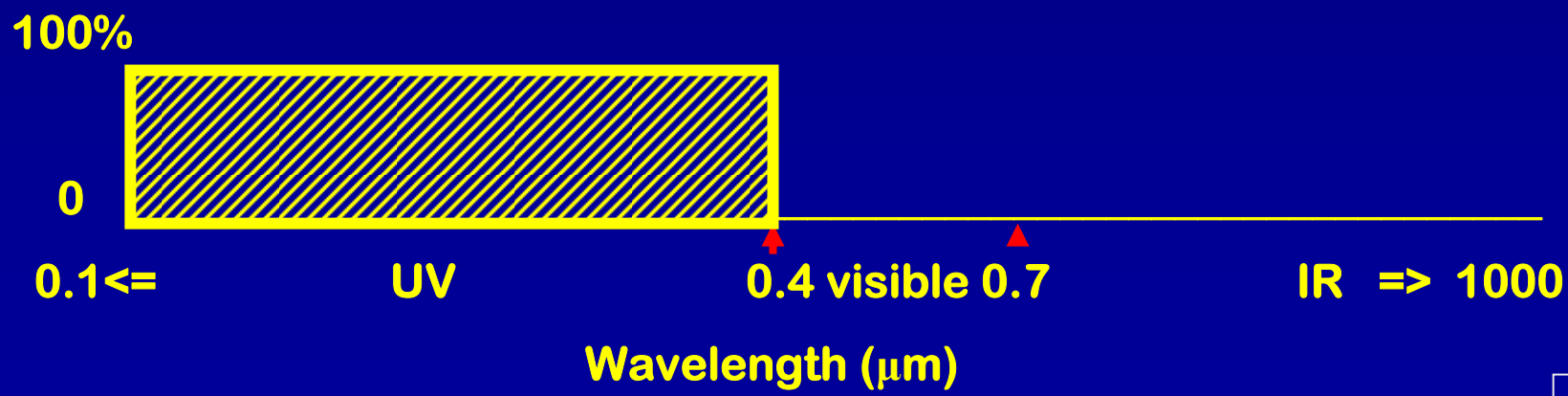
We use an absorption curve to show the relationship between wavelength (along the horizontal axis) and % of energy at a given wavelength that is **absorbed** (vertical axis):



Curve for a hypothetical gas that absorbs/emits ALL IR wavelengths but no visible or UV :

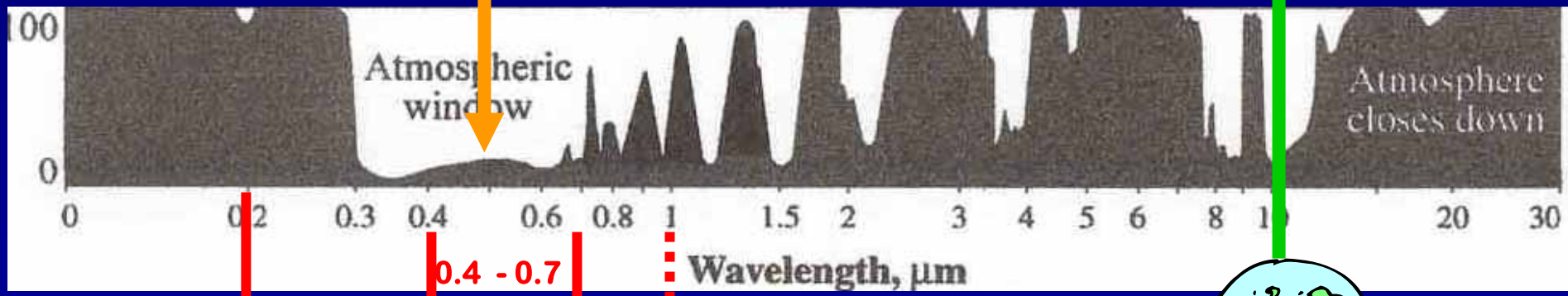


Curve for a hypothetical gas that absorbs/emits ALL UV wavelengths but no visible or IR :



Absorption by ALL the gases in the atmosphere put together –

i.e. curve for the "Whole Atmosphere"



Outgoing LW

thru UV / Vis atmospheric window

Incoming SW

thru IR atmospheric window

0.4 - 0.7

UV

Visible

NIR

Far IR

INFRARED

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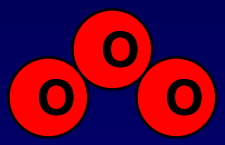
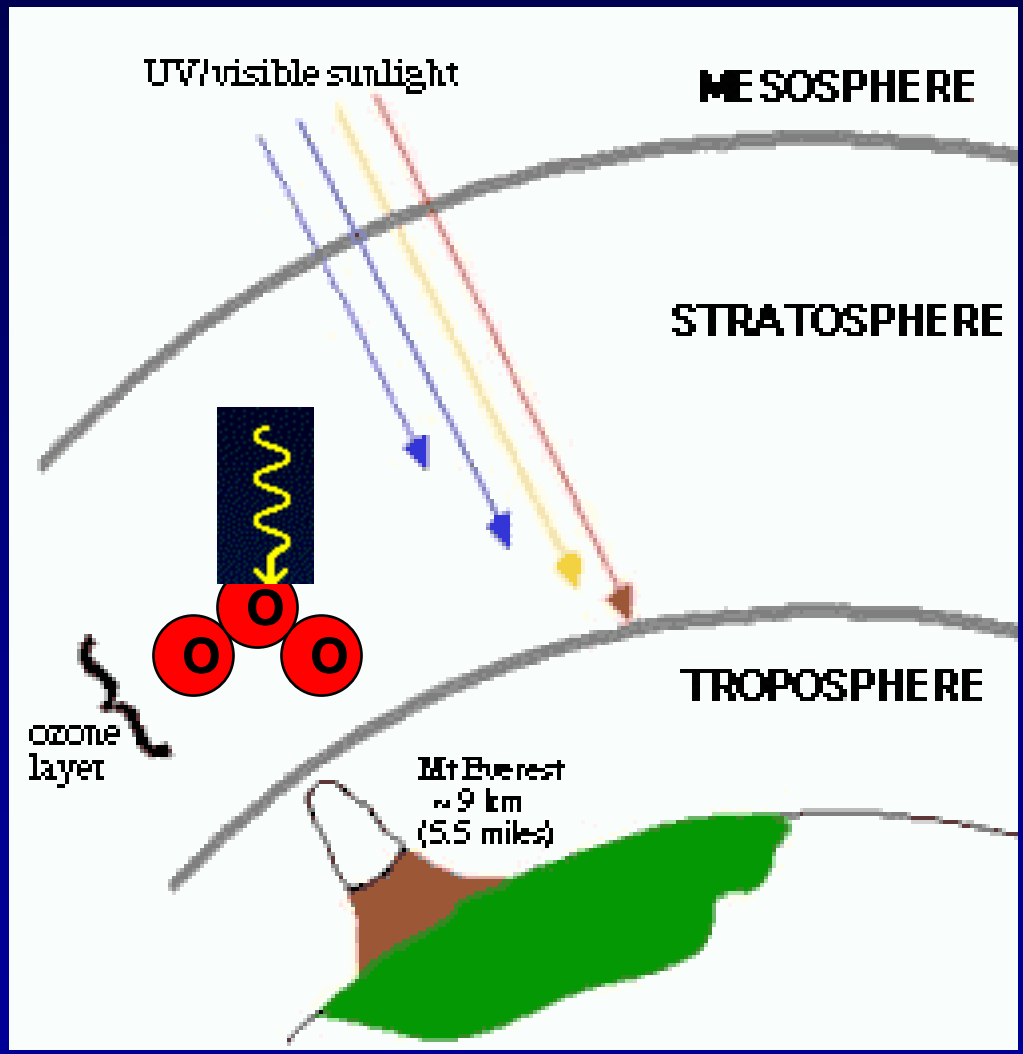
LINK TO GLOBAL CHANGE:



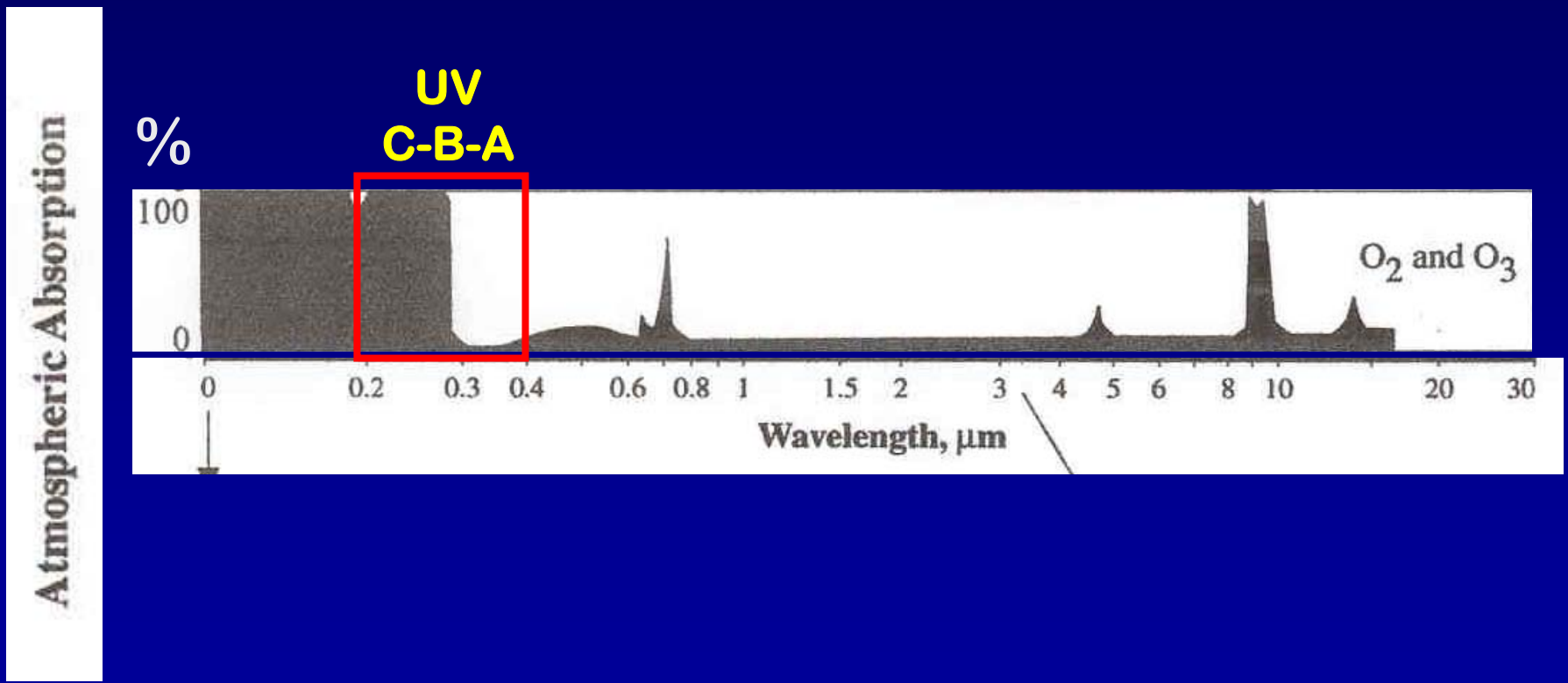
O_3

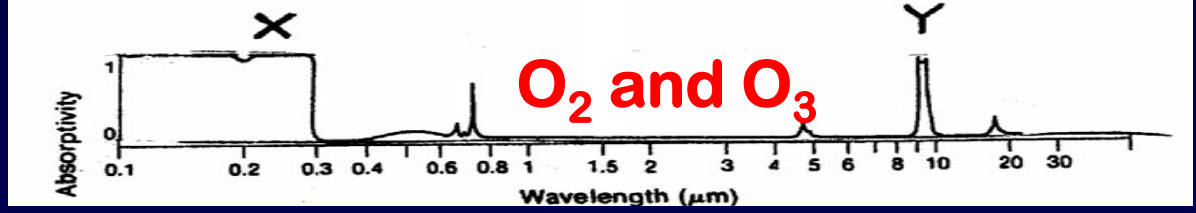
OZONE LAYER



OZONE ABSORPTION CURVE:

The pattern of electromagnetic wavelengths that are absorbed & emitted by O_3 & O_2

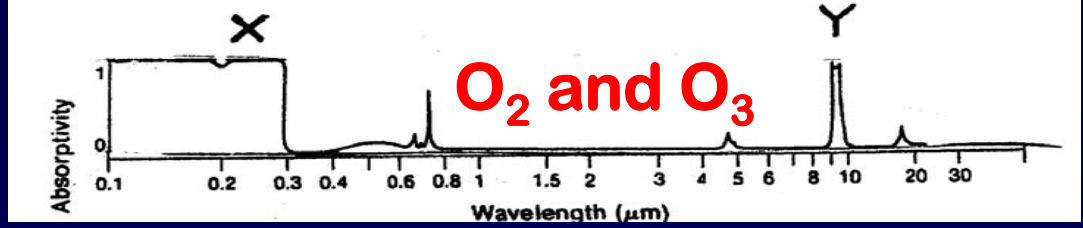




Q "The global change issue usually referred to as the Enhanced Greenhouse Effect is related to ozone due to the part of the absorption curve that is labeled ____."

1. **X** because this part of the curve indicates that ozone *is able to absorb radiation in the ultraviolet part of the spectrum* and hence can be considered one of the greenhouse gases.

2. **Y** because this part of the curve indicates that ozone *is able to absorb some wavelengths of terrestrial longwave radiation (IR)* and hence can be considered one of the greenhouse gases.



The global change issue usually referred to as the "Stratospheric Ozone Depeletion" or "the Ozone Hole" is related to the part of the curve that is labeled ____."

1. **X** because this part of the curve indicates that ozone is able to absorb ***some wavelengths of terrestrial longwave radiation*** which harm the ozone layer.

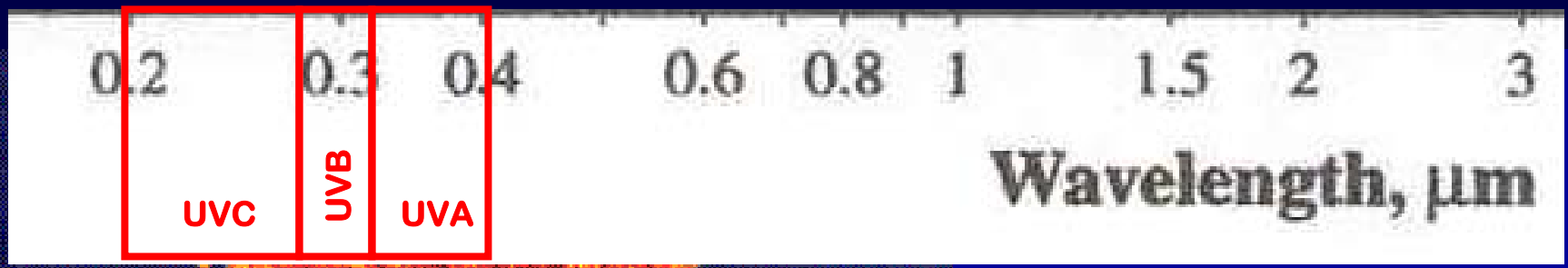
2. **2. X** because this part of the curve indicates that ozone ***is able to absorb*** **harmful solar** ***radiation in the ultraviolet part of the spectrum*** and hence if ozone is depleted, more ultraviolet radiation will reach the Earth's surface.

I-2 ASSIGNMENT

Sun Safety & The Electromagnetic Spectrum

Now posted under assignments
-- due Tue Sep 19th

ASSIGNMENT I-2



UVA = .32 to .4 µm
(once thought to be relatively harmless, BUT causes wrinkles, premature aging and associated sun-related skin damage; new research indicates possible skin cancer link)

UVB = .29 to .32 µm
(harmful, sunburn, skin cancer)

UVC = .20 to .29 µm
(extremely harmful, damages DNA)

Wavelength Range	Name	Biological Effect
.32 to .4 µm (320-400 nm)	**UVA** **(SPF doesn't rate UVA protection!)**	once thought to be relatively harmless, BUT causes wrinkles, premature aging and associated sun-related skin damage; new research indicates possible skin cancer link
.29 to .32 µm (290-320 nm)	**UVB** **(see SPF for protection)**	harmful, causes sunburn, skin cancer, and other disorders
.20 to .29 µm (200 - 290 nm)	**UVC** **(almost completely absorbed by O3)**	extremely harmful, damages DNA -- but almost completely absorbed by ozone

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WAVELENGTH PROTECTION FOR DIFFERENT SUNSCREEN INGREDIENTS:

UV WAVELENGTH BANDS	UVC	UVB	UVA
wavelength band range in nanometers	200-290	290-320	320-400
Padimate O, 290-315 nanometers		(X)	
Benzophenones, 250-350 nanometers	(X)	X	(X)
Octyl methoxycinnamate, 290-320 nanometers		X	
Avobenzone, 320-400 nanometers			X
Oxybenzone 270 to 350 nanometers	(X)	X	(X)
Titanium dioxide, 290-700 nanometers		X	X
Zinc oxide, 290-700 nanometers		X	X
➔NEW! Ecamsule (Mexoryl SX) max absorption 345 nm		X	X

Please add circles

X = over the entire band (X) = protects over part of the band

X = protects over the longer wavelength UVA band, now known to be harmful

Check the active ingredients:

- **titanium dioxide**
- **zinc oxide**
- **avobenzone** (also called butyl methoxydibenzoylmethane)
- **Ecamsule (Mexoryl SX) ← just approved**

are the ONLY ingredients authorized for use in U.S. products that protect you from the entire UVA spectrum.

Therefore, if one of those isn't listed as an active ingredient on the label, the product should not be used for sun protection by anyone!

I-2 ASSIGNMENT

- Background section on UV Radiation
- What is UV Index
- Active ingredients needed: sunscreen, cosmetics, sunglasses
- Product Comparison
- Product Recommendation
- Bonus Point Opportunity

KEY CONCEPTS TO GET OUT OF ALL OF THIS:

1. Solar radiation is mostly in **shortwave (SW) form (visible and UV)**.

Most visible & UV wavelengths are **TRANSMITTED** through the atmosphere but **some (esp. harmful UV) are absorbed** on their way to Earth's surface by O_2 and O_3.

2. Most of the incoming solar energy absorbed by the Earth and the atmosphere is absorbed ***at the EARTH'S SURFACE*** which then radiates IR outward to heat up the atmosphere.

Hence, the ATMOSPHERE is HEATED primarily from BELOW (i.e. from terrestrial radiation)

3. Terrestrial radiation is mostly in **longwave (LW) form (IR).**

Much of the outgoing terrestrial radiation is **ABSORBED by H_2O and CO_2 (and other GH gases)** before it escapes to space, and it is re-**radiated back to the Earth's surface**

This is the
"Greenhouse Effect".

4. The re-radiation of LW (IR) energy to the Earth's surface by GH gases is what keeps the Earth in the "just right" temperature range for water to be present in all 3 phases and just right for US too!

Without the "Greenhouse Effect," the Earth would be too COLD for life as we know it!


Thanks, Greenhouse Effect!