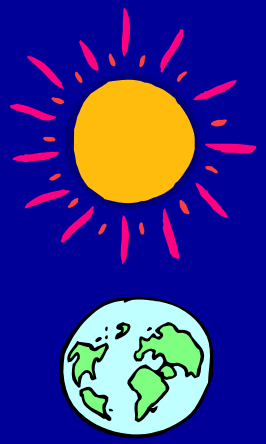
Thursday Sep 18th
ANNOUNCEMENTS

- **TODAY:** Find your **GROUP #** & **SIT in your GROUP'S GENERAL AREA** when you come in
- Grades are completed and will be posted in D2L for **Assignment I-1** and **Test #1** later this afternoon.
- **Your next RQ (RQ-3) will be due next Tuesday Sept 23, 30 minutes before class.**
- The **Self Test for RQ-3** is now posted. RQ-3 will be available to take immediately after class today.

TOPIC # 5
The RADIATION LAWS
PART 2

Class Notes p 29

OBJECTIVES:



To understand more essentials about
Solar radiation
&
Terrestrial radiation

based on the principles of the last 2 **"Radiation Laws."**

THE RADIATION LAWS

Review of
Laws # 2 – 4

REVIEW: Match each equation with the correct phrase below & fill in the name of the LAW:

(a) $E = \sigma T^4$ (b) $E = hc/\lambda$ (c) $\lambda_m = a/T$

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

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

"SHORTER wavelengths have HIGHER intensity radiation than LONGER wavelengths"

Top of p 29

ANSWERS!

(c) $\lambda_m = a / T$ **Wien's Law**

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

(a) $E = \sigma T^4$ **Stefan-Boltzmann Law**

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

(b) $E = h c / \lambda$ **Planck Function**

"SHORTER wavelengths have HIGHER intensity radiation than LONGER wavelengths"

On to the last two laws . . . .

#5 and #6

LAW #5: Radiation & distance -- the inverse-square law

The inverse square law describes:

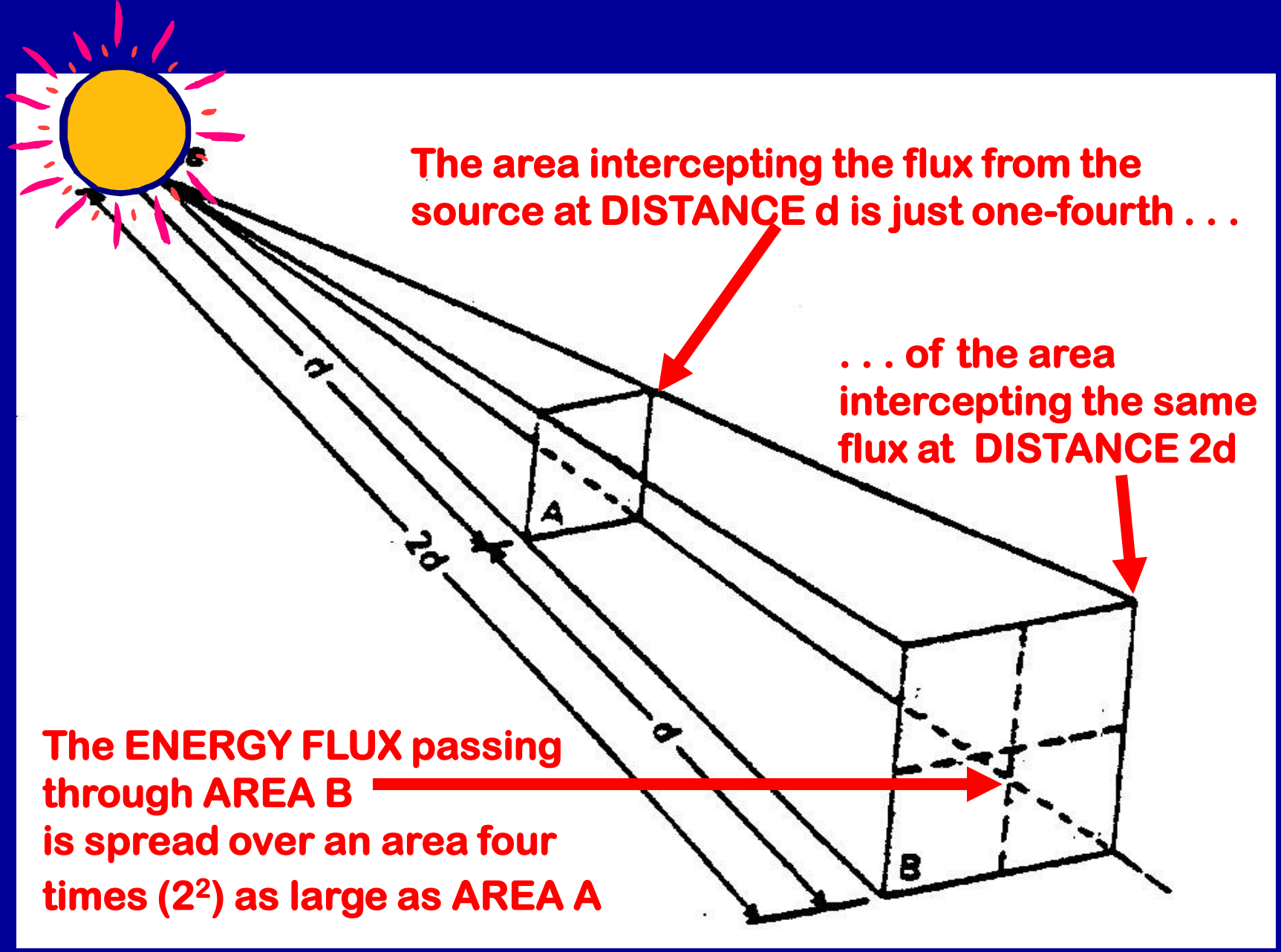
how solar **FLUX of ENERGY** <u>decreases</u>
with **increasing DISTANCE**
from the source of
the radiation flux
i.e., the **Sun**

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

$$(1/d^2)$$


The area intercepting the flux from the source at DISTANCE d is just one-fourth . . .
. . . of the area intercepting the same flux at DISTANCE 2d
d
2d
A
B
The ENERGY FLUX passing through AREA B is spread over an area four times (2^2) as large as AREA A

Inverse-Square Law (easy way):

If we double the distance from the source to the interception point, the intensity of the radiation decreases by a factor of

$(1/2)^2 = ¼$

OR

If we triple the distance from the source to the interception point, the intensity decreases by a factor of

$(1/3)^2 = 1/9$ . . . . etc, etc.

OR

if we reduce the distance from the source to the interception point by a factor of 2 or 3, the intensity of the radiation increases by a factor of

$2^2 = 4$

or

$3^2 = 9$

. . . etc, etc.

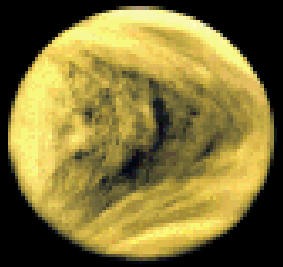
Why is this concept important?

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

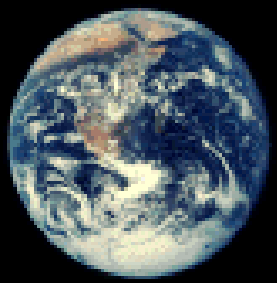
can result in LARGE changes in the amount of energy received by a planet's surface.

GOLDILOCKS & THE 3 PLANETS

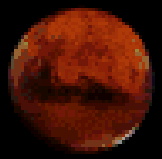
To Sun



VENUS

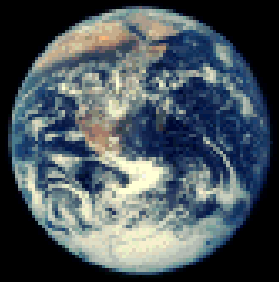


EARTH



MARS

GOLDILOCKS & THE 3 PLANETS

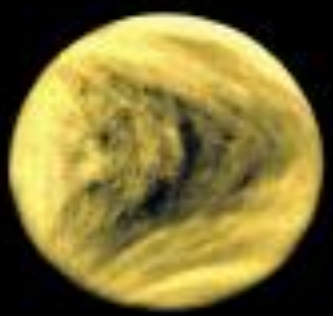


Yikes! Venus is too HOT!

GOLDILOCKS & THE 3 PLANETS

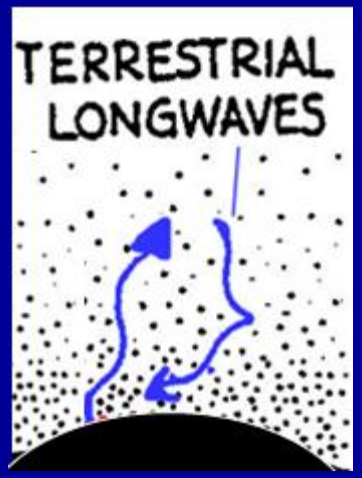
Brrrrrrrrrr, Mars is too COLD!!

GOLDILOCKS & THE 3 PLANETS



Ahhhh! Earth is JUST RIGHT!

But is being at "just the right distance" the primary determinant of Earth's temperature?



The absorption and re-radiation of Infrared radiation 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!

Q1 The inverse-square law (when applied to the distance between a planet and the Sun) is all that is needed to determines that planet's temperature.

YES or NO?

1. **Yes, this is what the Goldilock's Effect is illustrating.**
2. **No, how much solar energy the planet reflects back must also be taken into account**
3. **No, whether or not the planet has a greenhouse effect must also be taken into account.**

Q1 The inverse-square law (when applied to the distance between a planet and the Sun) is all that is needed to determines that planet's temperature.

YES or NO?

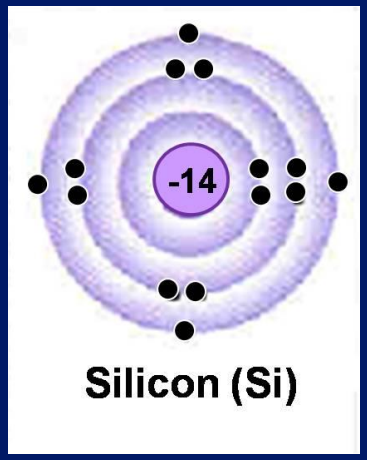
1. Yes, this is what the Goldilock's Effect is illustrating.
2. No, how much solar energy the planet reflects back must also be taken into account
3. No, whether or not the planet has a greenhouse effect must also be taken into account.

Both 2 & 3 are correct!

Re-Read SGC p 43 (look for the 2nd green Pushpin note!)

Yay! Another Sustainability Segment!

Starring:

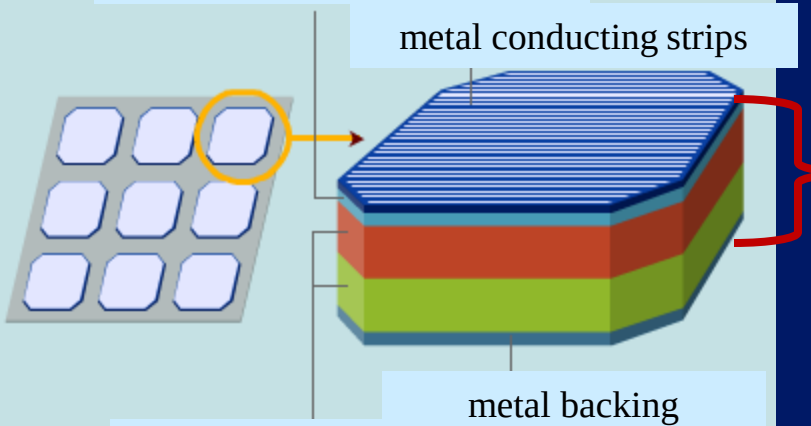


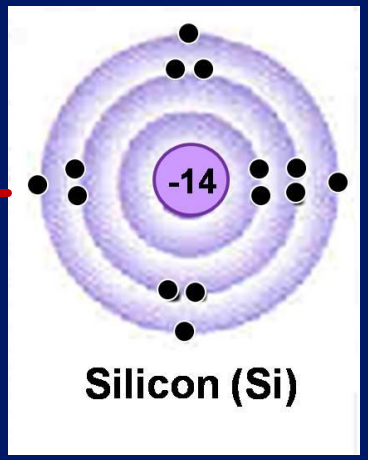
http://www.pbs.org/wgbh/nova/tech/saved-by-the-sun.html

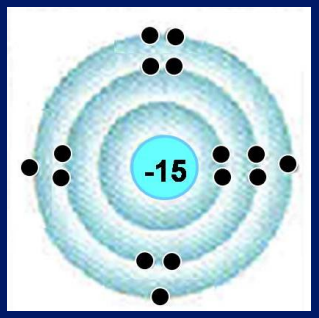
INSIDE A SOLAR CELL

SOLAR PANEL

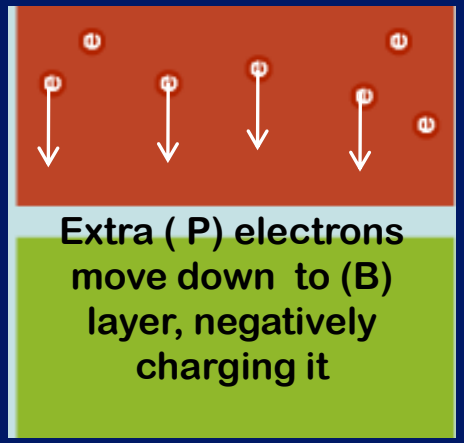
PHOTOVOLTAIC CELL (PV)



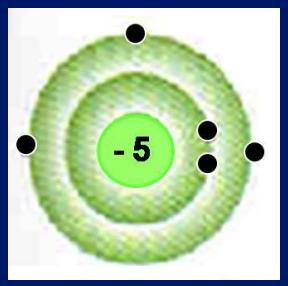




Phosphorus (P) "doped" Si layer



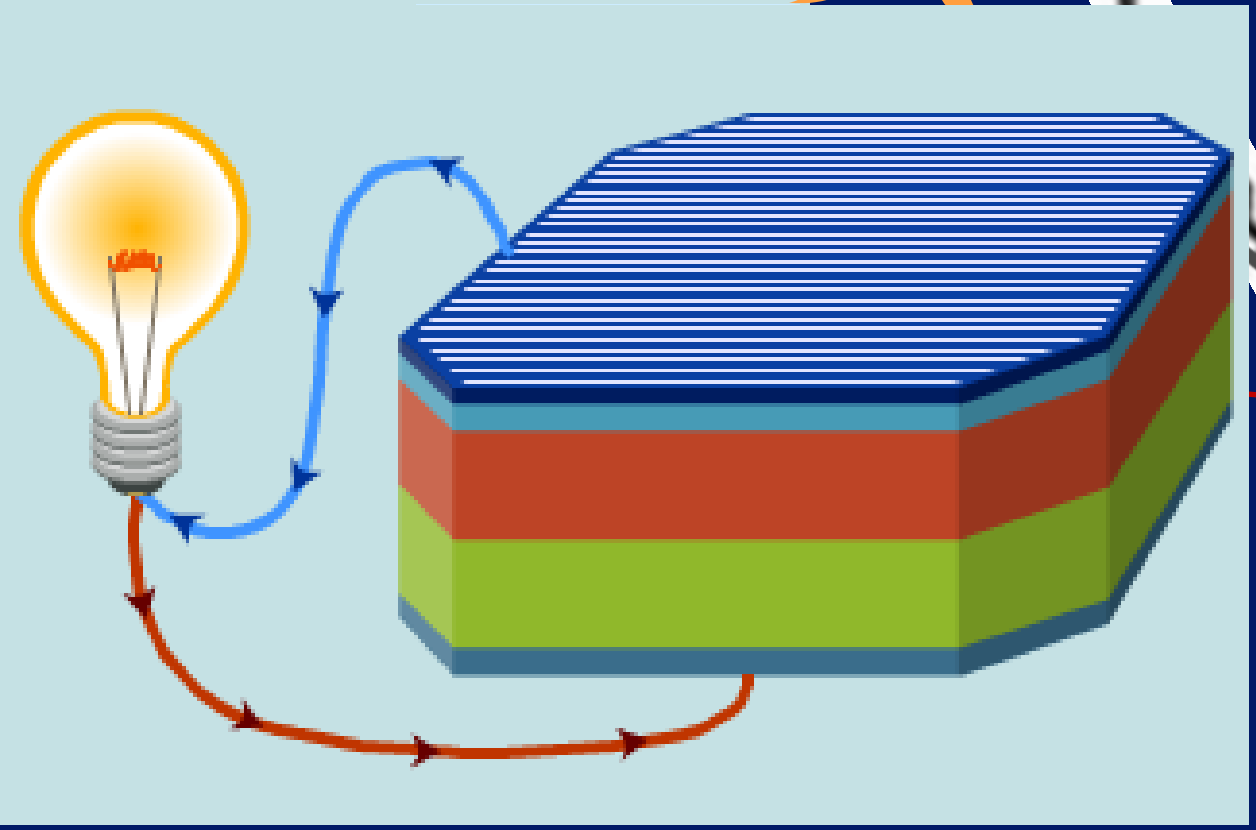
Boron (B) "doped" Si layer

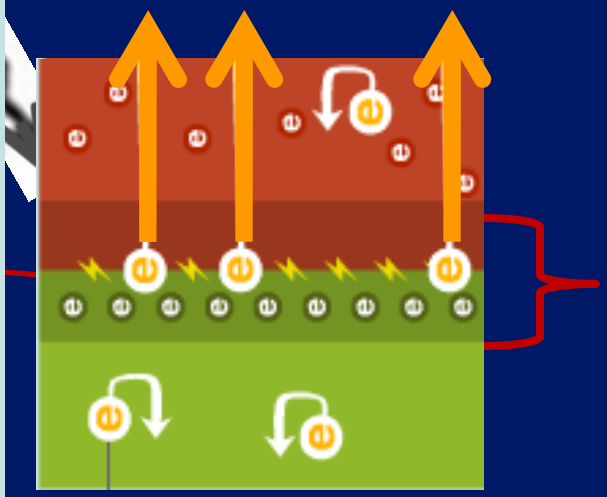


Read this explanation at:

http://www.pbs.org/wgbh/nova/tech/how-solar-cell-works.html /

INSIDE A SOLAR CELL





BEFORE

AFTER

The Maddox-Hirschboeck Residence

TFS
TECHNICIANS FOR SUSTAINABILITY, LLC

16 SunPower 230 watt modules

3.68 kW @ 156 hrs
Estimated Monthly Production: 576 kWh

6,912 kWh annually

Net Meter & Electric Panel

Inverter (DC → AC) Solar Meter & AC Disconnect

SUNPOWER MONITORING

Lifetime:

25,1377 kWh

SOLAR GENERATED

ENVIRONMENTAL SAVINGS:

40,170 lbs

Total CO_2 emissions avoided

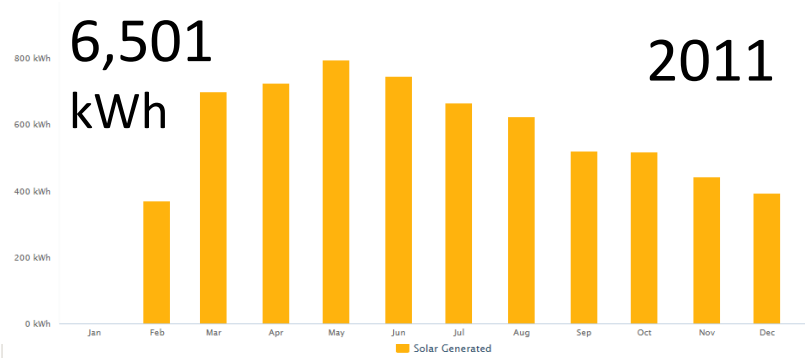
Equivalent to

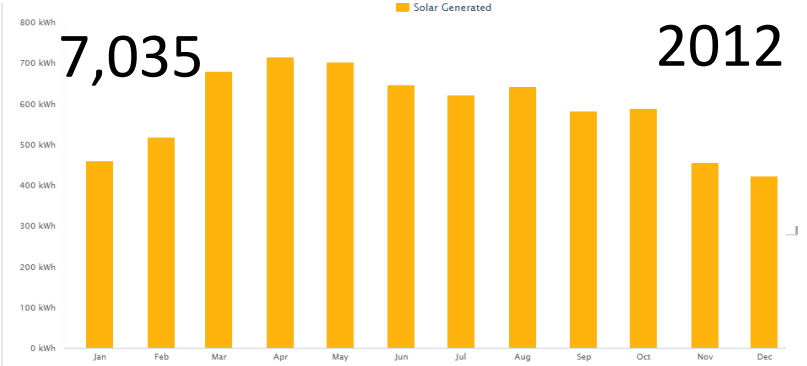
41,961 miles not driven

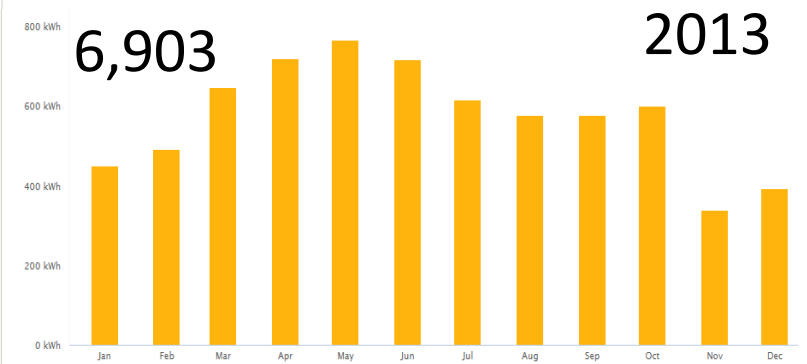
&

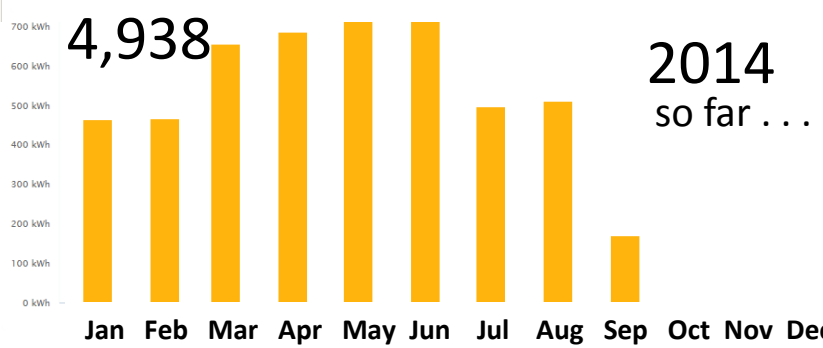
467 trees grown

for 10 years









Going Electric: My LEAF "EV"

"plugging in" at home

Electric & Solar powered!

NATIONAL DRIVE ELECTRIC WEEK - TUCSON / TUCSON PLUGS IN 2014

SUNDAY, SEPTEMBER 21, 2014, 8:00AM - 1:00PM

Location: Bookman's Sports Exchange
3330 E. Speedway Blvd.
Tucson, AZ 85716

Expected Plug-In Vehicles

Vehicle	Registered
Nissan LEAF	5
Tesla Model S	3
Ford C-Max Energi	1
Other Plug-In Vehicle	1
Tesla Roadster	1
Zero Motorcycle	1
6 Models	12

Registered attendees report 212,041 electric miles driven.

Also this SUNDAY . . . . .

[Tucson Peoples' Climate March - Facebook]

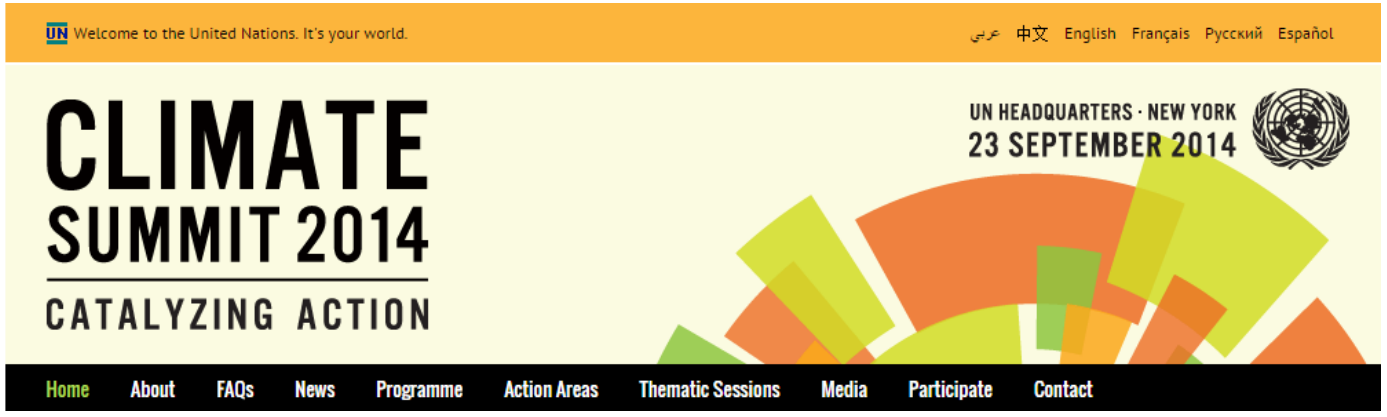
PERFECT TIMING
World leaders will be gathered in NYC for a landmark U.N. climate meeting – just the right moment for big public pressure.

MASSIVE SCALE
We'll peacefully flood the streets in historic numbers, both in New York City and in solidarity events around the world.

UNPRECEDENTED COLLABORATION
Over 1,400 (!) businesses, unions, faith groups, schools, social justice groups, environmental groups and more, all working together.

CENTERED ON JUSTICE
Committed to principles of environmental justice and equality – representing the communities that are being hit the hardest by climate change.

and beginning Tuesday . . .



THE LAST LAW!

Law #6:

"Selective Absorption and Emission"

. . . an important aspect of Law #6 is:

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

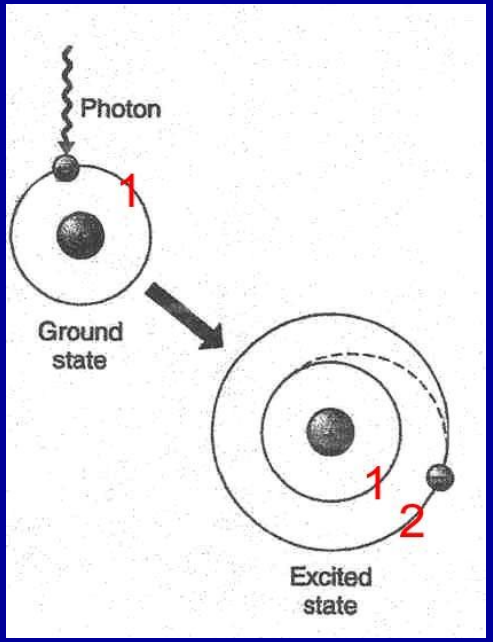
- **ABSORBED (and EMITTED)**
- TRANSMITTED
- SCATTERED, or
- REFLECTED . . .

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

So lets review some slides
from previous classes related to
electromagnetic energy,
absorption & emission . . .

Do you remember this from Topic # 4 ?

ELECTRONS can make "quantum" leaps between the orbits (or energy shells) by **ABSORBING** or **EMITTING** exactly the **energy difference** between the orbits . . . .

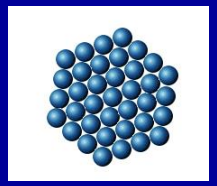


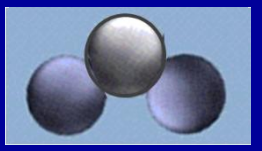
But how? . . . It happens when the electron **absorbs** or **emits** exactly the right **wavelength** & **frequency** of electromagnetic energy for that particular atom

Review – just listen ☺

Quantum behavior also takes place in molecules :

GAS MOLECULES
are able to **absorb** or **emit** only those
frequencies & wavelengths
of electromagnetic energy that
"match up" with a molecule's
frequencies of **vibrating,**
bending,
or **rotating . . . .**

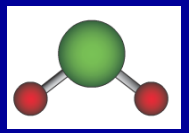




. . . . These **frequencies** depend on
different aspects of the molecule's
structure & bonding between its atoms:

For example:

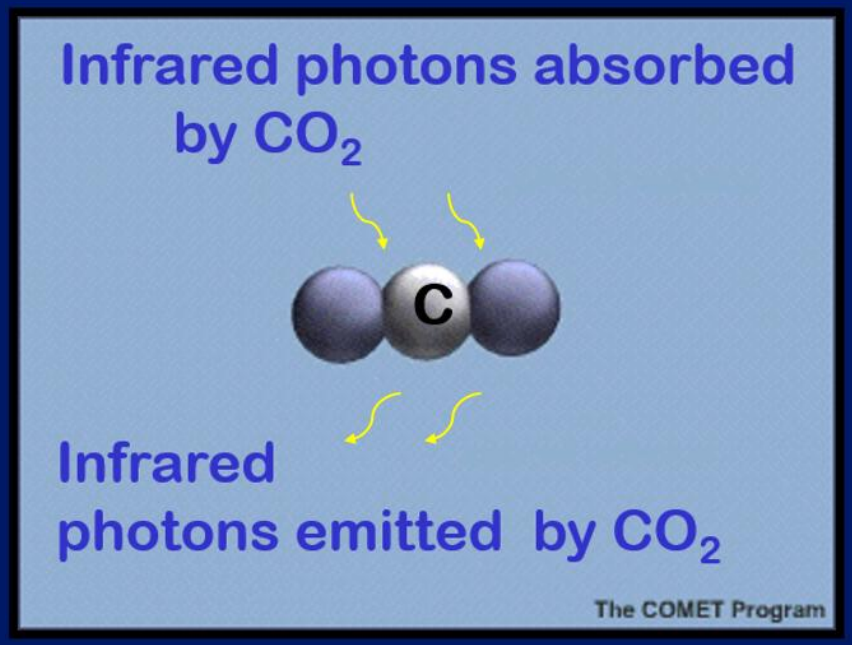
"di-atomic"



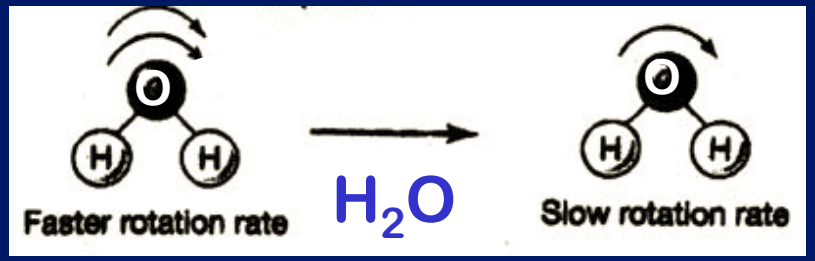
"tri-atomic"

Just listen ☺

So . . . the LINK to GLOBAL CHANGE is . . .



Infrared photon is emitted ➔



Tri-atomic!

The type and frequency of molecular quantum motions in gases like CARBON DIOXIDE and WATER VAPOR explain why THEY contribute to The Greenhouse Effect while other gases (O_2, N_2 . . .) do not!!

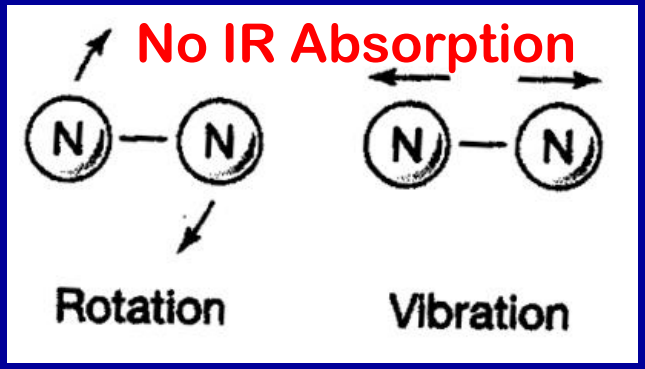
Di-atomic!

☺ The above is stated on the bottom of p 24

N_2 is NOT a Greenhouse gas:

NITROGEN GAS MOLECULE

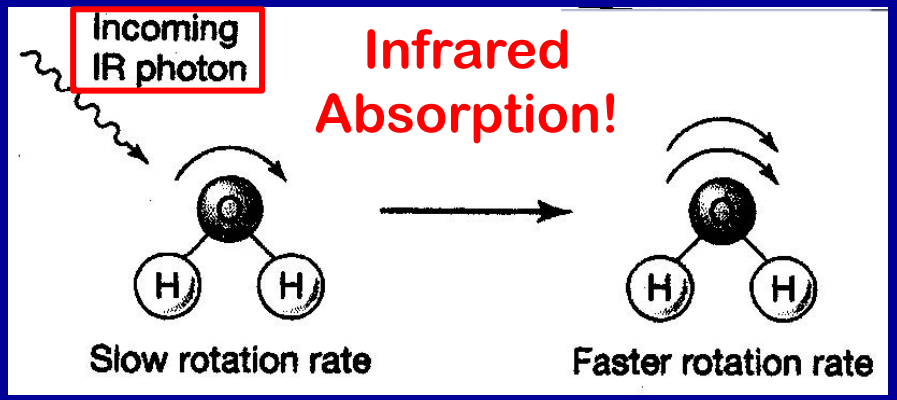
N_2



BUT H_2O and CO_2 ARE Greenhouse gases:

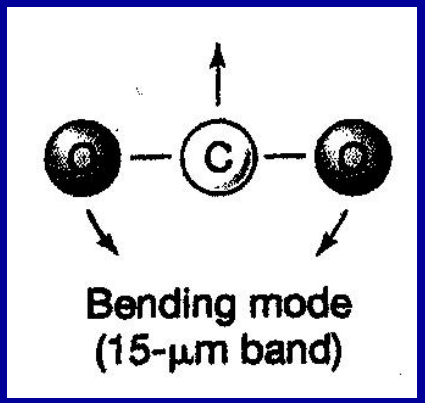
WATER VAPOR MOLECULE

H_2O



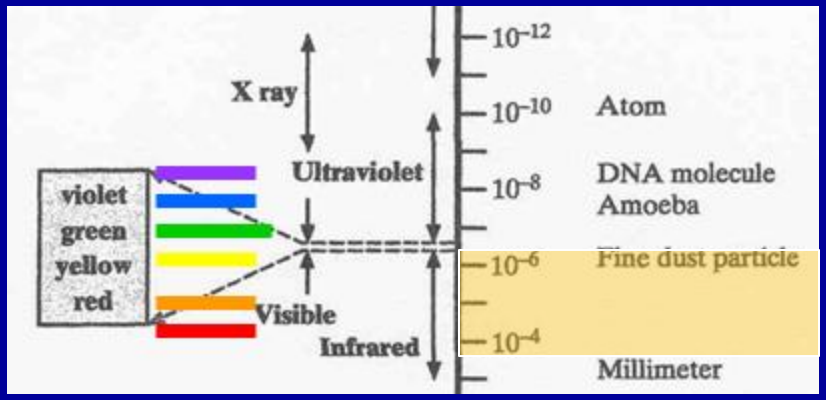
CARBON DIOXIDE GAS MOLECULE

CO_2



Review of the definition:
Greenhouse Gas

GHG = a gas than can absorb and emit INFRARED wavelengths of Electromagnetic Radiation



0.7 to 1000+ micrometers

IR radiation

LAW #6: Selective emission and absorption (of gases)

has 2 parts:

a) Some substances emit and absorb radiation at certain wavelengths only.

(This is mainly true of gases.)

b) These substances absorb only radiation of wavelengths they can emit.

Two implications of Law #6:

" IR absorbed by the gas → IR emitted by the gas "

[The frequency & wavelength of energy absorbed by a particular gas molecule will be the same as the frequency & wavelength with which it is emitted.]

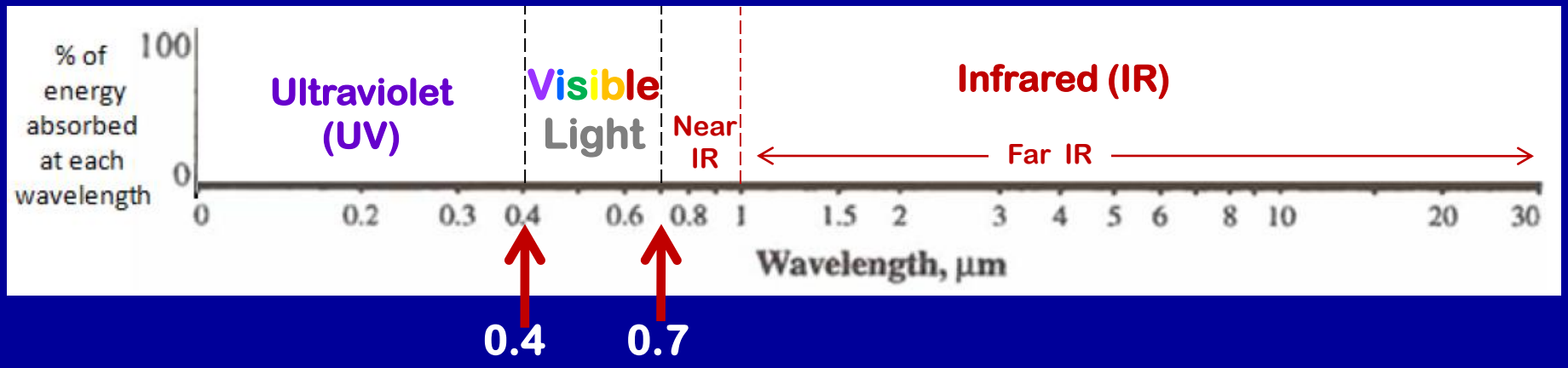
&

" IR NOT absorbed = IR transmitted "

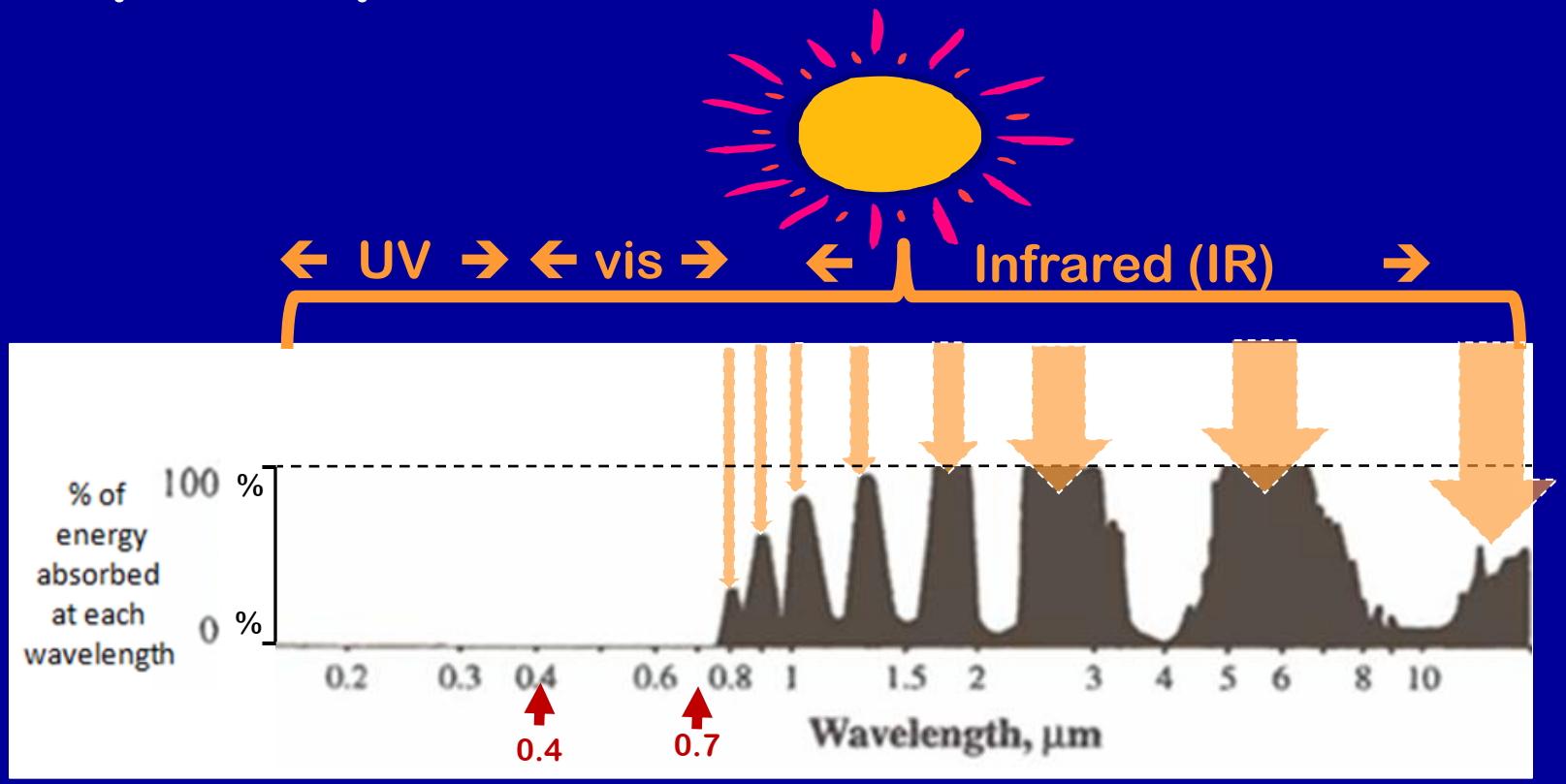
[Wavelengths of energy that are NOT absorbed (or only partially absorbed) by a gas molecule, get transmitted right through the ATMOSPHERE!]

So let's tie Law #6 to the Electromagnetic Spectrum

Review of the spectrum:



The pattern of electromagnetic wavelengths that are absorbed (& emitted) by a particular gas molecule . . . is called the gas's Absorption Spectrum or ABSORPTION CURVE



Radiation is ABSORBED (or partially ABSORBED) at THESE wavelengths by this particular gas!

☺

But is ABSORPTION & EMISSION ALL that happens to Electromagnetic Energy?

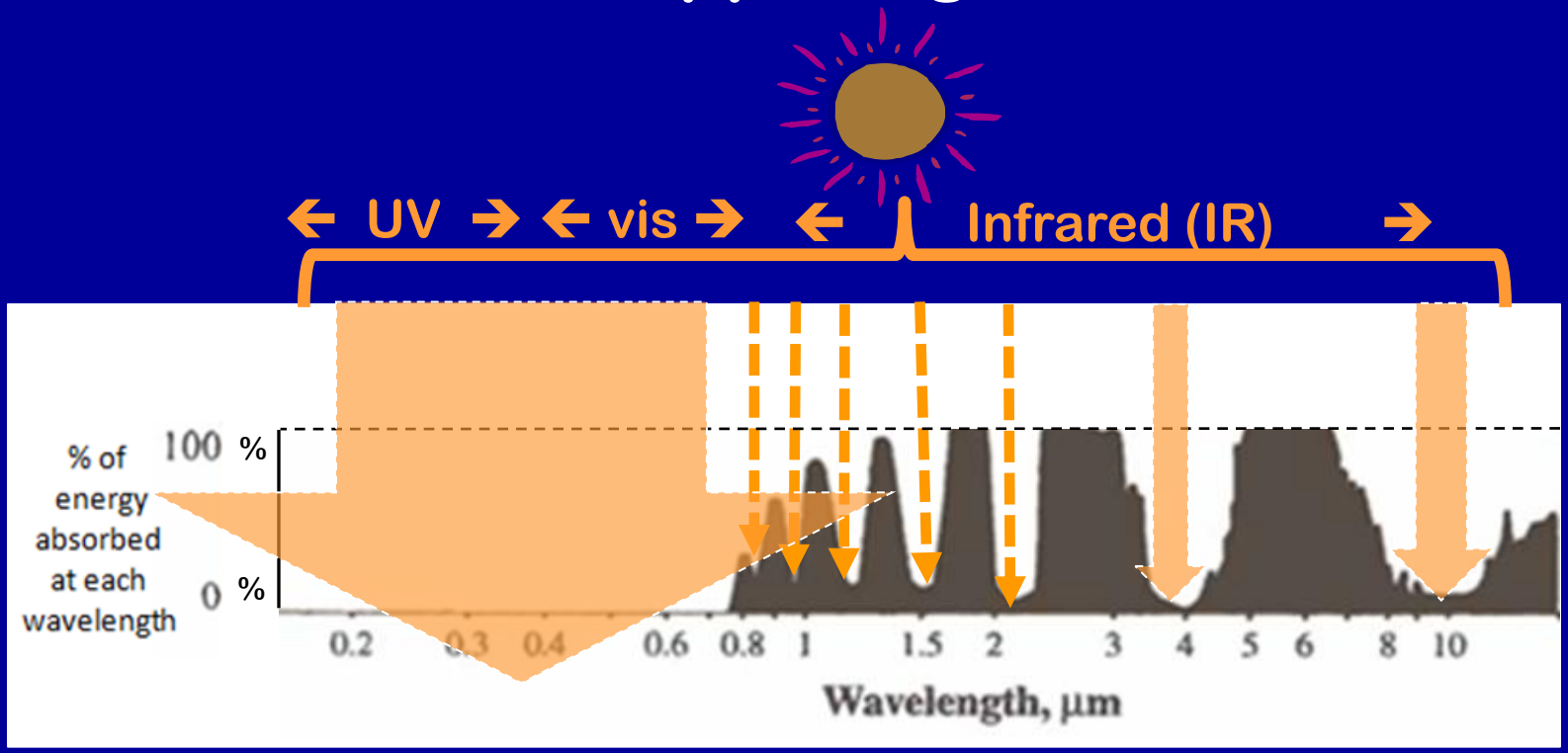
Electromagnetic energy does not NEED matter to be transferred, but when it DOES **react with matter,** it can be:

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

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

Here's the absorption curve of the same gas:

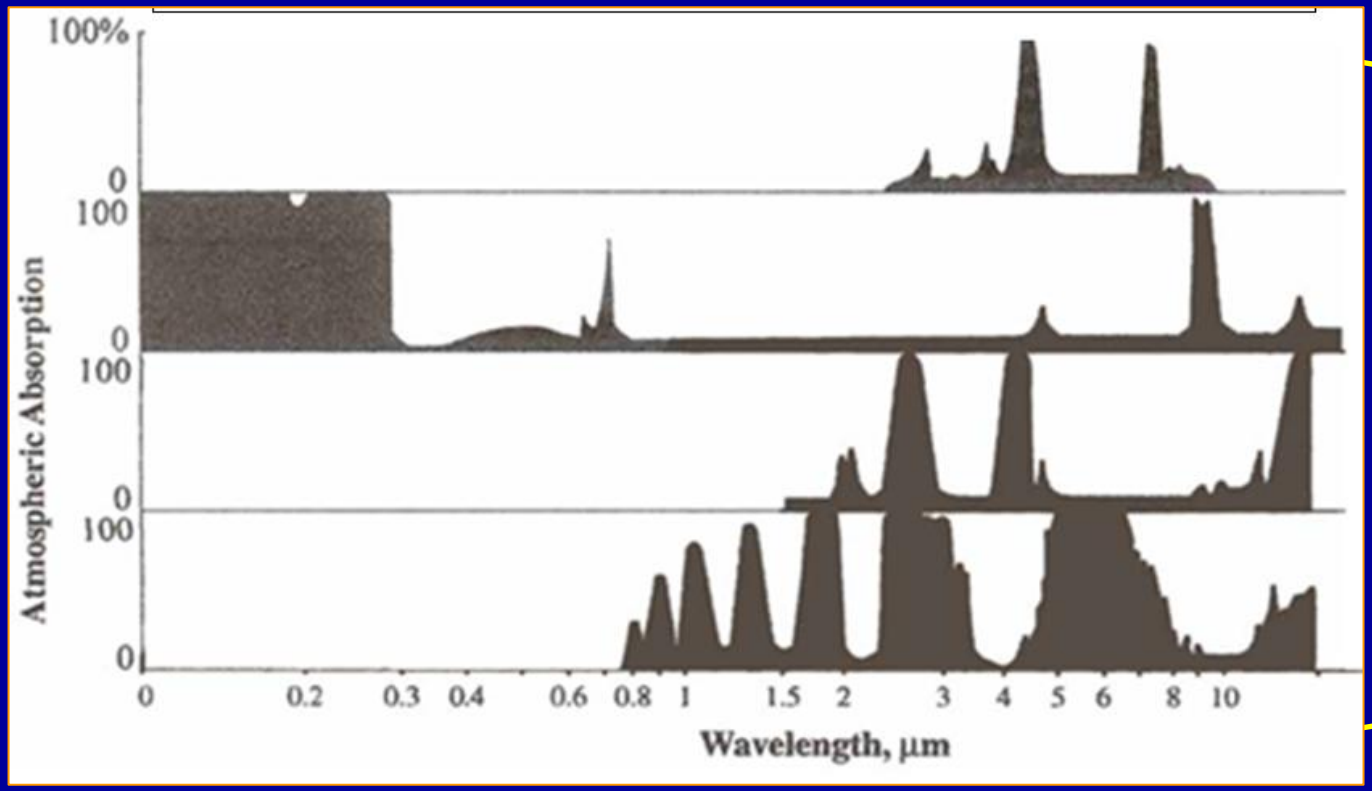
Radiation is TRANSMITTED through the atmosphere at the wavelengths where no absorption is happening!



[The "open areas" (0 % or low values) on the Absorption Curve represent electromagnetic wavelengths that are NOT absorbed (or only partially absorbed) by a particular gas molecule .]

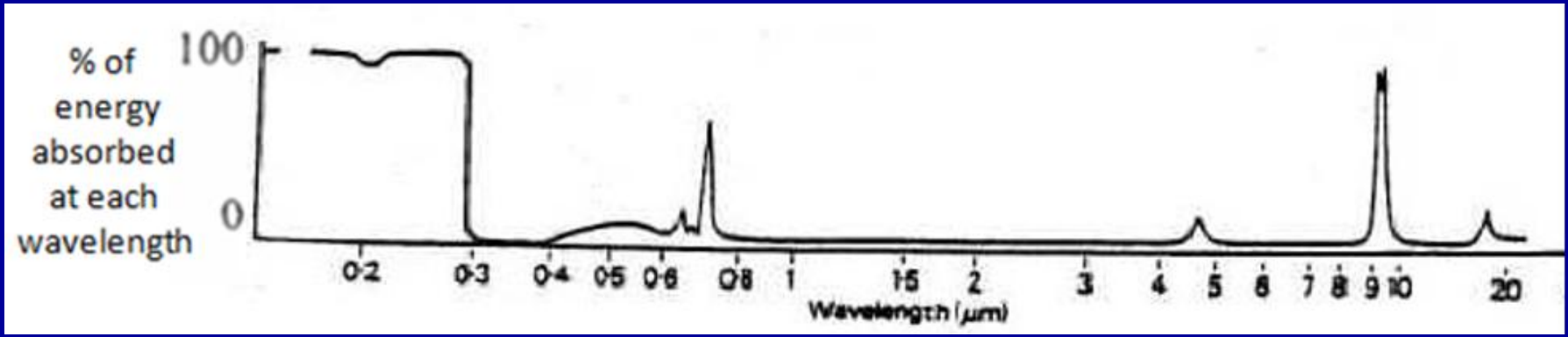
Here are Absorption Curves for 4 different gases:

energy absorbed at each wavelength



Each row is the Curve for a different gas

Here's another view of an absorption curve (without shading under the curve)

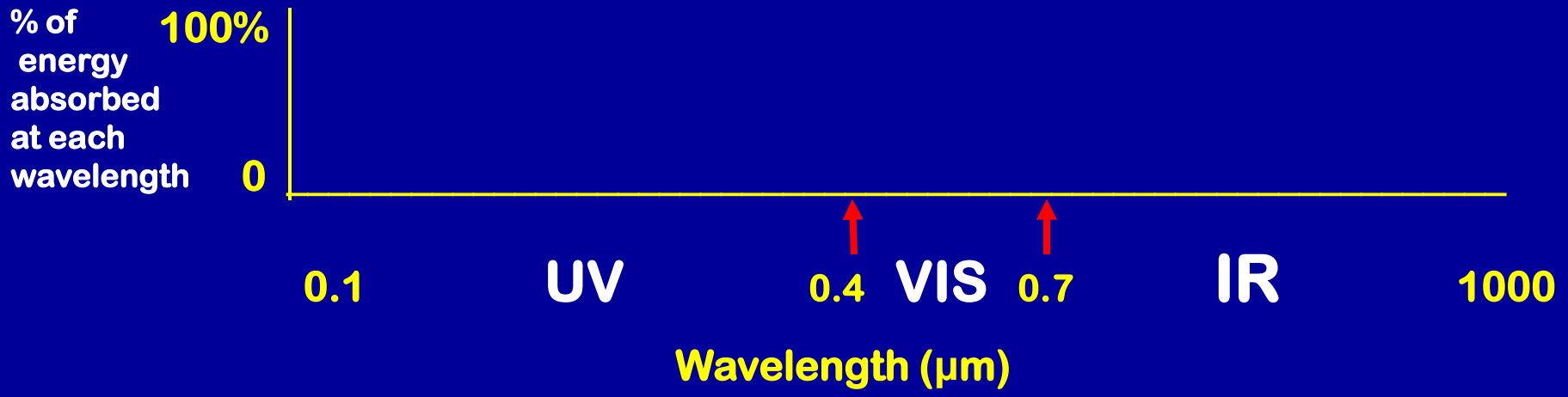


ABSORPTION CURVES

SKETCH THE AXES IN
(on the bottom of p 29 or in your own notes)

HORIZONTAL AXIS: wavelength

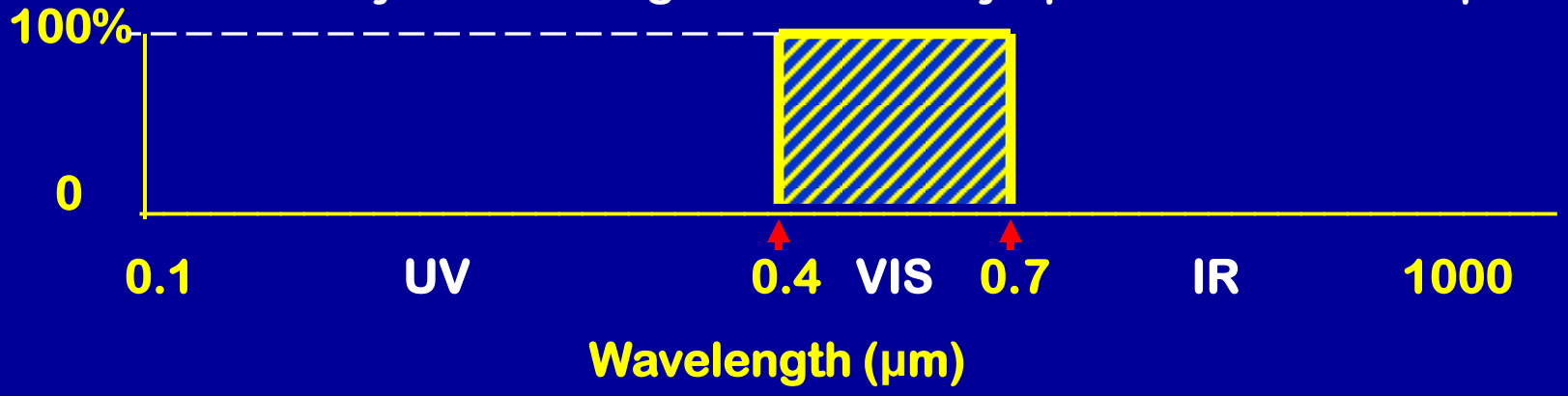
VERTICAL AXIS: % of energy at each wavelength that is ABSORBED



What would a curve for a hypothetical gas that absorbs **ALL VISIBLE LIGHT** but **ZERO UV** or **IR**

LOOK LIKE ??

Be sure your sketch goes all the way up to 100% for this question!



SKETCH IT IN . . . .

And now . . . .

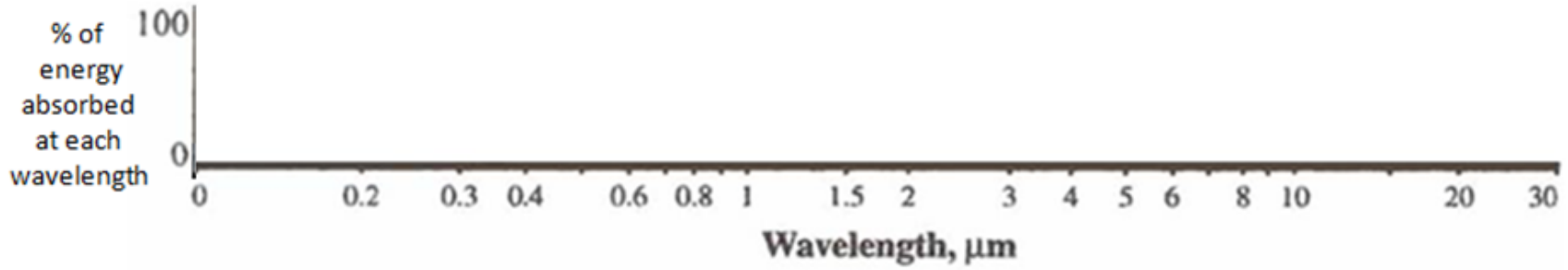
GROUP ASSIGNMENT G-1

Understanding Radiation, Absorption & Wavelengths of the Electromagnetic Spectrum

WORTH 10 pts

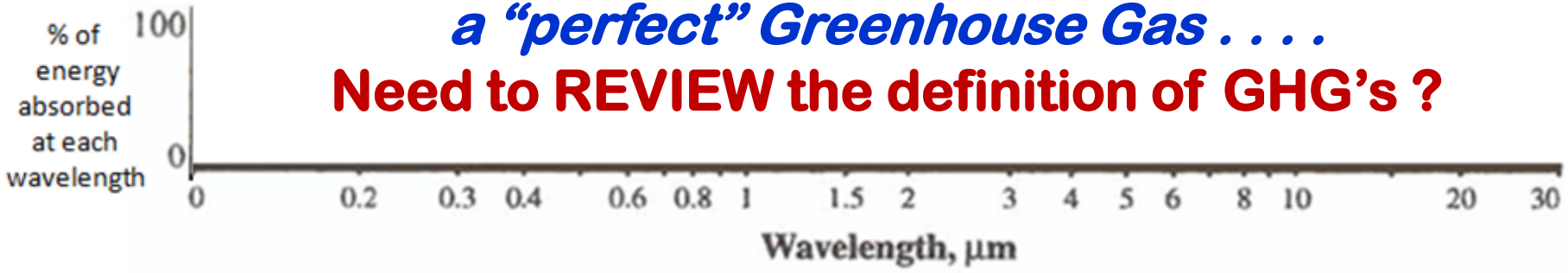
Q1. All UV but zero vis and zero IR?

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. All IR but zero vis and zero UV?

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



a "perfect" Greenhouse Gas . . . .

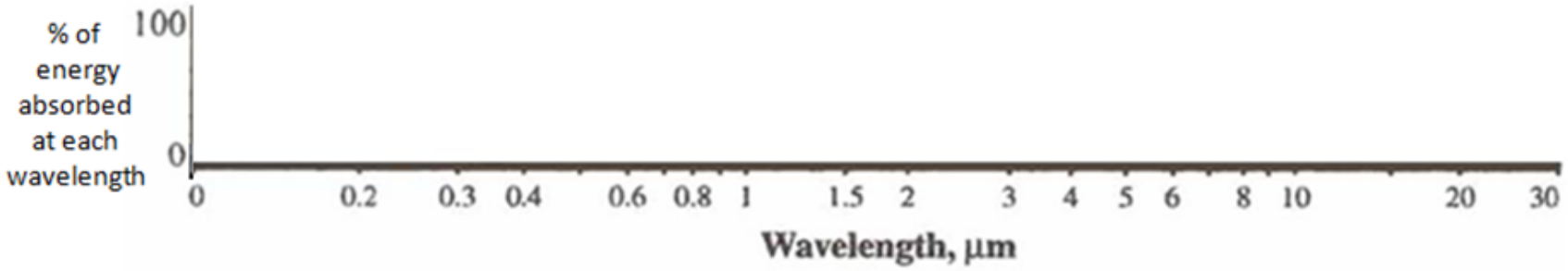
Need to REVIEW the definition of GHG's ?

Remember the GHG definition to help you answer Q2:

Greenhouse gases are gases which both absorb and emit electromagnetic radiation in the infrared (IR) part of the spectrum.

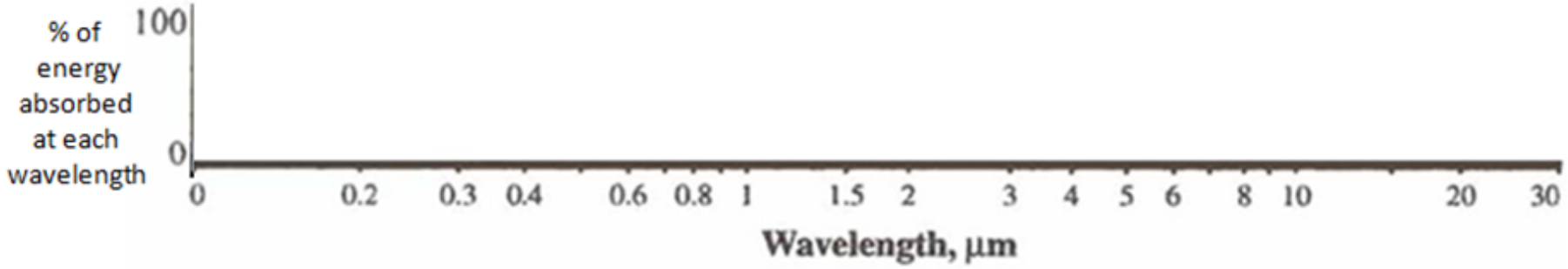
Q3. All UV & IR absorbed but VIS transmitted?

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. All IR absorbed in specific wavelength bands?

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**



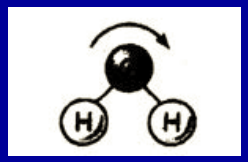
Q5. Is the hypothetical gas in Q4 likely to be a GREENHOUSE GAS?

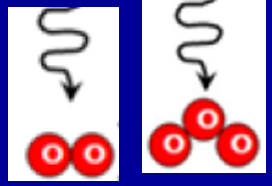
YES NO ***(circle one)***

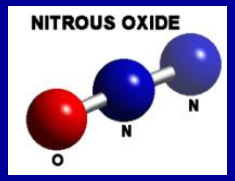
Briefly explain WHY you answered YES or NO: ***(in a few sentences)***

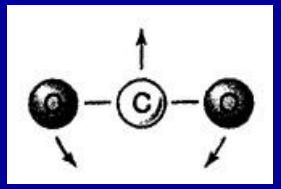
(discuss in your group first!)

Q6 is on p 32







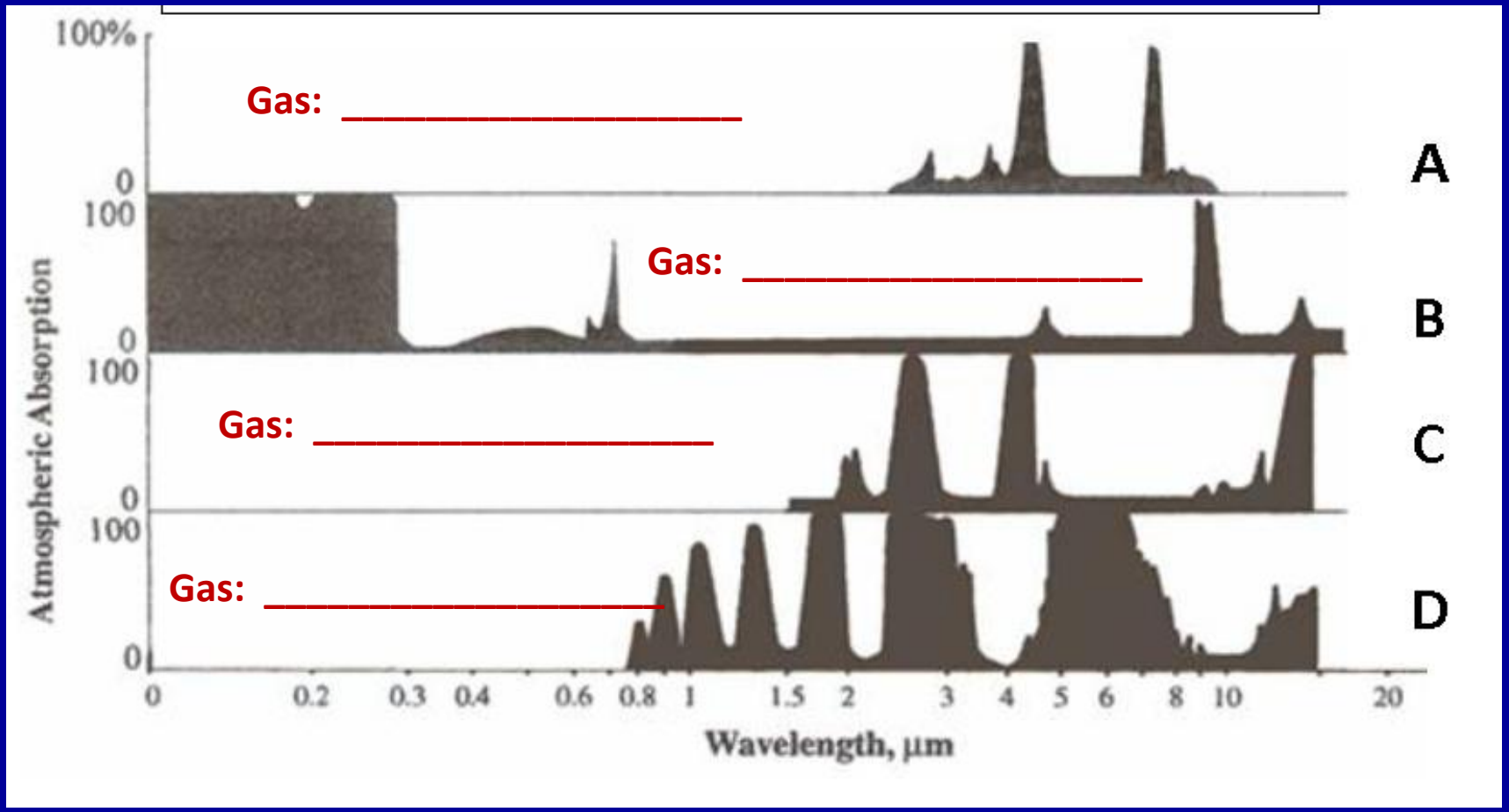


Here are the specific wavelengths each gas absorbs!

Gas	Primary absorption wavelengths *(in micrometers)*	
Water vapor (H_2O)	0.8	4 to 7
	1	9 to 10
	1.5	11 to 20
	2 to 3.5	
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	

Match the GAS with its Absorption Curve:

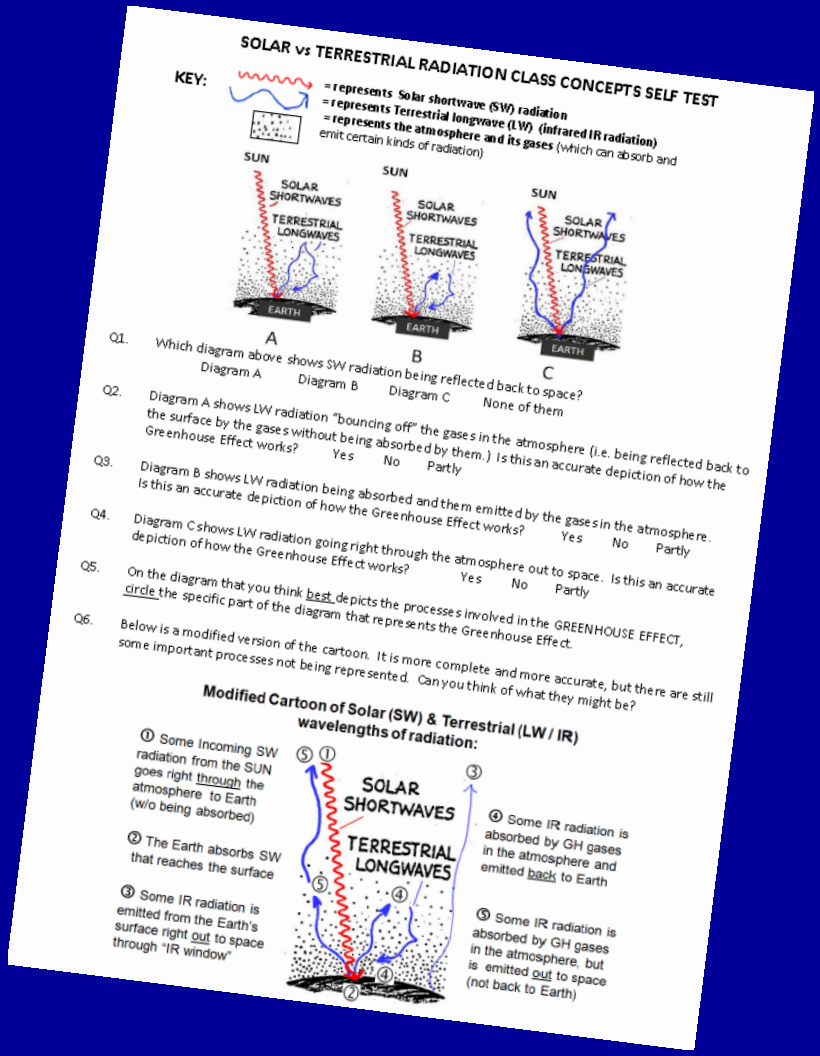
CHOICES: CO_2 H_2O $O_2 + O_3$ N_2O



Solar vs. Terrestrial Radiation Class Concepts Self Test

For Q7 – Q11 work individually or in pairs on the last page (same as p 33 in CLASS NOTES)

. . . . then compare answers with the rest of the Group and record the group's consensus answers on the G-1 form.



SOLAR vs TERRESTRIAL RADIATION CLASS CONCEPTS SELF TEST

KEY: = represents Solar shortwave (SW) radiation
= represents Terrestrial longwave (LW) (infrared IR radiation)
= represents the atmosphere and its gases (which can absorb and emit certain kinds of radiation)

SUN SOLAR SHORTWAVES TERRESTRIAL LONGWAVES EARTH — A

SUN SOLAR SHORTWAVES TERRESTRIAL LONGWAVES EARTH — B

SUN SOLAR SHORTWAVES TERRESTRIAL LONGWAVES EARTH — C

Q1. Which diagram above shows SW radiation being reflected back to space? Diagram A Diagram B Diagram C None of them

Q2. Diagram A shows LW radiation "bouncing off" the gases in the atmosphere (i.e. being reflected back to the surface by the gases without being absorbed by them.) Is this an accurate depiction of how the Greenhouse Effect works? Yes No Partly

Q3. Diagram B shows LW radiation being absorbed and then emitted by the gases in the atmosphere. Is this an accurate depiction of how the Greenhouse Effect works? Yes No Partly

Q4. Diagram C shows LW radiation going right through the atmosphere out to space. Is this an accurate depiction of how the Greenhouse Effect works? Yes No Partly

Q5. On the diagram that you think best depicts the processes involved in the GREENHOUSE EFFECT, circle the specific part of the diagram that represents the Greenhouse Effect.

Q6. Below is a modified version of the cartoon. It is more complete and more accurate, but there are still some important processes not being represented. Can you think of what they might be?

Modified Cartoon of Solar (SW) & Terrestrial (LW / IR) wavelengths of radiation:

① Some incoming SW radiation from the SUN goes right through the atmosphere to Earth (w/o being absorbed)

② The Earth absorbs SW that reaches the surface

③ Some IR radiation is emitted from the Earth's surface right out to space through "IR window"

SOLAR SHORTWAVES

TERRESTRIAL LONGWAVES

④ Some IR radiation is absorbed by GH gases in the atmosphere and emitted back to Earth

⑤ Some IR radiation is absorbed by GH gases in the atmosphere, but is emitted out to space (not back to Earth)

Will be a good review of Topic 5!

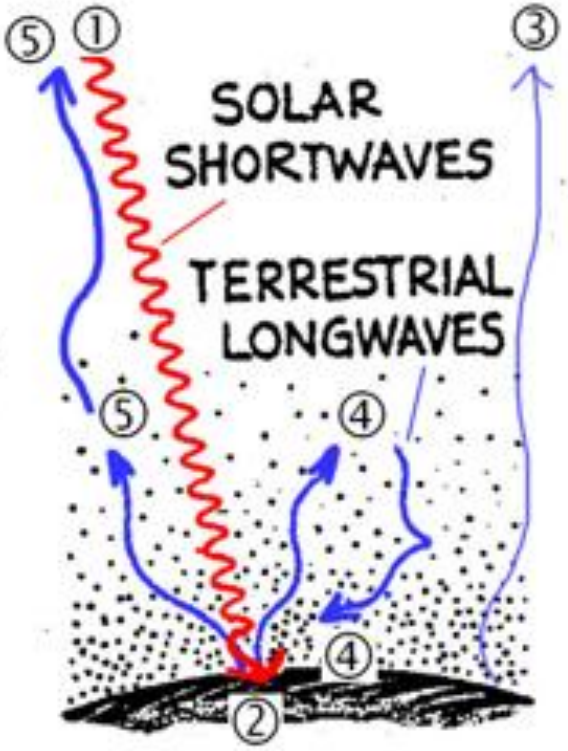
THINKING MORE DEEPLY "TAKE HOME"

Modified Cartoon of Solar (SW) & Terrestrial (LW / IR) wavelengths of radiation:

① Some Incoming SW radiation from the SUN goes right <u>through</u> the atmosphere to Earth (w/o being absorbed)

② The Earth absorbs SW that reaches the surface

③ Some IR radiation is emitted from the Earth's surface right <u>out</u> to space through "IR window"



④ Some IR radiation is absorbed by GH gases in the atmosphere and emitted <u>back</u> to Earth

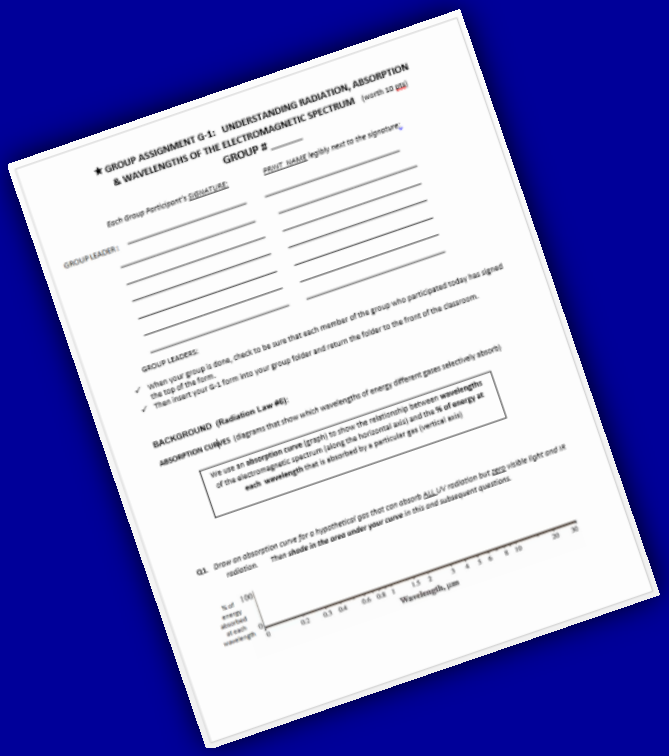
⑤ Some IR radiation is absorbed by GH gases in the atmosphere, but is emitted <u>out</u> to space (not back to Earth)

This diagram is more complete and more accurate than the one at the top of the page, but there are still some important processes not being represented.

Can you think of what they might be?

When you get your GROUP FOLDER . . .

. . . You'll find your GROUP ANSWER FORM:



★ GROUP ASSIGNMENT G-1: UNDERSTANDING RADIATION, ABSORPTION & WAVELENGTHS OF THE ELECTROMAGNETIC SPECTRUM (worth 10 pts)

GROUP # _____

Each Group Participant's SIGNATURE: PRINT NAME legibly next to the signature.

GROUP LEADER: _____

GROUP LEADER:

- When your group is done, check to be sure that each member of the group who participated today has signed the top of the form.
- Then insert your G-1 form into your group folder and return the folder to the front of the classroom.

BACKGROUND (Radiation Law #6):

ABSORPTION CURVES (diagrams that show which wavelengths of energy different gases selectively absorb)

We use an **absorption curve** (graph) to show the relationship between **wavelengths** of the electromagnetic spectrum (along the horizontal axis) and the **% of energy at each wavelength** that is absorbed by a particular gas (vertical axis).

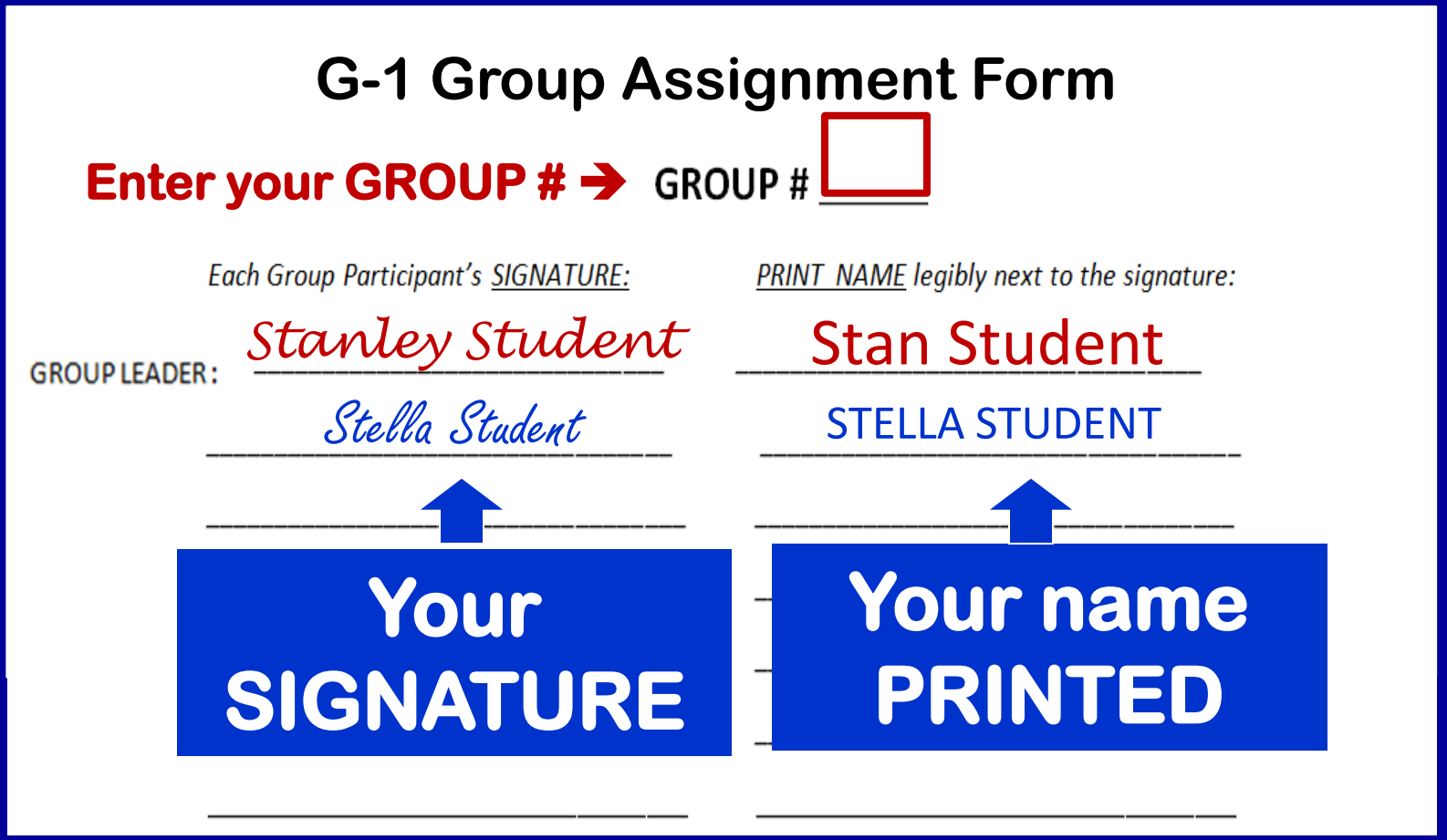
Q1. Draw an absorption curve for a hypothetical gas that can absorb ALL UV radiation but ZERO visible light and all radiation. Then **shade in the area under your curve** in this and subsequent questions.

% of energy absorbed at each wavelength

Wavelength, μm

Group Assignment grades are given to those students **present in class** who work on the activity and who indicate this by **SIGNING THE FORM . . .**

BOTH your signature & printed name are needed →



TODAY's GROUP LEADER = Student whose last name is **LAST** in the ALPHABET on the Group List

LEADER passes the GROUP FORM around so each student **SIGNS IT** & **PRINTS HIS /HER NAME**

OK – LETS GET TO WORK!

- **REMEMBER: Please do not remove the GROUP FOLDERS from the CLASSROOM**

- **REMINDER: RQ-3 is due Tue Sep 23**

(30 minutes before our next class)

- **Want to get active and do something about Climate Change?**

SUNDAY Sep 21 – Join the rest of the nation in the People's Climate March

Tucson Peoples' Climate March - Facebook

and / or visit Tucson Plugs In – 2014

http://tucsonelectricvehicle.org/events.html