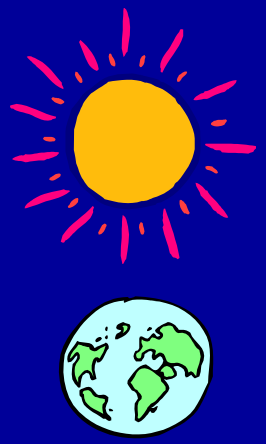
TOPIC # 6
The RADIATION LAWS
PART 2

Class Notes p 31

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

Fill in Top of p 31

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 31

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 . . . .

These last two laws (#5 and #6) will not be on the Thursday's test . . .
Laws # 1-4 will

But TODAY'S CLASS will definitely help you to do well on the Test if you pay attention!

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

The inverse square law describes:

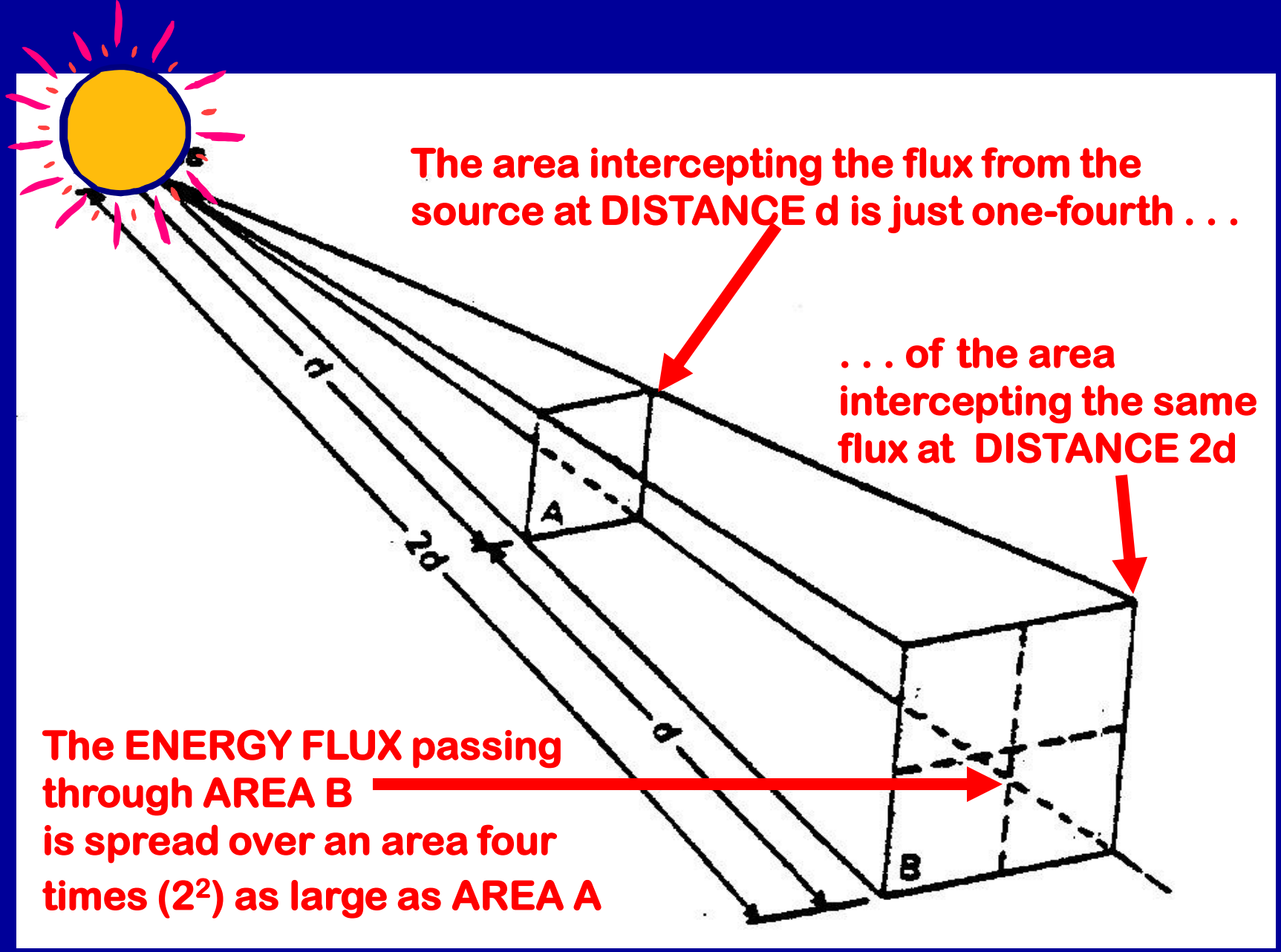
how solar FLUX of ENERGY
decreases
with increasing DISTANCE
from the source of
the radiation flux
i.e., the Sun

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.

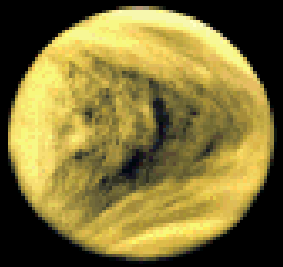
Why is this concept important?

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

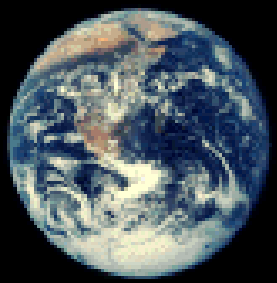
can result in LARGE changes in the amount of energy received by a planet's surface.

GOLDILOCKS & THE 3 PLANETS

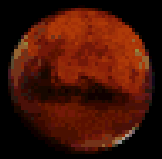
To Sun



VENUS

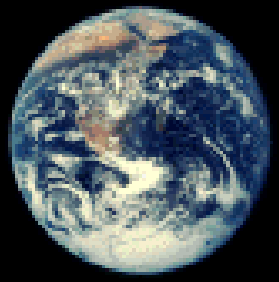


EARTH



MARS

GOLDILOCKS & THE 3 PLANETS

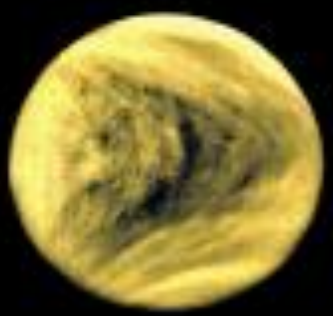


Yikes! Venus is too HOT!

GOLDILOCKS & THE 3 PLANETS

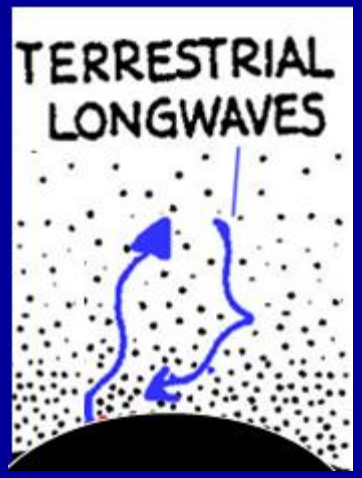
Brrrrrrrrrr, Mars is too COLD!!

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 exactly what 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 exactly what 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!)

THE LAST LAW!

Law #6

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 the other 2 processes in upcoming lectures . . . .

LAW #6: Selective emission and absorption

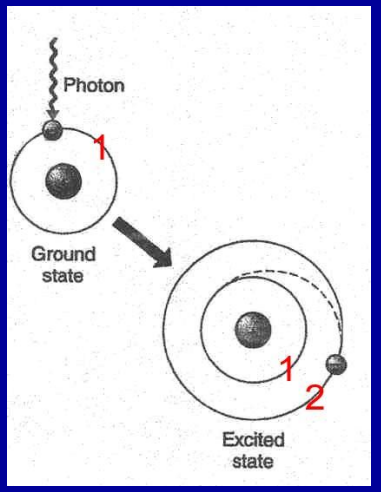
Part (a) of the law:

Some substances emit and absorb radiation at certain wavelengths only.

This is mainly true of gases.

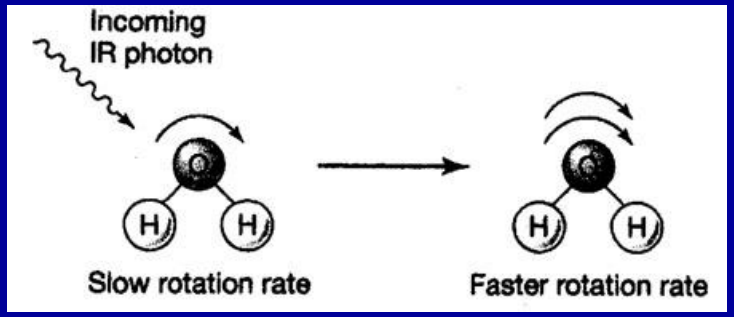
Why?

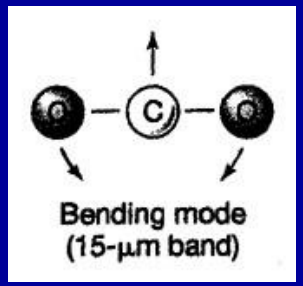
Recall QUANTUM BEHAVIOR!



ELECTRON energy states allow absorption of photons/wavelengths of only a specified frequency

Different GAS MOLECULES allow absorption of photons/waves of only specified frequencies (and wavelengths) because of how the gas molecules vibrate, bend, and rotate





Part (b) of the law:

Some substances (like gases) absorb only radiation of wavelengths they can emit.

Two implications of Part (b):

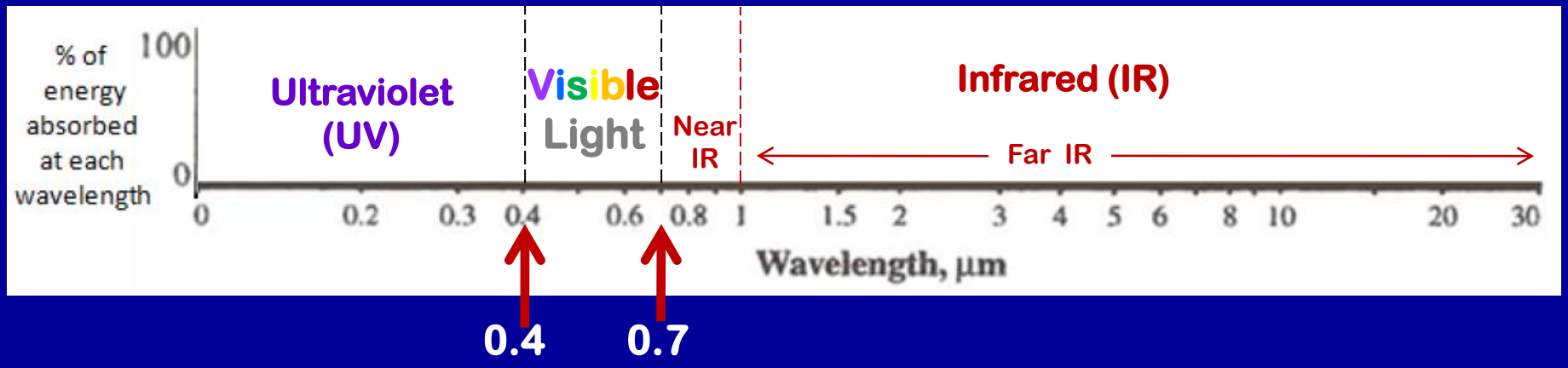
(1) The **frequency & wavelength** of energy absorbed by a particular gas molecule **will be the same as** the frequency & wavelength with which it is emitted.

" IR absorbed by the gas ➔ IR emitted by the gas "

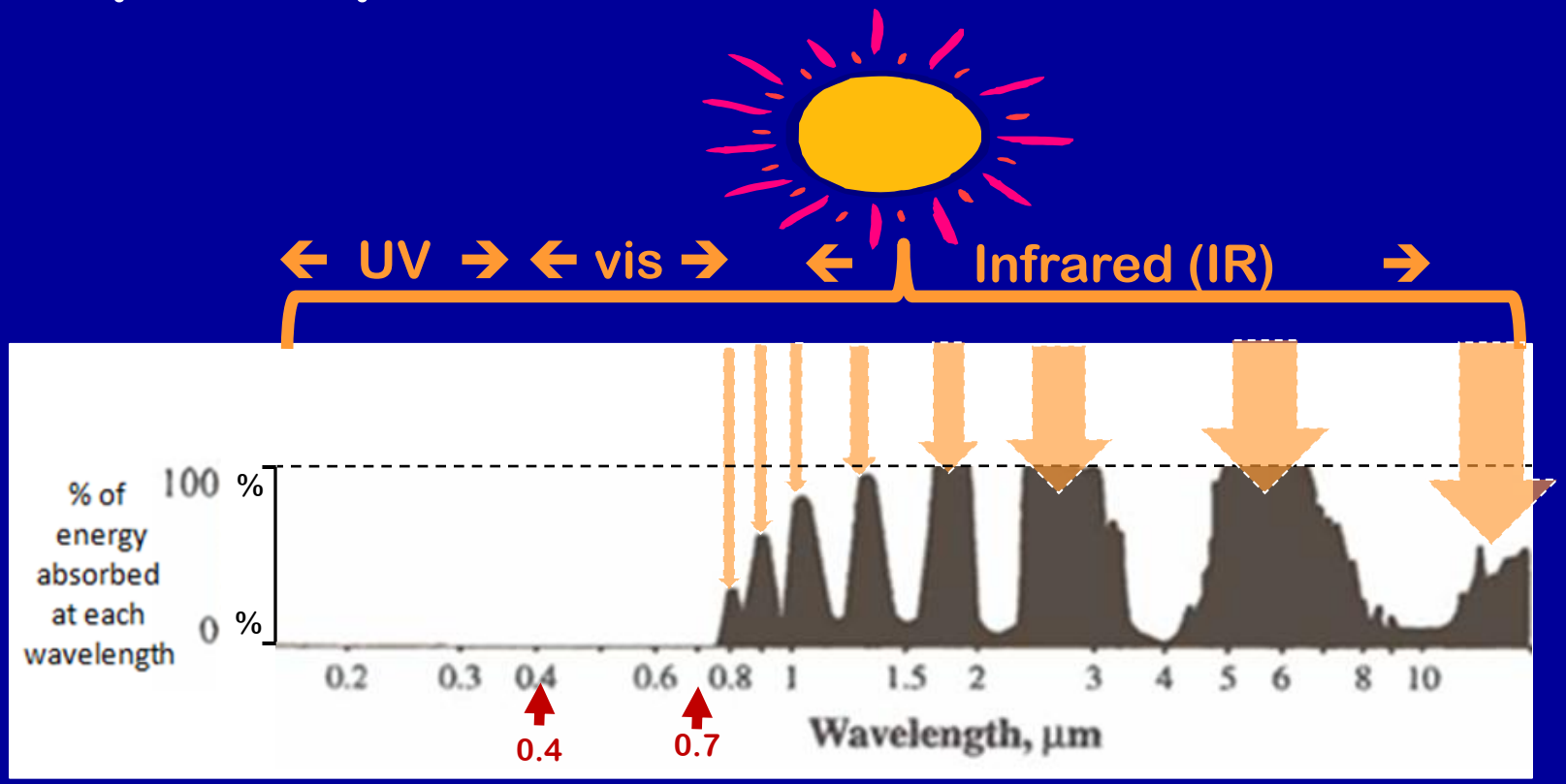
(2) Wavelengths of energy that are NOT absorbed (or only partially absorbed) by a gas molecule, **get transmitted** right through the ATMOSPHERE! " IR NOT absorbed = IR transmitted "

QUICK SPECTRUM REVIEW:

What are the key parts of the spectrum?



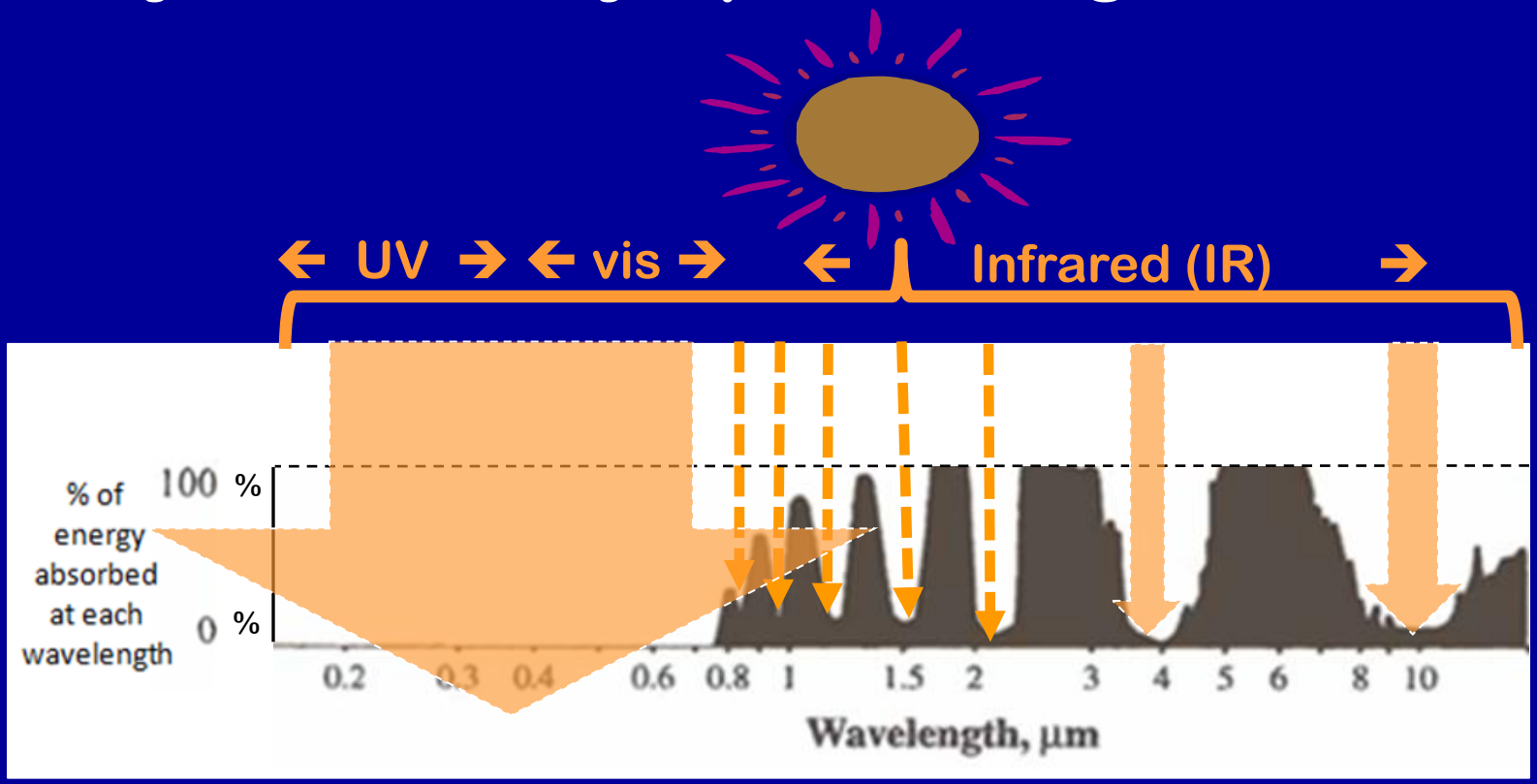
The pattern of electromagnetic wavelengths that are absorbed (& emitted) by a particular gas molecule . . . is called the gas's Absorption Spectrum or ABSORPTION CURVE



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

☺

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 . .



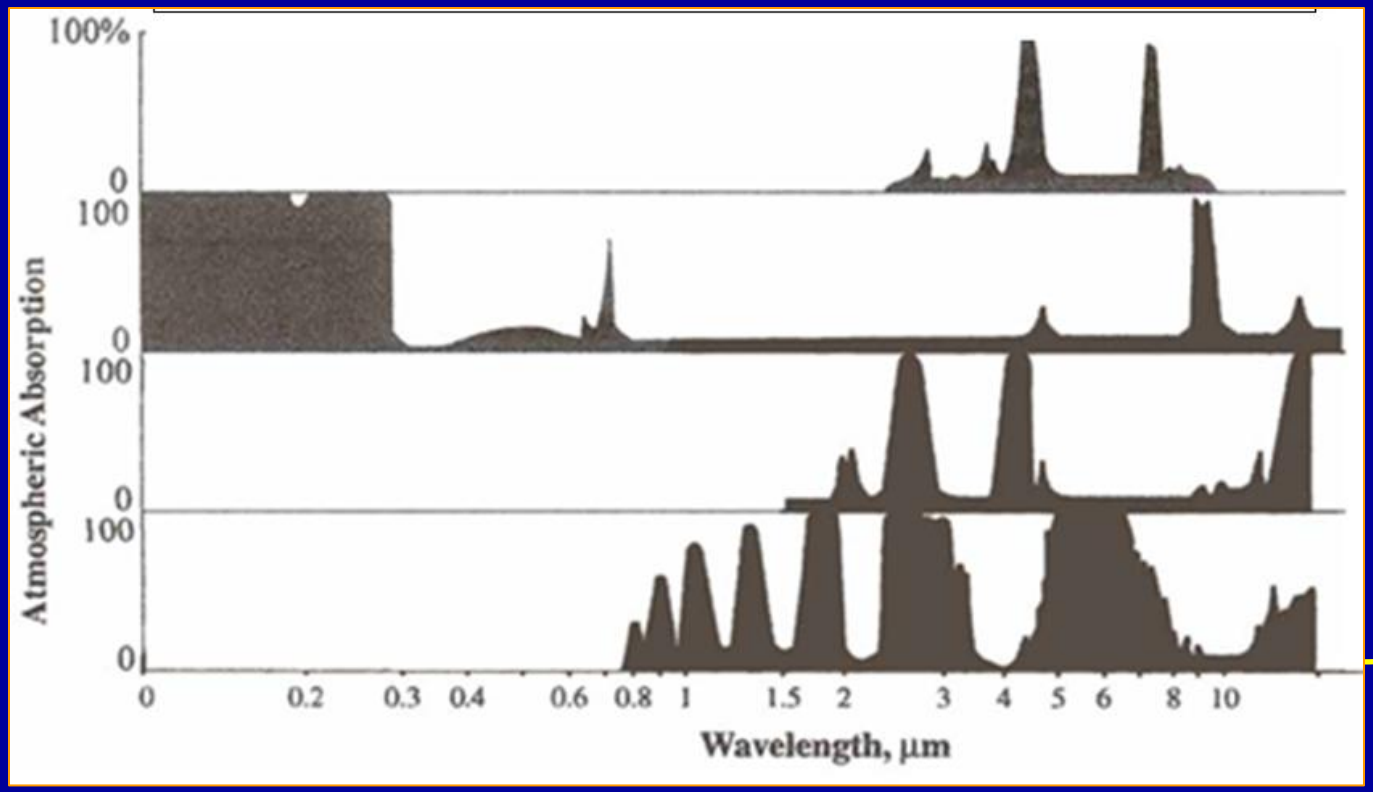
Radiation is **TRANSMITTED** through the **atmosphere** and **very little is absorbed** at these wavelengths by this particular gas!

The pattern of electromagnetic wavelengths that are absorbed & emitted by a particular gas molecule . . . is called the gas's

Absorption Spectrum or ABSORPTION CURVE

energy absorbed at each wavelength

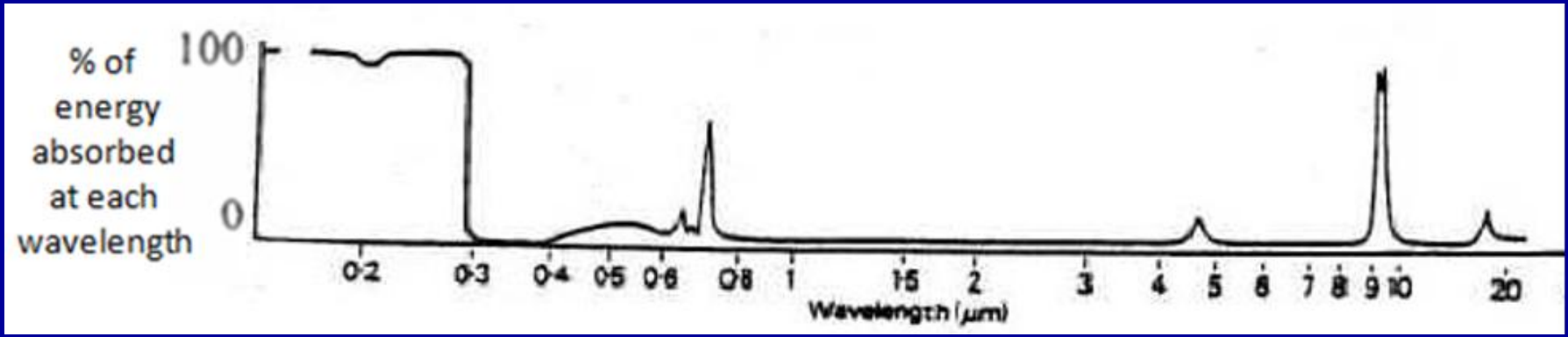
4 different gases:



Each row is the Absorption Curve for a different atmospheric gas molecule!

☺

An absorption curve: another view (without shading under the curve)

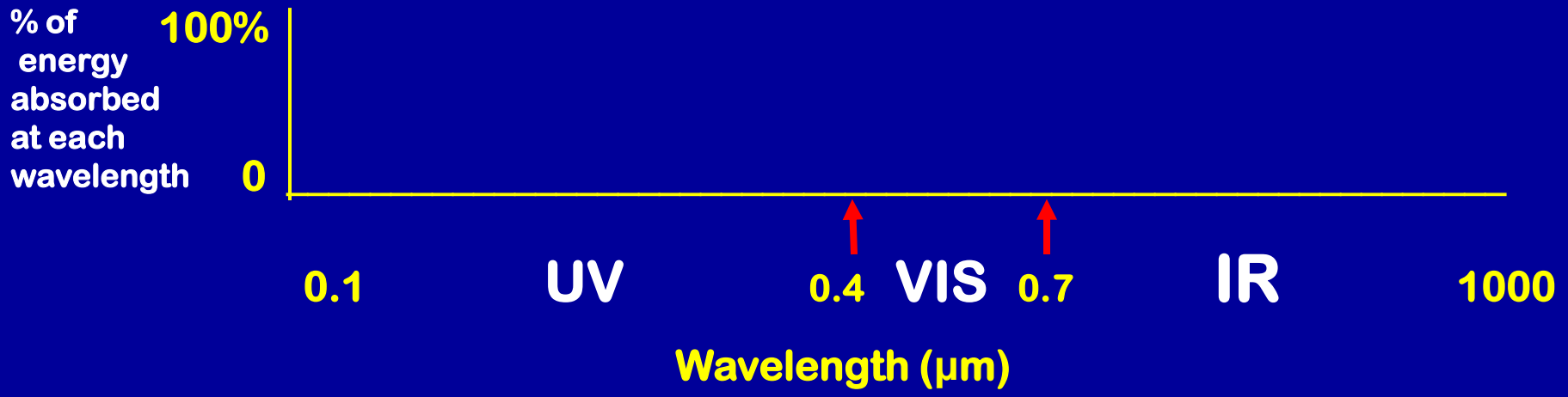


ABSORPTION CURVES

SKETCH THE AXES IN
(on the bottom of p 31 or in your own notes)

HORIZONTAL AXIS: wavelengths in the spectrum

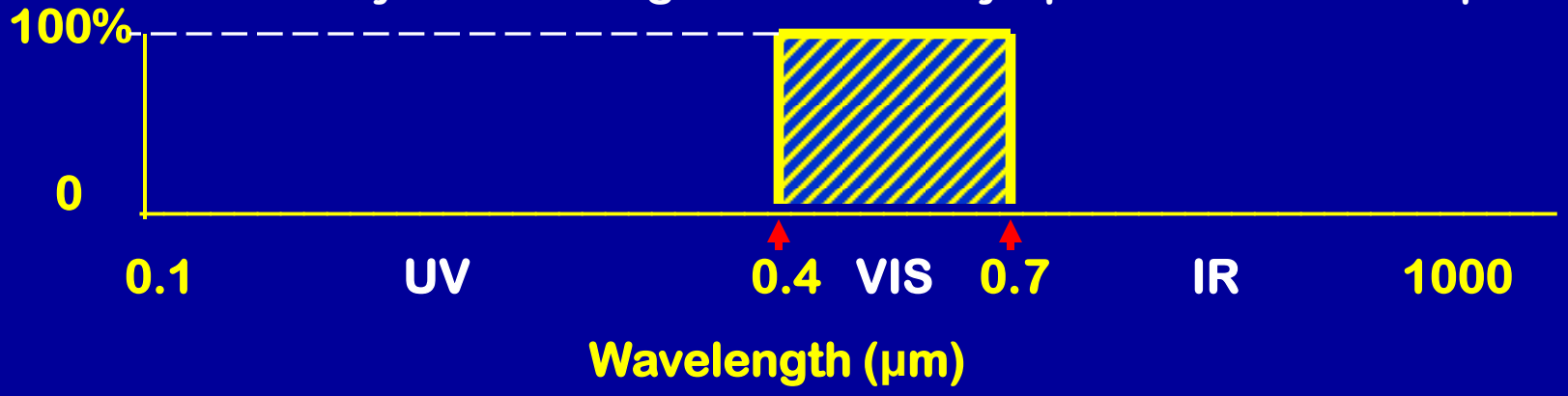
VERTICAL AXIS: % of energy at a given wavelength that is absorbed



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 . . . .

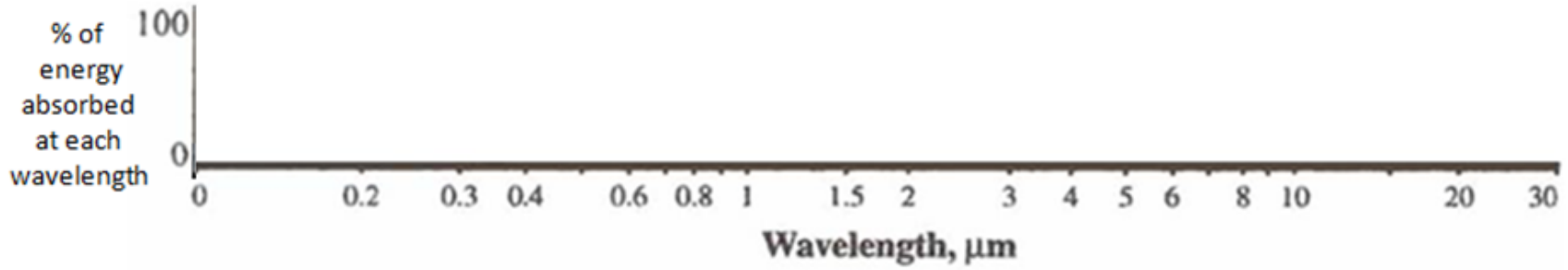
GROUP ASSIGNMENT G-1

Understanding Radiation, Absorption & Wavelengths of the Electromagnetic Spectrum

WORTH 10 pts

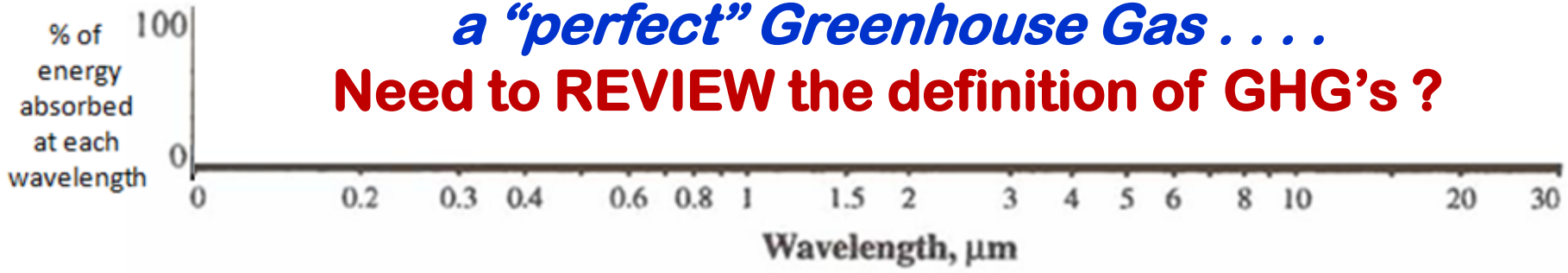
Q1. All UV but zero vis and zero IR?

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 ?

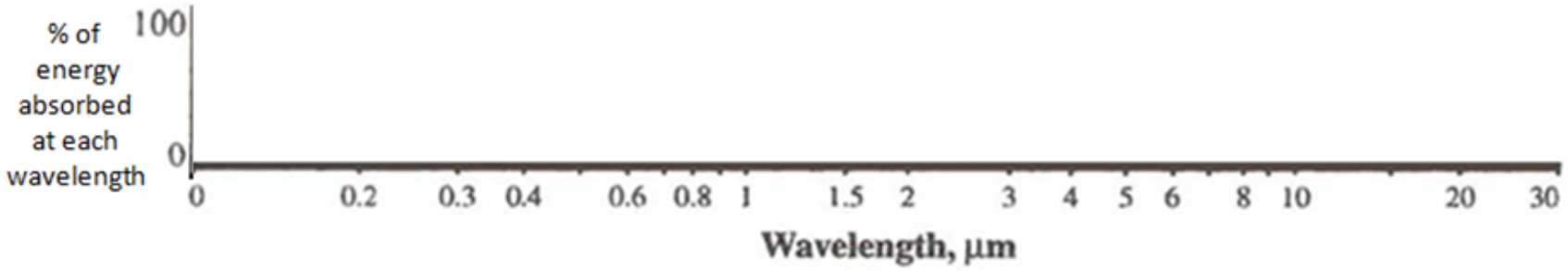
Review for Q2:

DEFINITION OF GREENHOUSE GASES

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

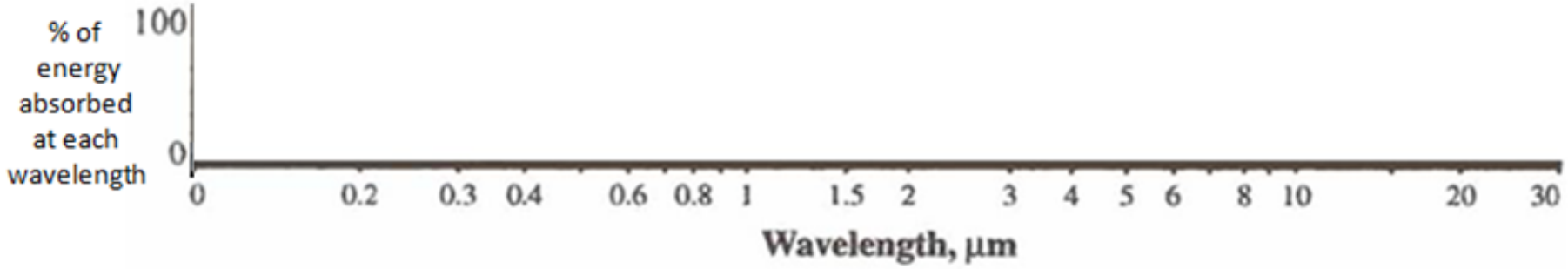
Q3. All UV & IR absorbed but VIS transmitted?

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**



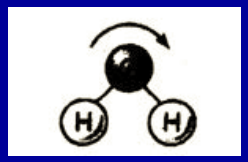
Q5. Is the hypothetical gas in Q4 likely to be a GREENHOUSE GAS?

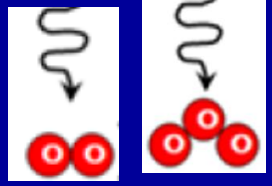
YES NO ***(circle one)***

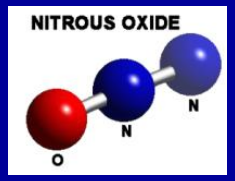
Briefly explain WHY you answered YES or NO: ***(in a few sentences)***

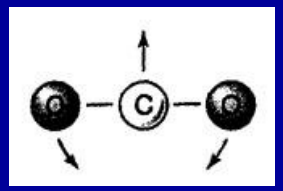
(discuss in your group first!)

Q6. (skip to p 34)







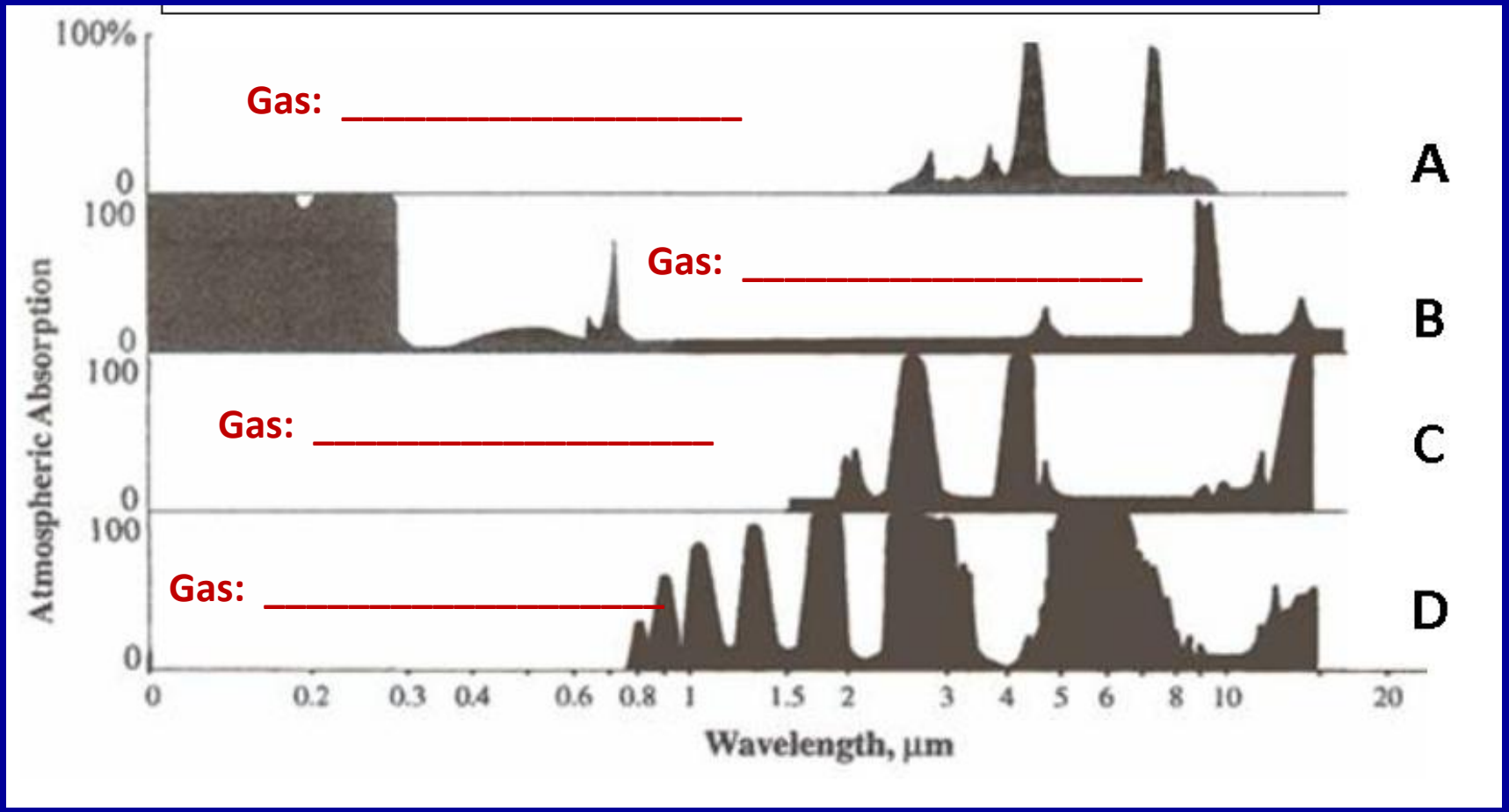


Here are the specific wavelengths each gas absorbs!

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	

Match the GAS with its Absorption Curve:

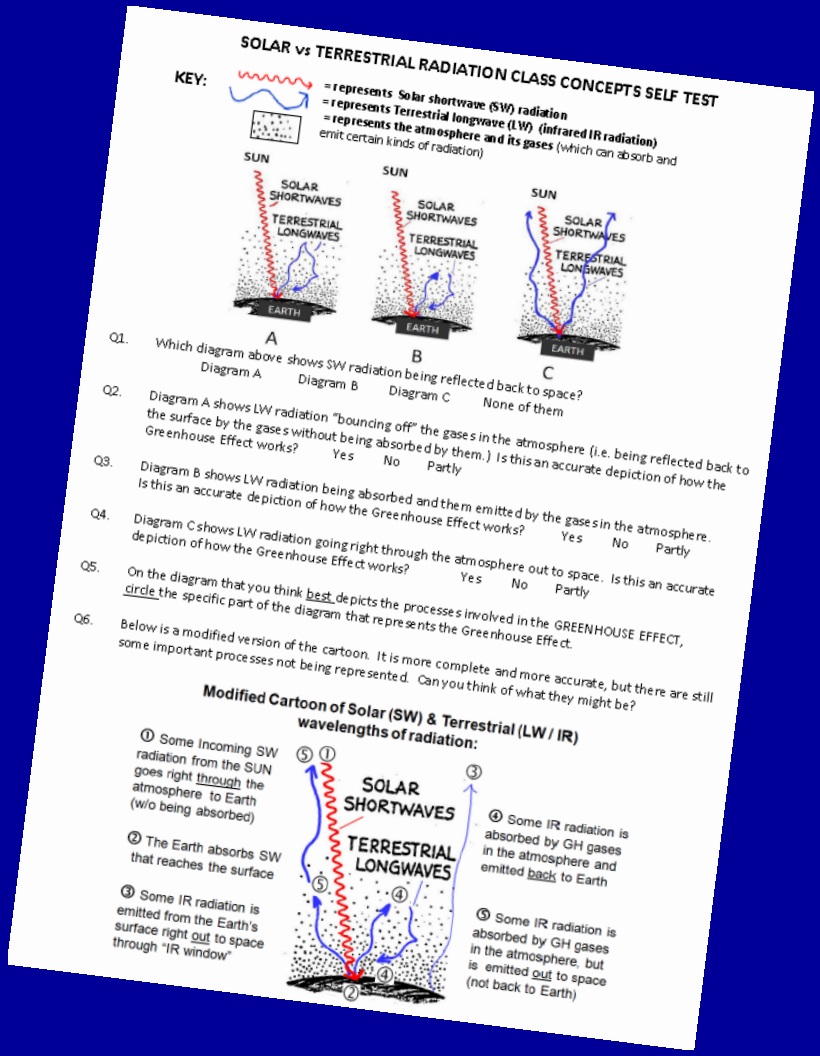
CHOICES: CO_2 H_2O $O_2 + O_3$ N_2O



Solar vs. Terrestrial Radiation Class Concepts Self Test

For Q7 – Q11
work individually or in pairs on the last page
(same as p 35 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 B 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)

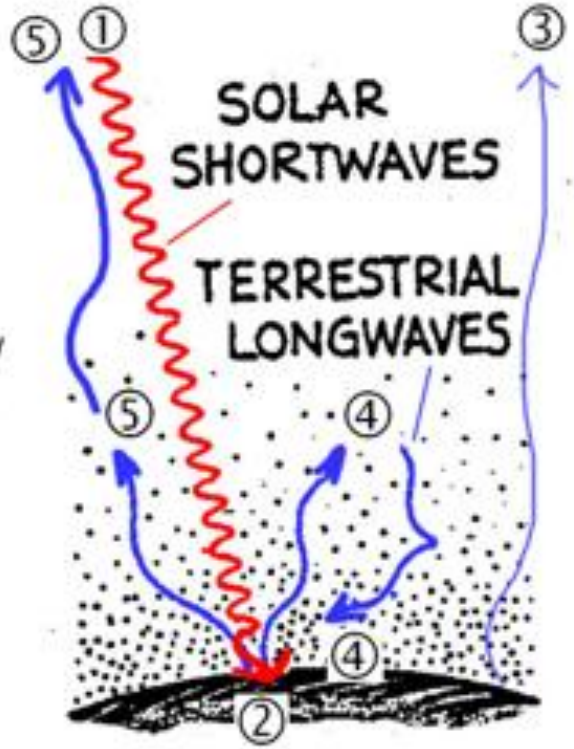
Will be a good review of Test #1

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"

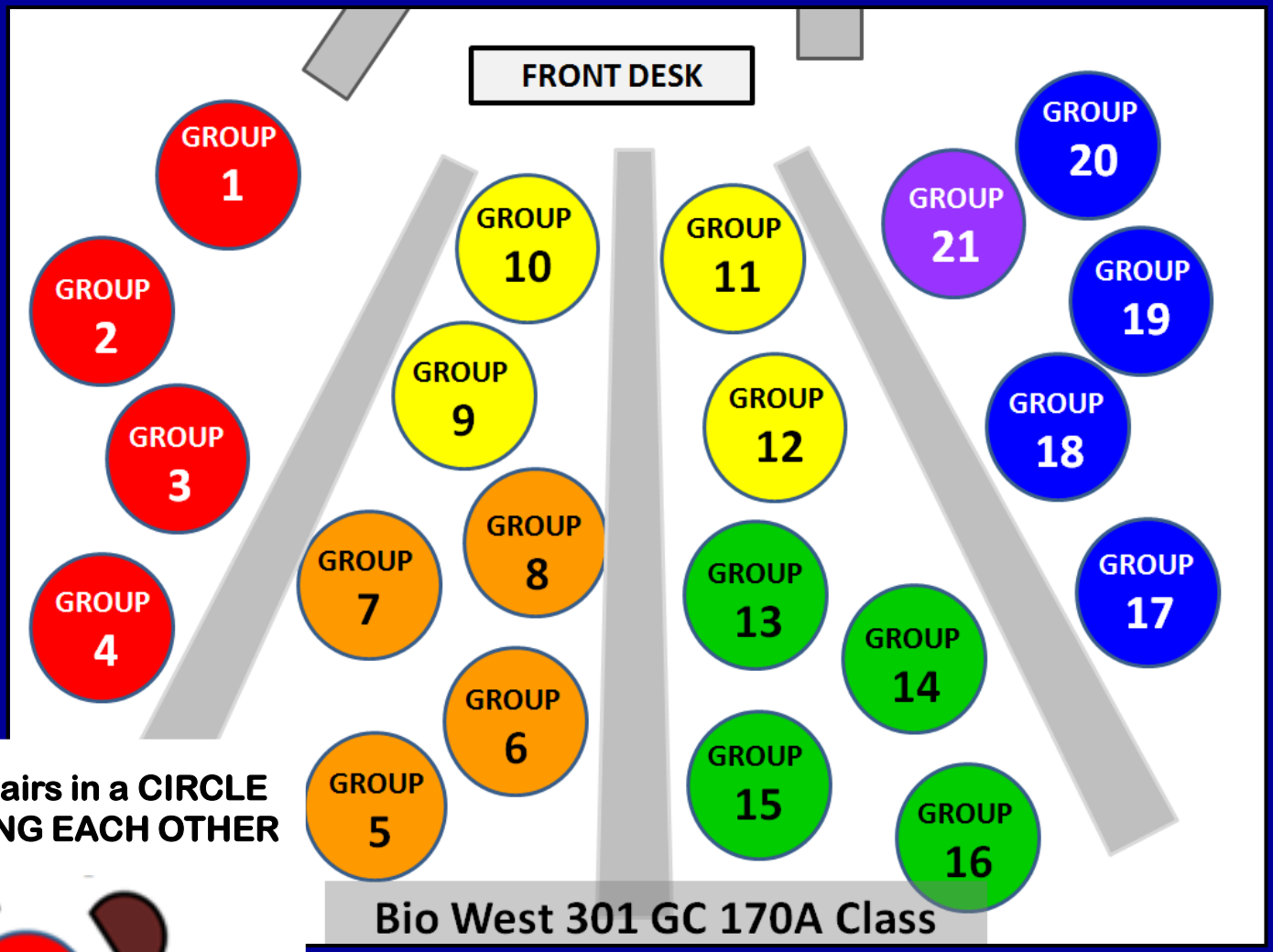


④ Some IR radiation is absorbed by GH gases in the atmosphere and emitted <u>back</u> to Earth

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

THINKING MORE DEEPLY: **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?**

You should be sitting in your assigned GROUP location:



Arrange your chairs in a CIRCLE so you are FACING EACH OTHER

FIRST THING YOU SHOULD DO IS BE SURE YOU ARE SITTING IN THE RIGHT GROUP!

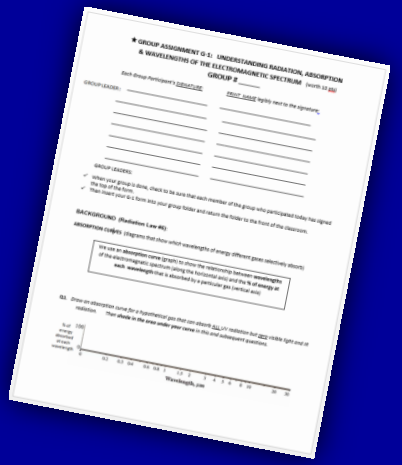
and then SIGN IN . . . . . .

When you get your GROUP FOLDER . . .

. . . Sign in with your SIGNATURE next to your name & photo on the GROUP LIST inside the folder

Add your Nickname if you like!

Then sign today's Group Assignment Form:



G-1 Group Assignment Form

Enter your GROUP # ➔ GROUP # ☐

	Each Group Participant's SIGNATURE:	*PRINT NAME legibly next to the signature:*
GROUP LEADER:	*Stanley Student*	Stan Student
	Stella Student	STELLA STUDENT

Your SIGNATURE

Your name PRINTED

TODAY's GROUP LEADER = Student whose last name is 1st in the ALPHABET on ther Group List

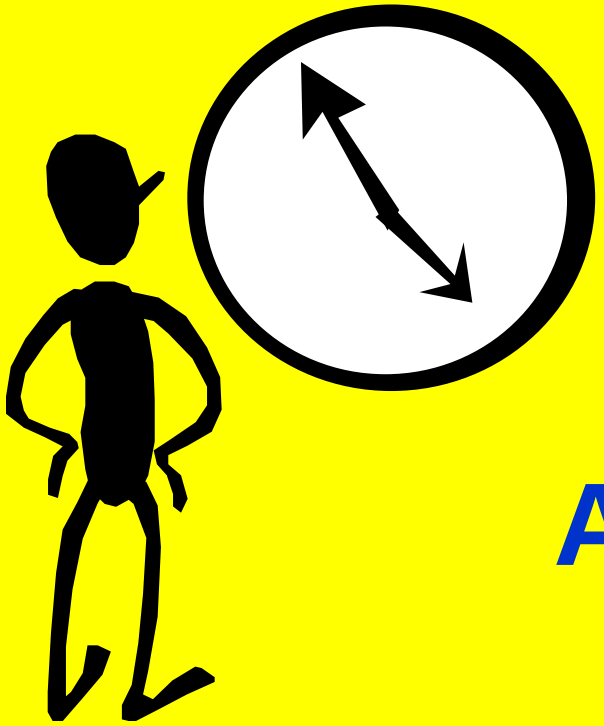
LEADER passes the GROUP FORM around so each student SIGNS IT & PRINTS HIS /HER NAME

When your group is done with Q11, return your folder to the front of the classroom.

Then return to your group and work on the "Thinking More Deeply" question (Q6) on the bottom of p 35 in Class Notes.

The CORRECT G-1 ANSWERS WILL BE GIVEN WHEN ALL FOLDERS ARE IN

OK – LETS GET TO WORK!

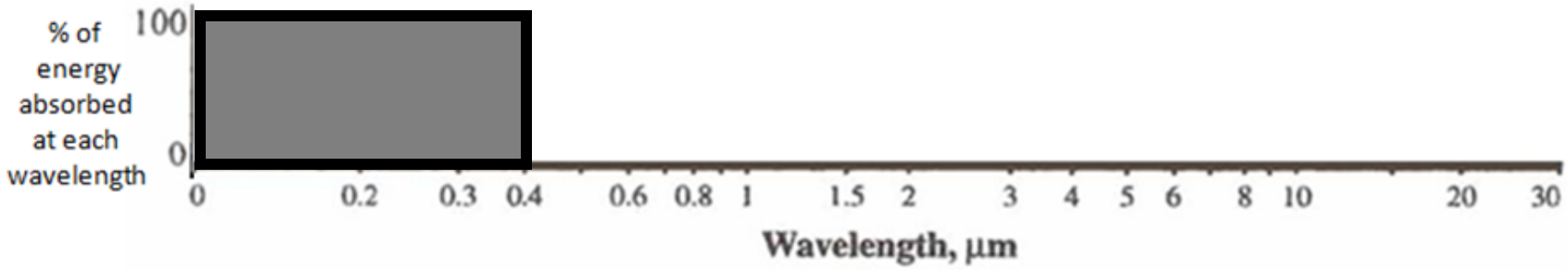


IT'S TIME TO
WRAP IT UP
AND QUIET DOWN

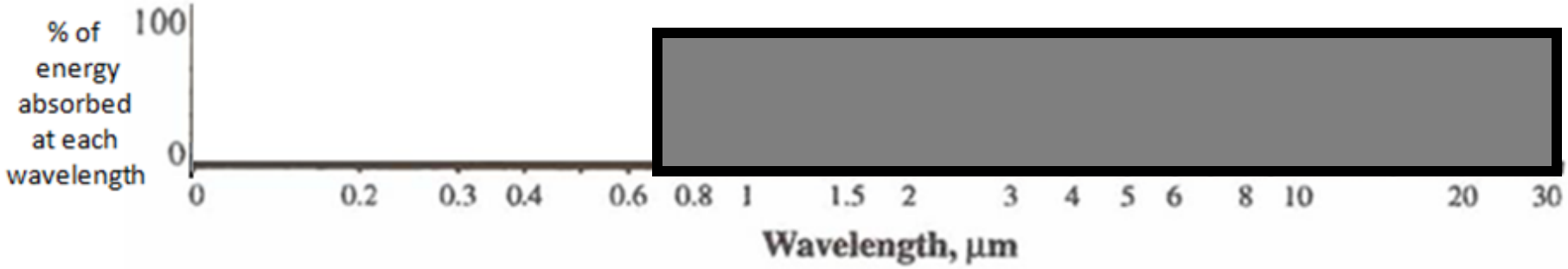
ALL FOLDERS IN?

THE ANSWERS . . .

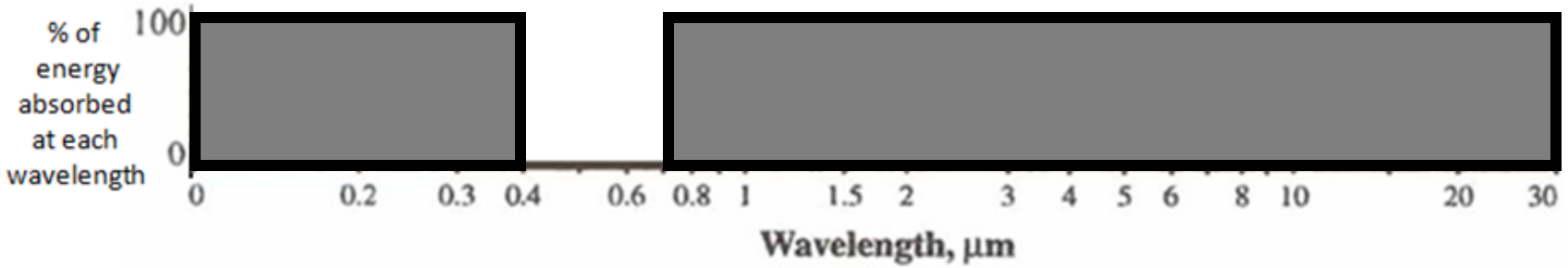
Q1. *Draw an absorption curve for a hypothetical gas that can absorb ALL UV radiation but zero visible light and IR radiation. Then* ***shade in the area under your curve*** *in this and subsequent questions.*



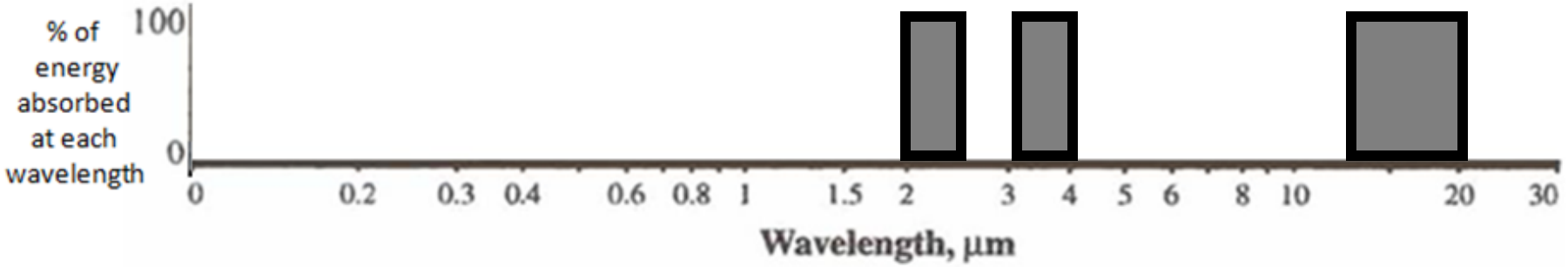
Q2. *Draw an absorption curve for a "perfect" greenhouse gas that absorbs ALL IR radiation, but no visible or UV:*

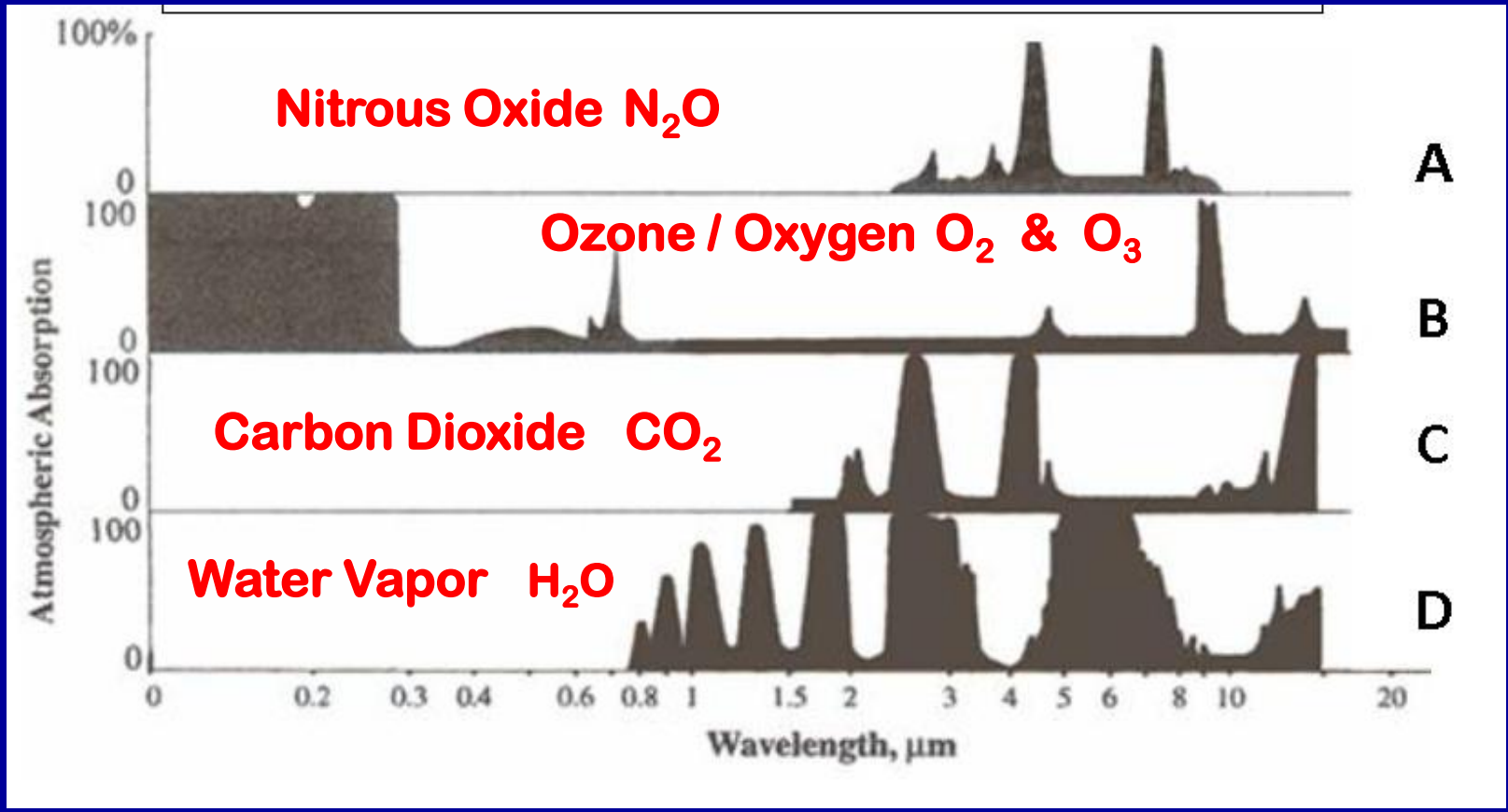


Q3. *Draw an absorption curve for a hypothetical gas that absorbs ALL UV radiation and ALL IR radiation, but leaves a "WINDOW" open for visible light, allowing the visible light wavelengths to pass through the gas unimpeded <u>without</u> being absorbed:*



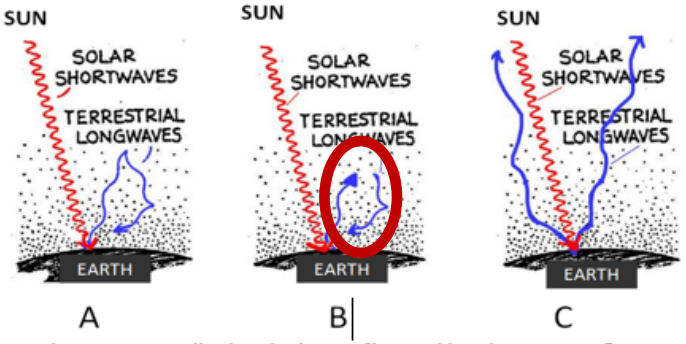
Q4. *Draw an absorption curve for a hypothetical gas that can absorb 100% of the IR radiation in these three wavelength bands*: **band from 2 to 2.5 µm** **band from 3 to 4 µm** **band from 13 to 20 µm**




Nitrous Oxide N_2O
Ozone / Oxygen O_2 & O_3
Carbon Dioxide CO_2
Water Vapor H_2O
A
B
C
D
100%
0
100
0
100
0
100
0
Atmospheric Absorption
0
0.2
0.3
0.4
0.6
0.8
1
1.5
2
3
4
5
6
8
10
20
Wavelength, μm

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 & emit certain kinds of radiation)



Q7. Which diagram above shows SW radiation being reflected back to space?

Diagram A *Diagram B* *Diagram C* *None of them*

Q8. **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*

Why or Why not? _____

_____

Q9. **Diagram B** shows LW radiation being absorbed and them emitted by the gases in the atmosphere. Is this an accurate depiction of how the **Greenhouse Effect** works? *Yes* *No* *Partly*

Why or Why not? _____

_____

Q10. **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

Why or Why not? _____

_____

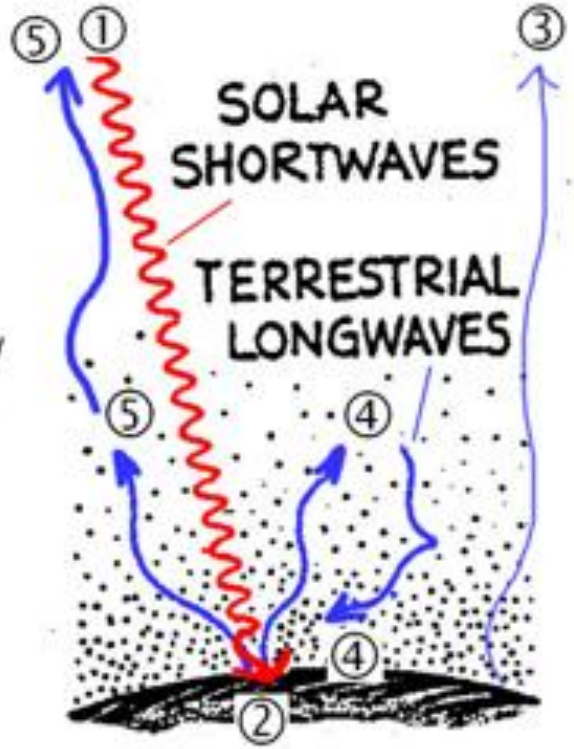
Q11. On the diagram above that you think **best depicts the processes involved in the GREENHOUSE EFFECT (A, B or C), circle** the specific part of the diagram that represents **the Greenhouse Effect.**

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)

THINKING MORE DEEPLY: **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?**

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

- **REMINDER: TEST #1 is next class, in THIS classroom on: Thursday Sep 19th**

- **The "TOP TEN" Study Guide is posted in D2L under STUDY GUIDES.**

GOOD LUCK STUDYING!!!