

TOPIC # 6

ELECTROMAGNETIC RADIATION & THE ELECTROMAGNETIC SPECTRUM

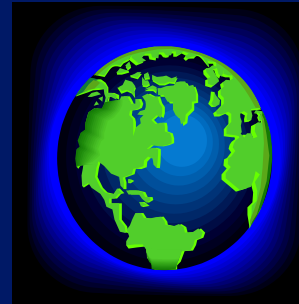
An important KEY to unlocking the
topics of: The GREENHOUSE
EFFECT, GLOBAL WARMING &
OZONE DEPLETION!



Class Notes: pp 31-34

GOAL for this class:

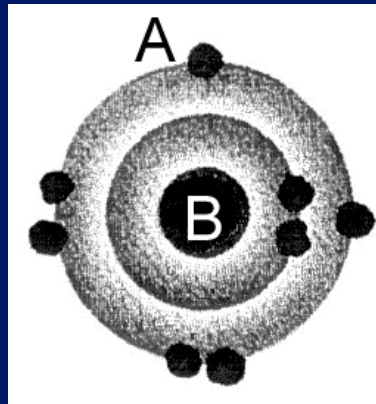
To understand the key aspects of
ELECTROMAGNETIC RADIATION
and the
ELECTROMAGNETIC SPECTRUM
that most directly relate to
GLOBAL CHANGE!



Two radiating bodies!



But first, some review -- from last Thursday:



Dot diagram of an
OXYGEN ATOM:

A = ELECTRON

B = NUCLEUS

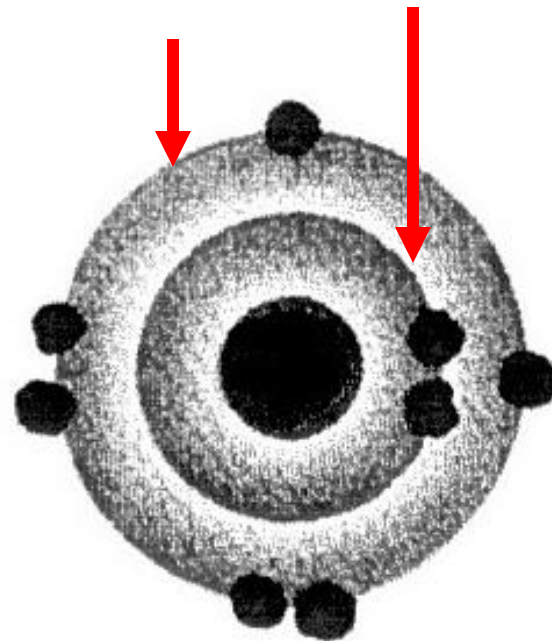
electrons = 8

protons = 8
(if atom is neutral)

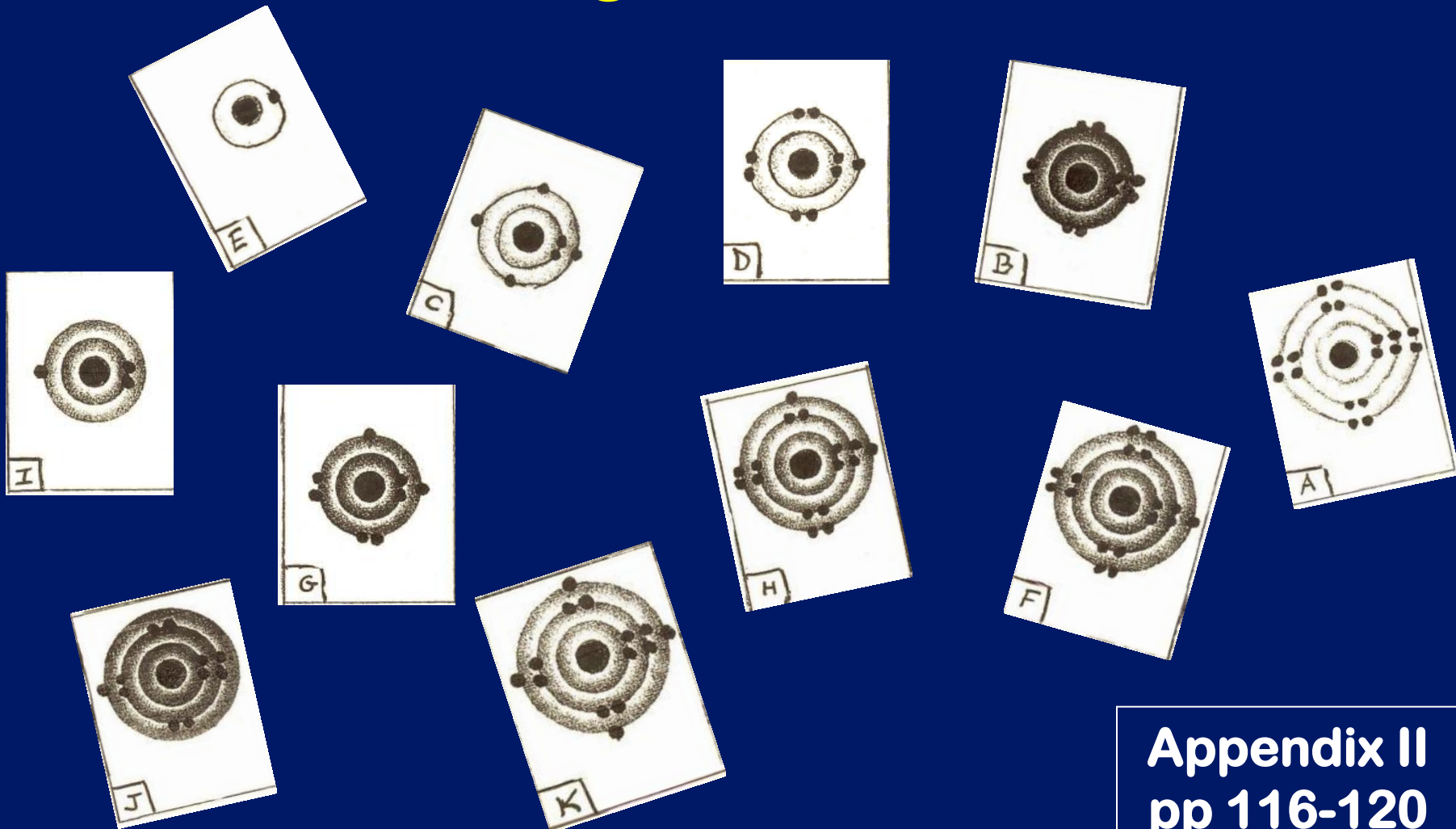
neutrons = 8

atomic # = 8

“shells” or energy levels



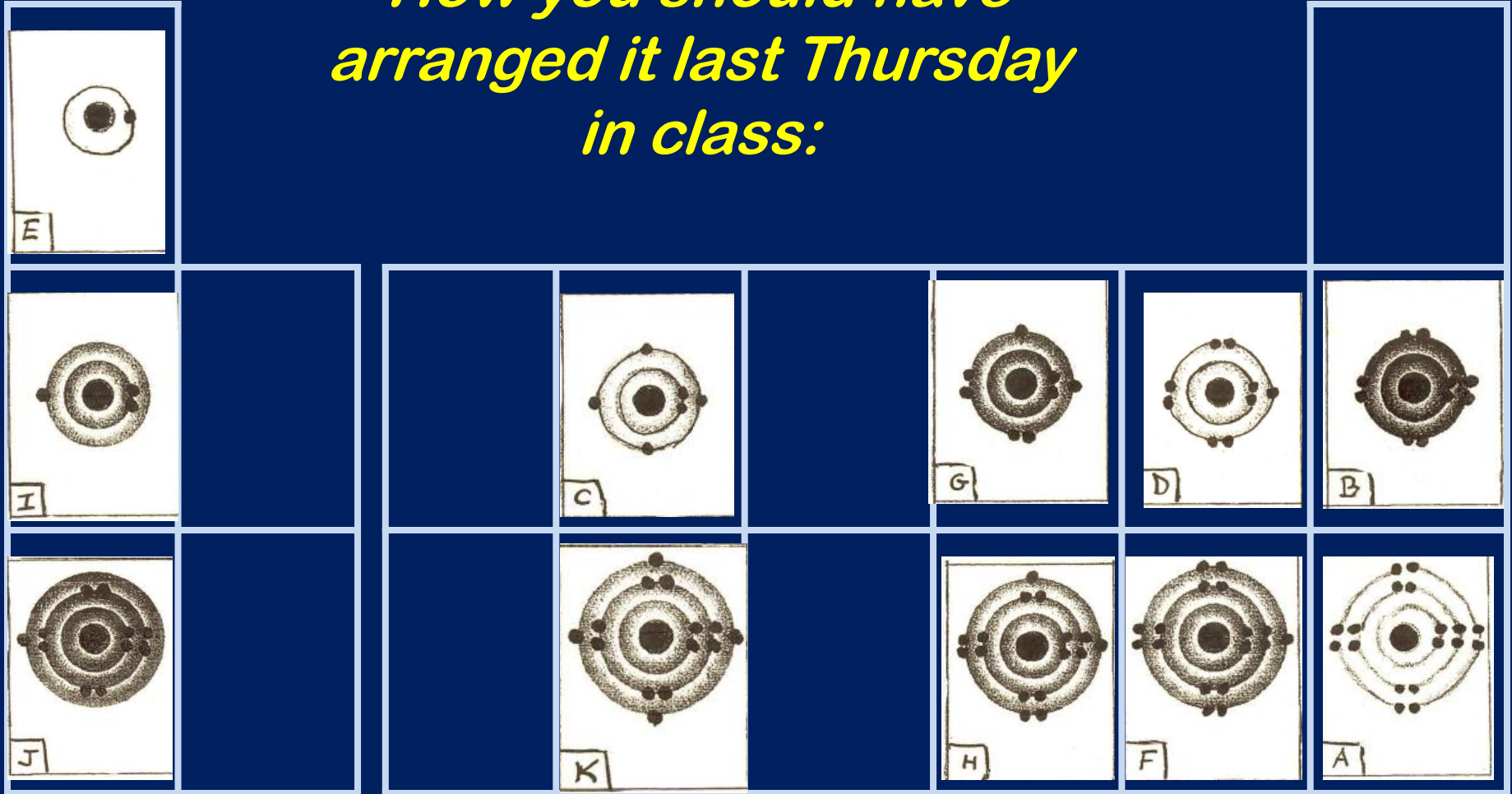
How is the PERIODIC TABLE OF THE ELEMENTS organized?



Appendix II
pp 116-120

How is the PERIODIC TABLE organized?

How you should have arranged it last Thursday in class:



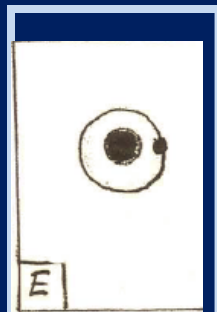
How is the PERIODIC TABLE organized?

1 electron in
outer shell in
this column

The Periodic Table is organized by:

of shells (rows)

of electrons in the outer shell (columns)



Row 1:
1 shell

4 electrons in
outer shell in
this column

6 electrons in
outer shell in
this column

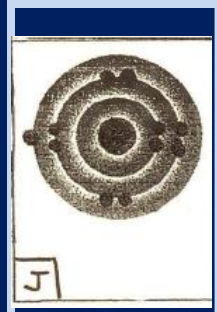
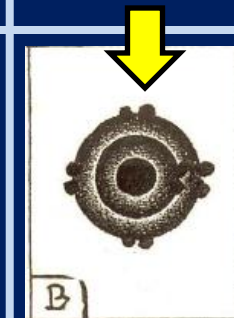
7
electrons

2
electrons

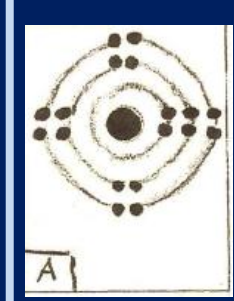
8 **
electrons



Row 2:
2 shells



Row 3:
3 shells

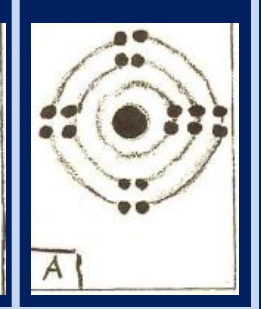
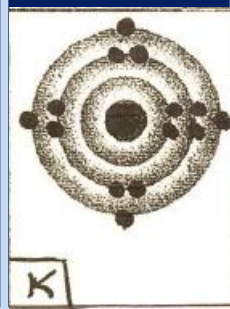
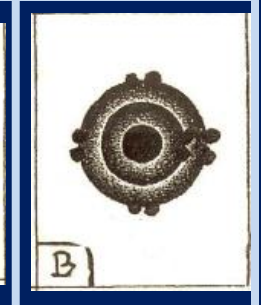
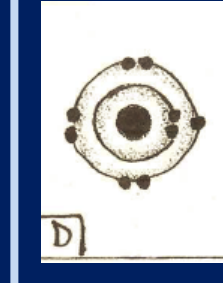
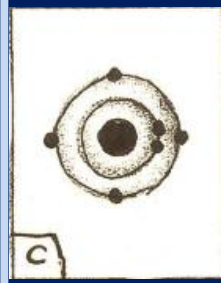
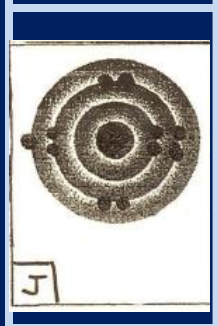
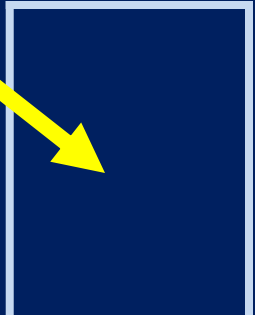
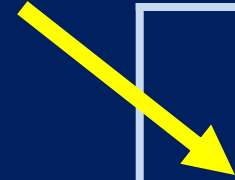
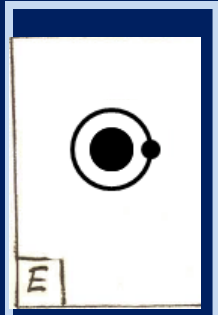


In Row 1 the outer shell is “full” with only 2 electrons in last column **

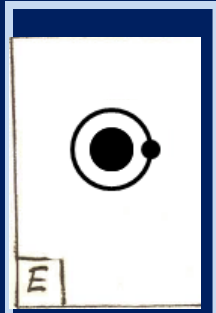
In Row 2 the outer shell is “full” with 8 electrons in last column

In Row 3 the outer shell is “full” with 8 electrons . . . and so forth

Q1. Which of these is the proper dot diagram for the element in this position ?



Q1. Which of these is the proper dot diagram for the element in this position ?



A



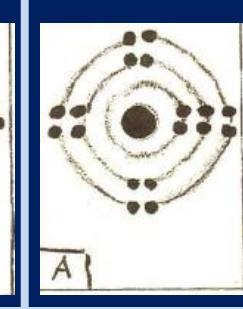
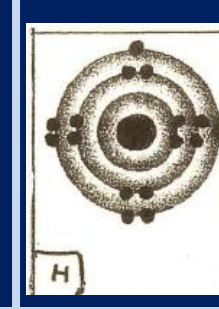
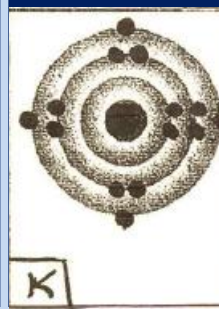
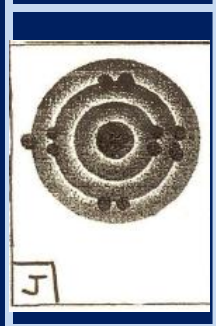
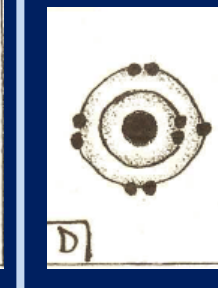
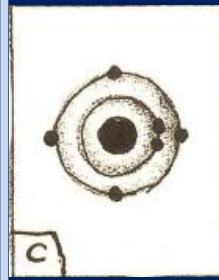
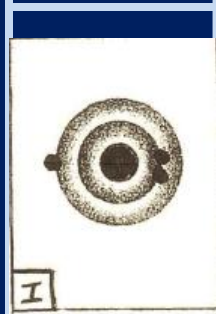
B



C



D



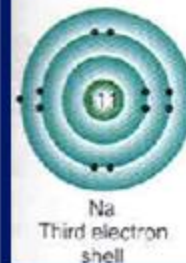
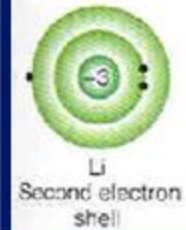
B is correct! The element is Helium (He)

Q2. Where does Boron fit in the Table?



*Answer with the correct box #
(choose from 1 – 7)*

1



2

3

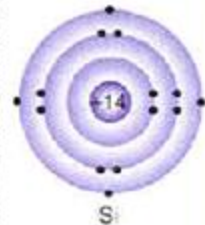


4

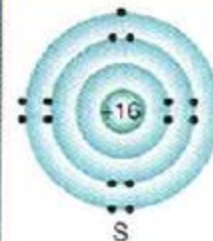


5

6



7

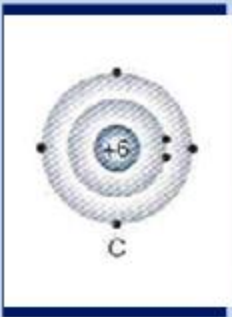
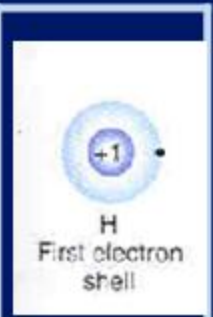


Q2. Where does Boron fit in the Table?

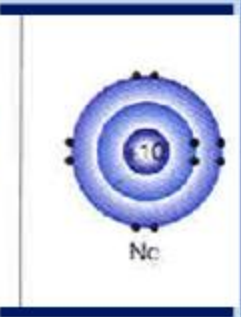
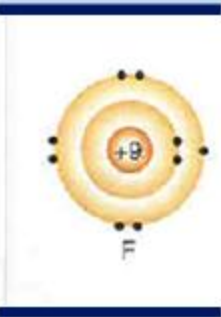
3 is correct!

(2 shells & 3 electrons in the outer shell)

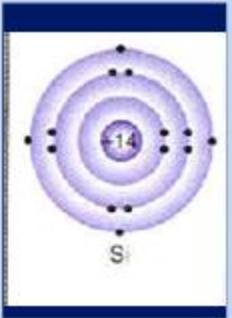
1



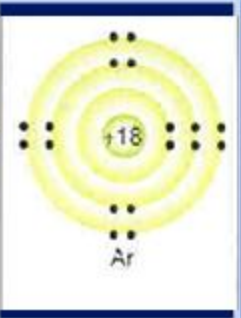
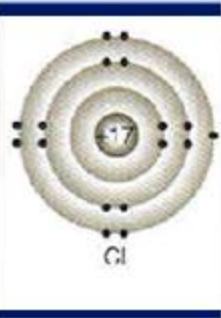
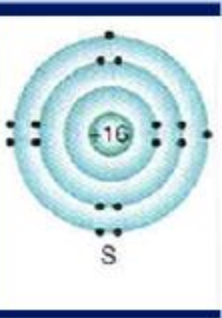
4

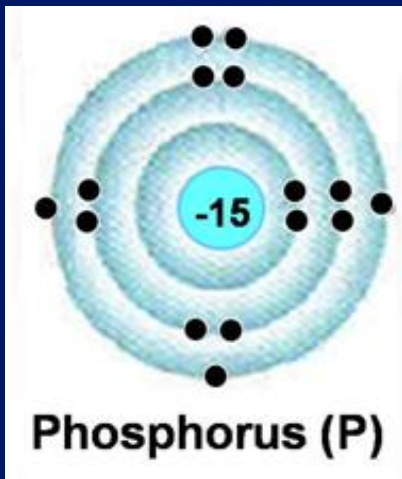


6

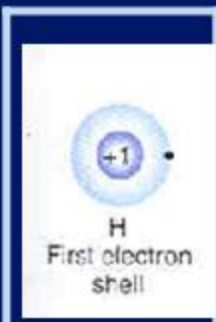


7

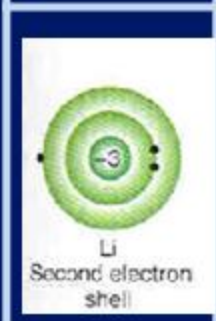




Q3. Where does Phosphorus fit in the Table?

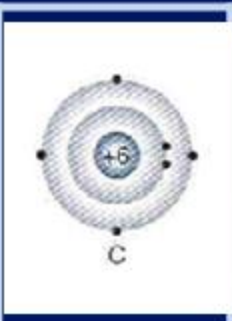


1

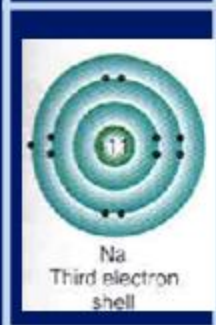
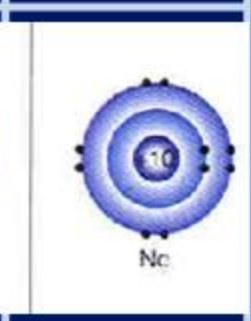
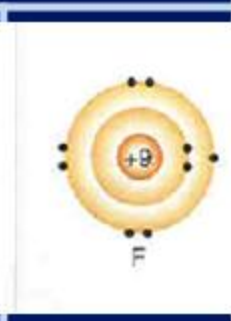
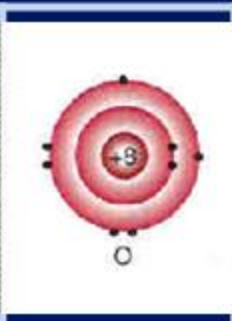


2

3

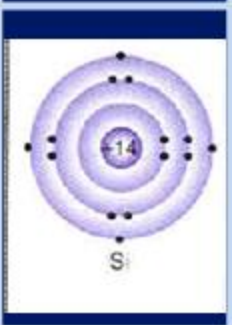


4

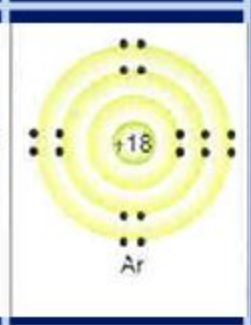
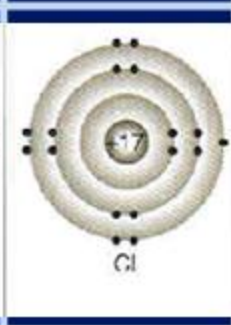
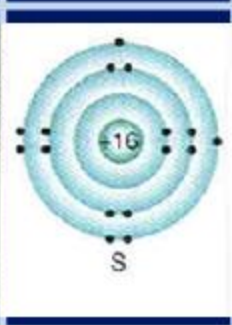


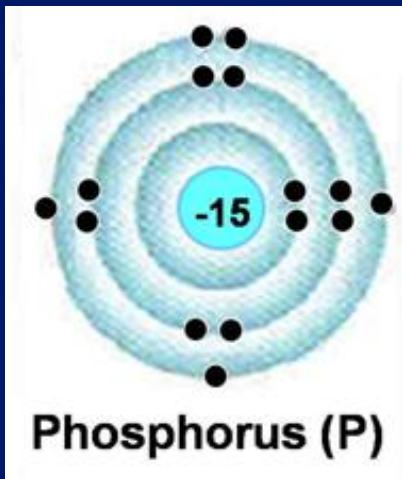
5

6



7



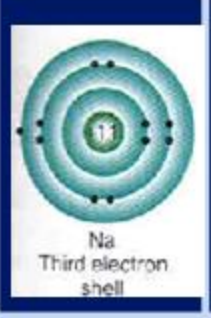
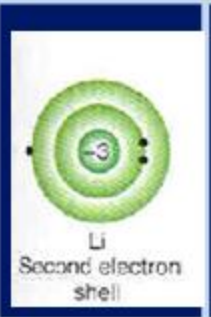


Q3. Where does Phosphorus fit in the Table?

7 is correct!

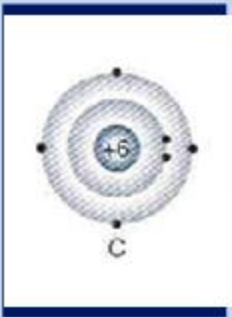
(3 shells & 5 electrons in the outer shell)

1

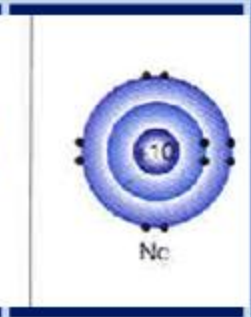
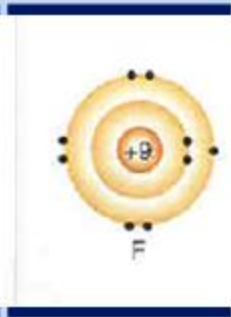
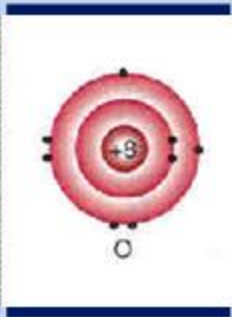


2

3

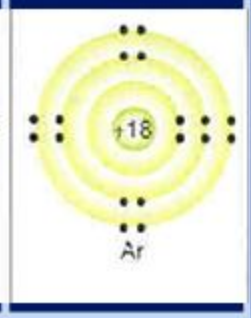
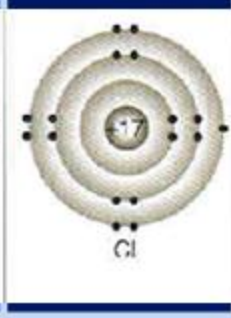
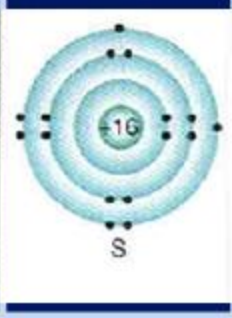
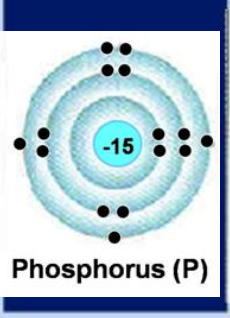
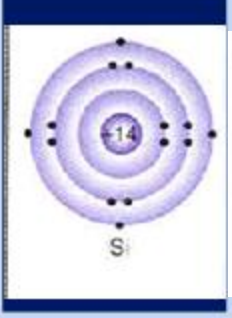


4



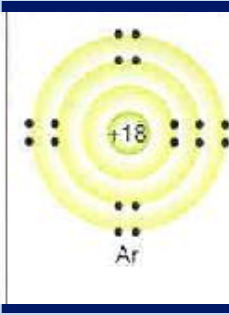
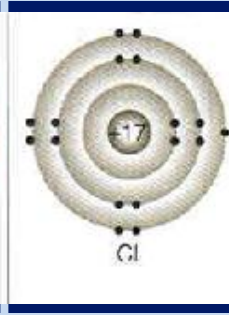
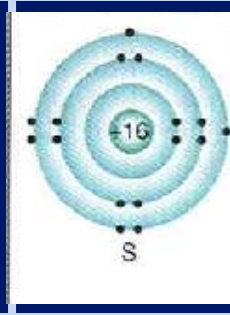
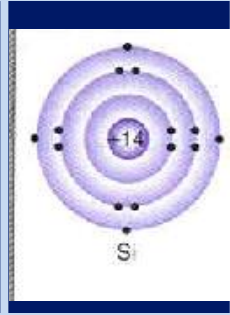
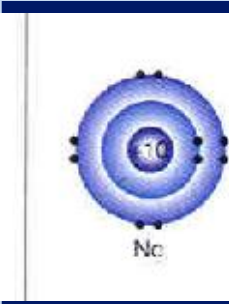
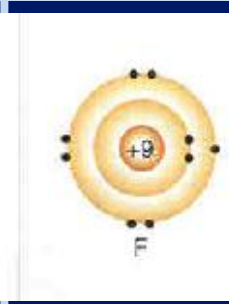
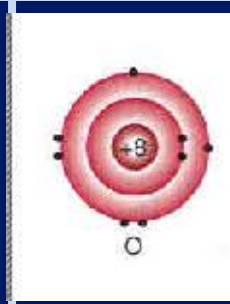
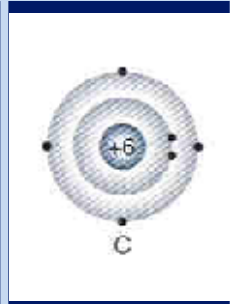
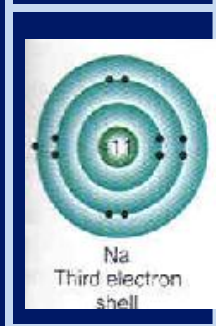
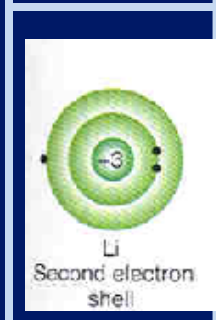
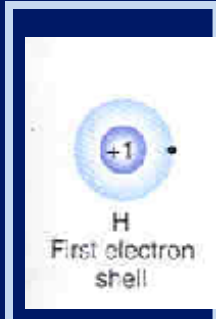
5

6



KEY POINT → Because each atom type (element) has a unique set of energy levels,

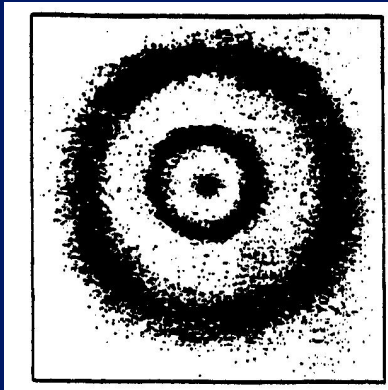
each atom type (e.g. H, He, etc.) **will ABSORB** over a **PARTICULAR SET OF Electromagnetic FREQUENCIES & WAVELENGTHS.**



Take notes

Review of last Thursday:

The Bohr
Model of
the Atom:

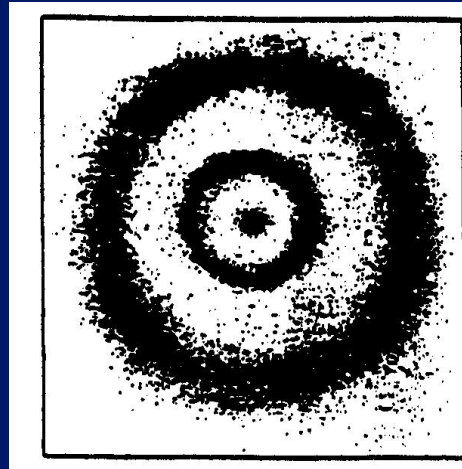


- The “empty” spaces represent areas with *little likelihood* of finding an electron
 - Dark areas represent places (or energy levels) where electrons are “allowed” to be
- . . . but how do they get from one level to another???**

Review
pp 24-25

The **quantum model** of the atom states that:

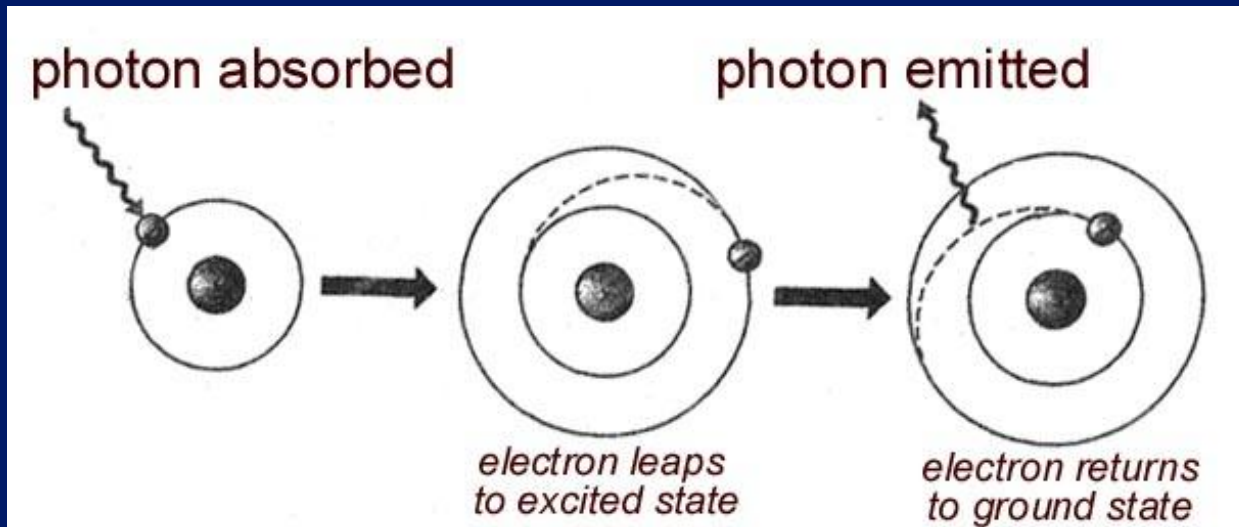
electrons can exist only in discrete allowed places within shells (or energy levels) and not in between.



Review
pp 24-25

The electrons move -- NOT according to Newtonian laws of motion

-- but according to
quantum mechanics.



**But what "causes" the leap?
And what does it have to
do with Global Change?**

**Review
pp 24-25**

TOPIC #6

ELECTROMAGNETIC

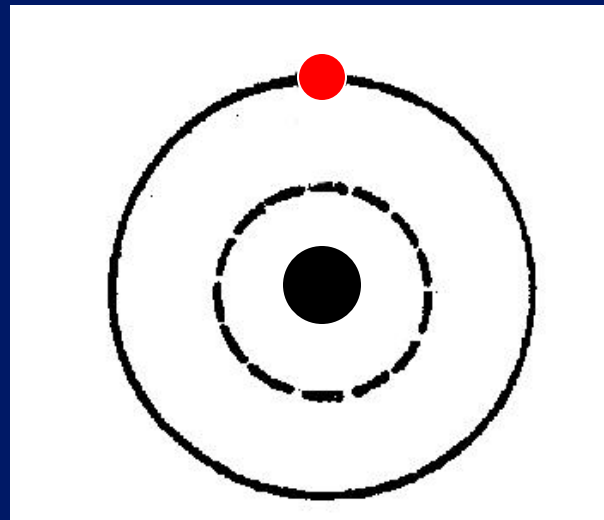
RADIATION

**Not only is the universe
stranger than we imagine, it is
stranger than we can imagine.
~Arthur Eddington**

An electron moves between shells or energy levels by “quantum leaps,”

i.e., it disappears from one energy level and reappears in another without ever traversing any of the positions in between!

What
causes
the
“leap” ?



- Electrons can be promoted to higher energy levels or even knocked free from their atoms in a variety of ways

One way is critical to global change processes:

it involves a packet of energy called a **PHOTON**

Energy in the form of **PHOTONS** is absorbed or emitted as electrons change energy levels within the structure of an atom.

Photons, NOT protons!

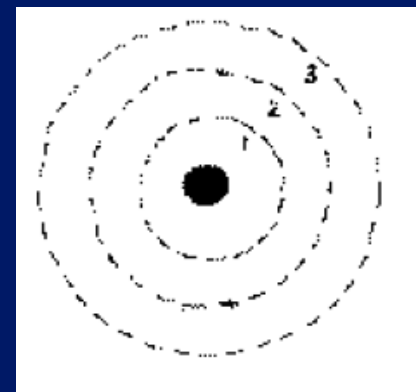
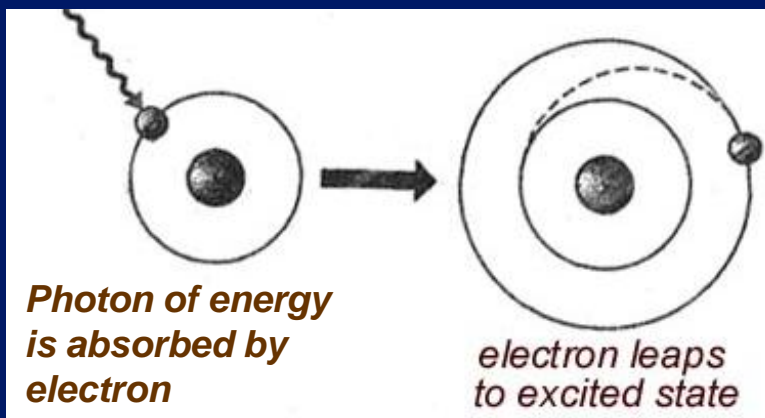
Photon =

A particle-like unit of electromagnetic energy (light), **emitted or absorbed** by an atom when an electrically charged electron changes state.

= also the form of a single packet of **ELECTROMAGNETIC ENERGY**

WHAT HAPPENS WHEN ELECTRONS CHANGE LEVELS:

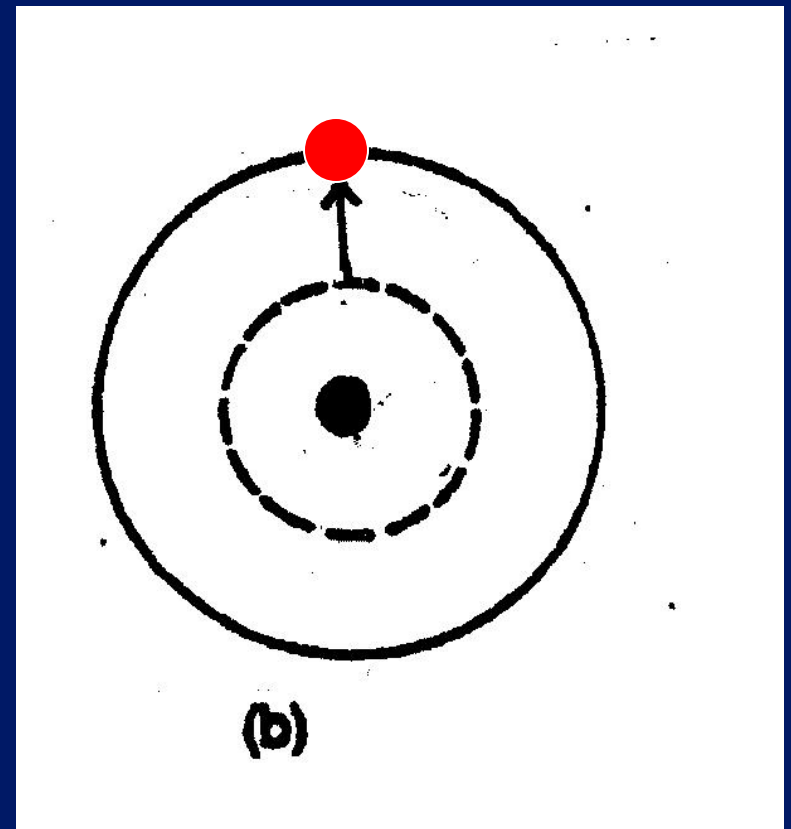
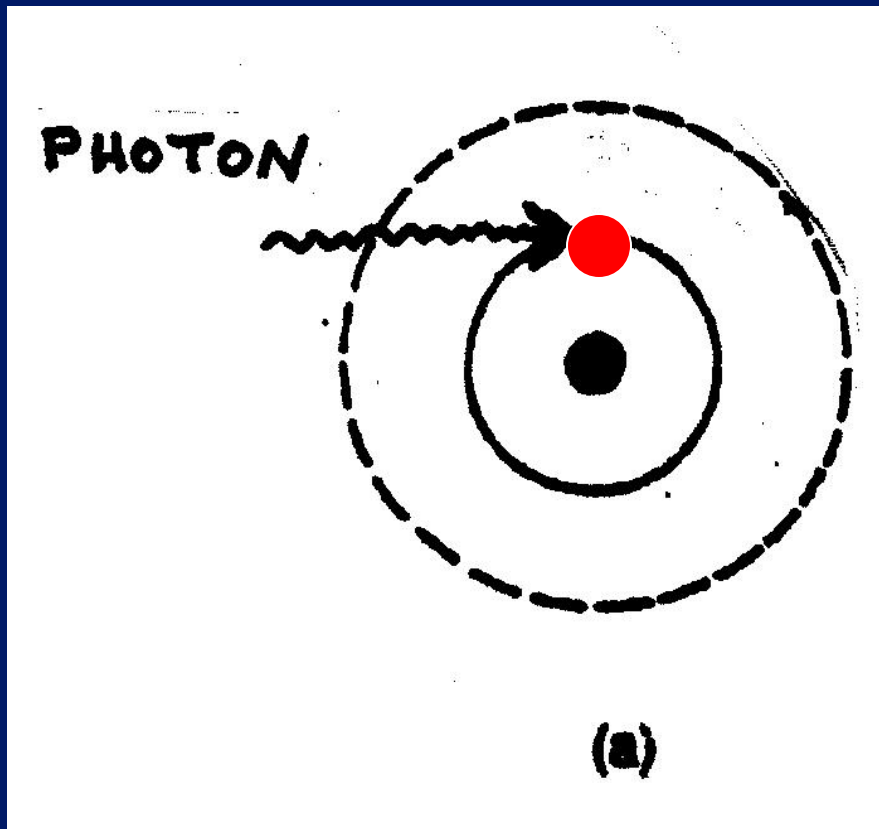
As an electron receives & **absorbs** electromagnetic energy (in form of a photon), it jumps from a **Lower** → **Higher** energy state (level).



Sketch it
yourself
←

WHAT HAPPENS WHEN ELECTRONS CHANGE LEVELS:

As an electron receives & **absorbs** electromagnetic energy (in form of a photon), it jumps from a **Lower** → **Higher** energy state (level).



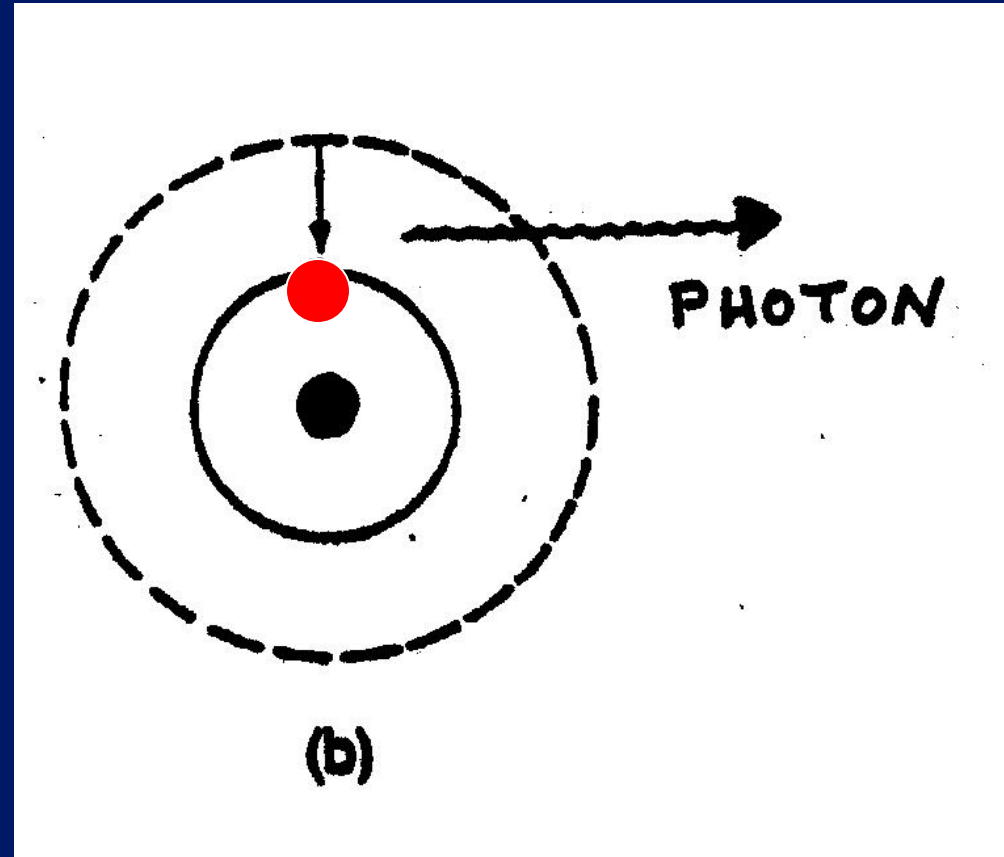
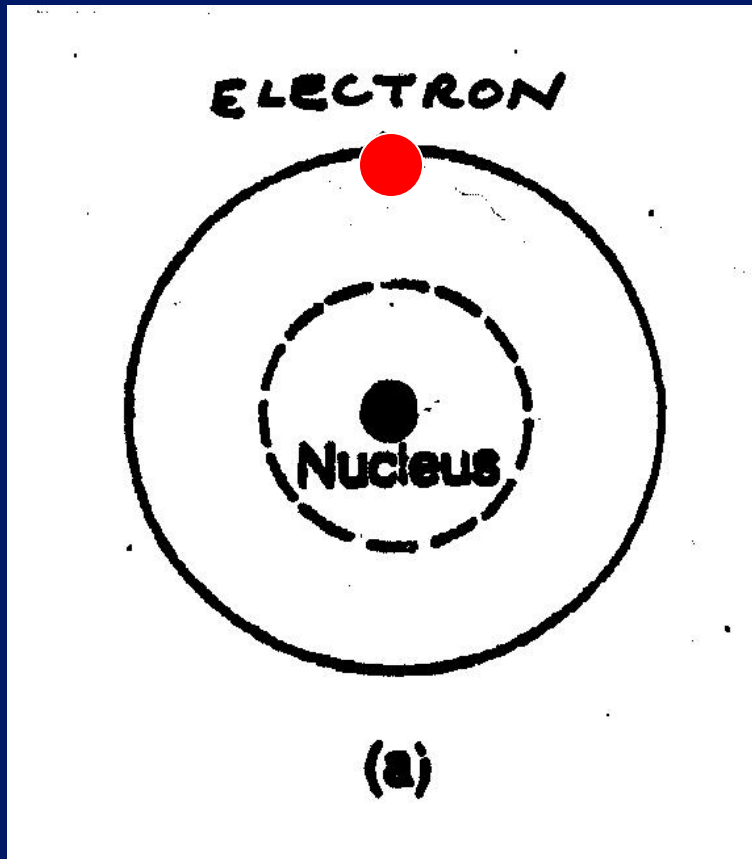
(a) An electron in its ground state, about to absorb a photon

(b) The electron leaps to a higher level as the photon is absorbed

WHAT HAPPENS WHEN ELECTRONS CHANGE LEVELS:

As an electron **emits** or “**gives off**” electromagnetic energy (in form of a photon),

it **jumps from a Higher** → **Lower** energy state (level)



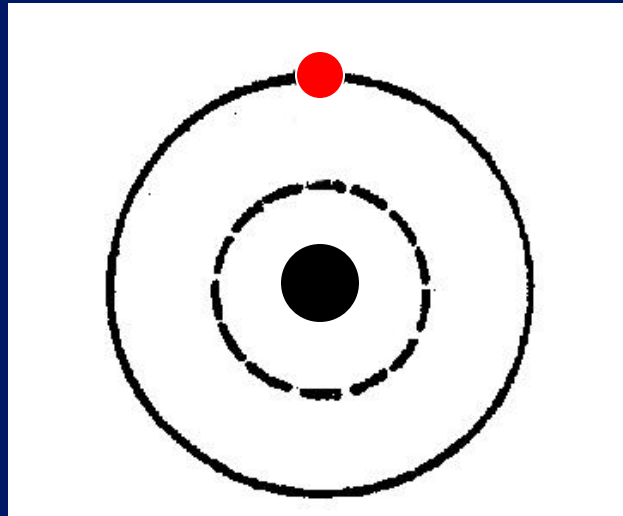
(a) An electron in an excited state.

(b) When the electron drops to a lower level, a photon is emitted.

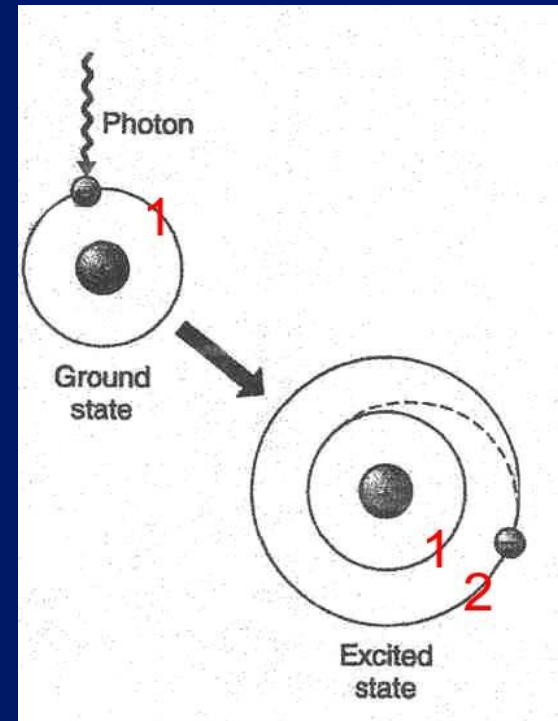
SUMMARY:

An electron moves between shells or energy levels by “**quantum leaps,**”

i.e., it disappears from one energy level and reappears in another without ever traversing any of the positions in between!

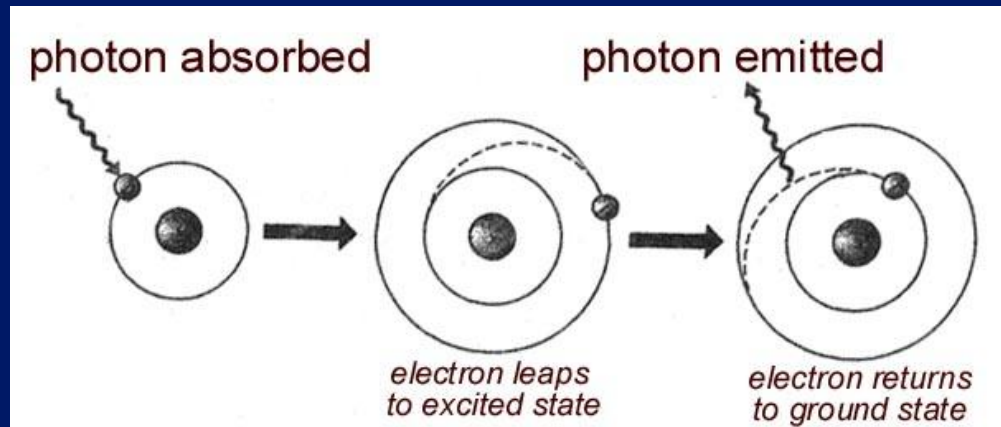


Another depiction →



RECAP: Electromagnetic Radiation

(under certain higher-energy conditions, e.g. light) exhibits a particle-like nature which we call PHOTONS.

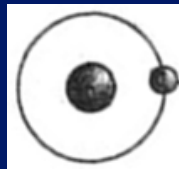


Photons are energy packets having a well-defined **wavelength** and **frequency**

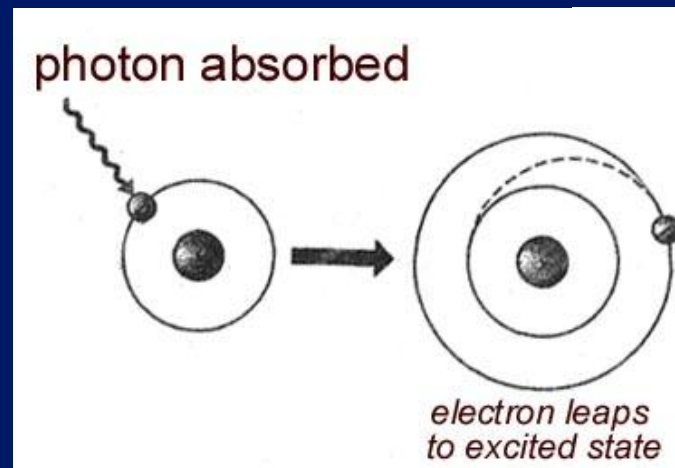
QUANTUM MECHANICS & the LINK to ABSORPTION OF ELECTROMAGNETIC ENERGY AT THE SUBATOMIC SCALE

- If a photon of electromagnetic energy strikes an atom,
- and if the **FREQUENCY** of the electromagnetic radiation is such that it is equal to:
the *difference* in the energy
of the ground level & the first excited level,
- the electron **ABSORBS** the photon energy and . . .
- the electron is “moved” (quantum leap) to “Level 2”

Hydrogen atom:



with electron in
ground state
(Level 1 shell)

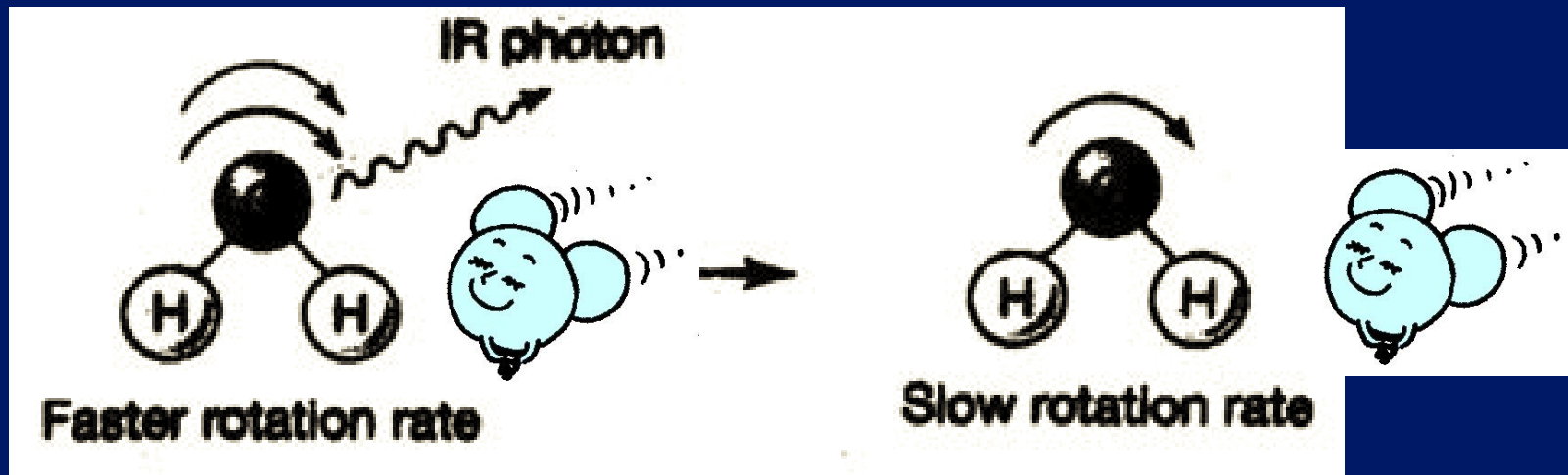


Quantum Behavior of MOLECULES

Quantum leaps of electrons between discrete energy levels (shells) **within atoms** involve photons which are absorbed or emitted, but

Quantum theory also involves the **behavior of molecules**: the molecular-scale motion (i.e., rotation, bending, & vibration) of molecules!





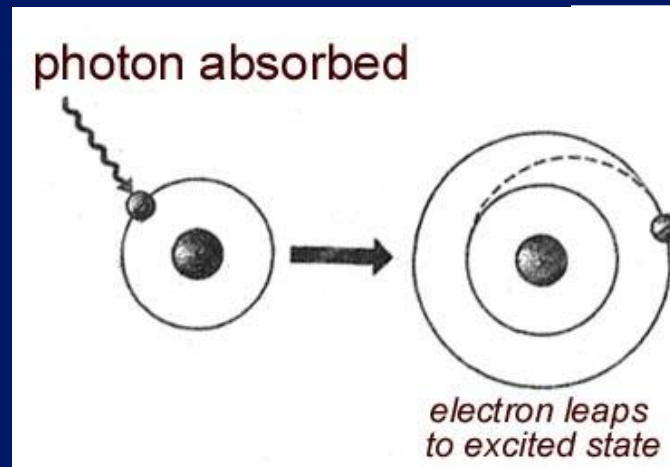
LINK TO GLOBAL CHANGE:

Molecular motions in the gases WATER VAPOR and CARBON DIOXIDE (H₂O and CO₂) explain why some gases (e.g., H₂O, CO₂) contribute to the greenhouse effect and others (e.g., O₂, N₂) do not!!

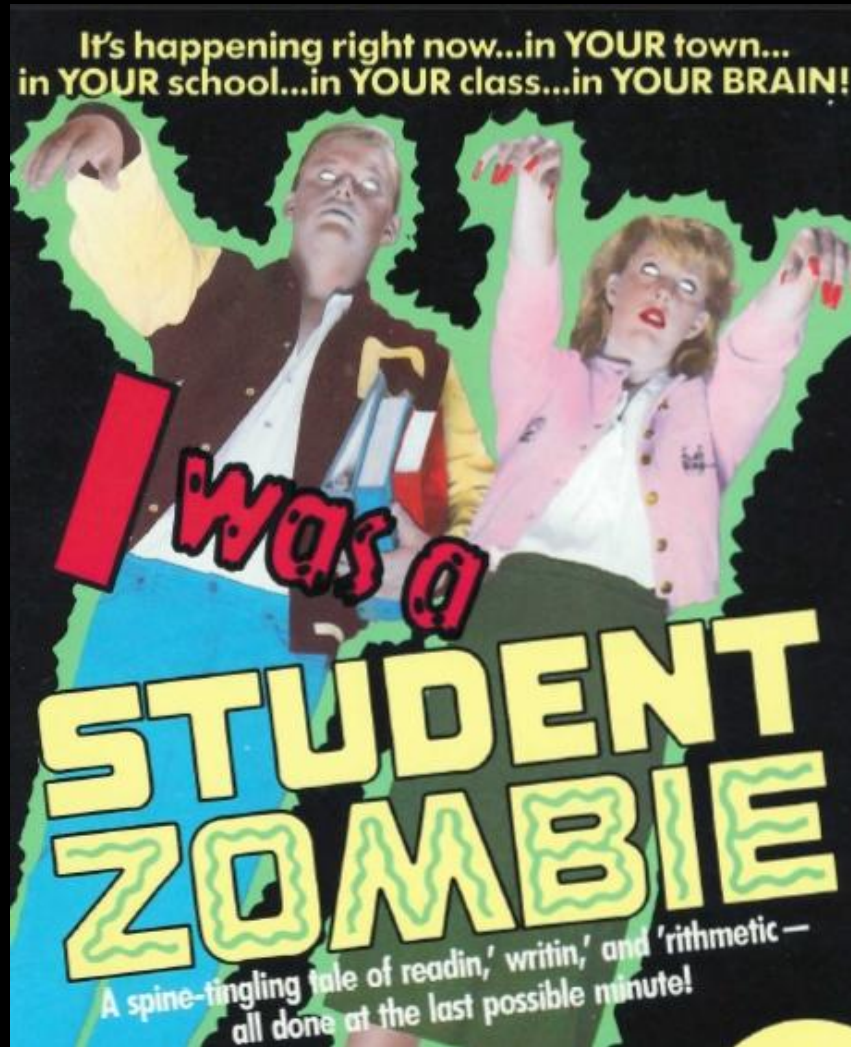
(more on this later . . .)

Recap of Key Concept:

ENERGY & MATTER INTERACT !!!



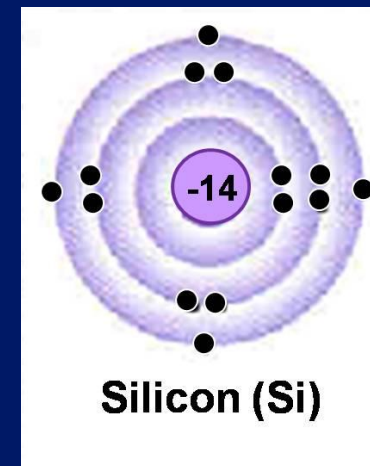
**ZOMBIE
BREAK !**



PRESENTING A New Feature: **The SUSTAINABILITY SEGMENT!!!**



Staring:
The **SUN** & 



See also ***“Inside a Solar Cell”*** at:

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

You can watch the film on your own in D2L – click the Videos icon.

We watched the first 10 minutes in class today – and will watch more in subsequent classes.

*See also “**Inside a Solar Cell**” at:*

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

TOPIC # 6 (cont.)
THE
ELECTROMAGNETIC
SPECTRUM

Class Notes:
pp 33-34

**Come forth into the
light of things.**

Let nature be your teacher.

~ William Wordsworth

Frequency, Wavelengths & Energy of Photons



Energy emitted from the sun
(i.e, electromagnetic radiation)
exhibits both a **wave-like**
(**electromagnetic wave**)
and
particle-like (**photon**) nature.



**Both Sun & Earth
are radiating
energy**

**. . . at different
electromagnetic
wavelengths**

**. . . . and at different
frequencies**

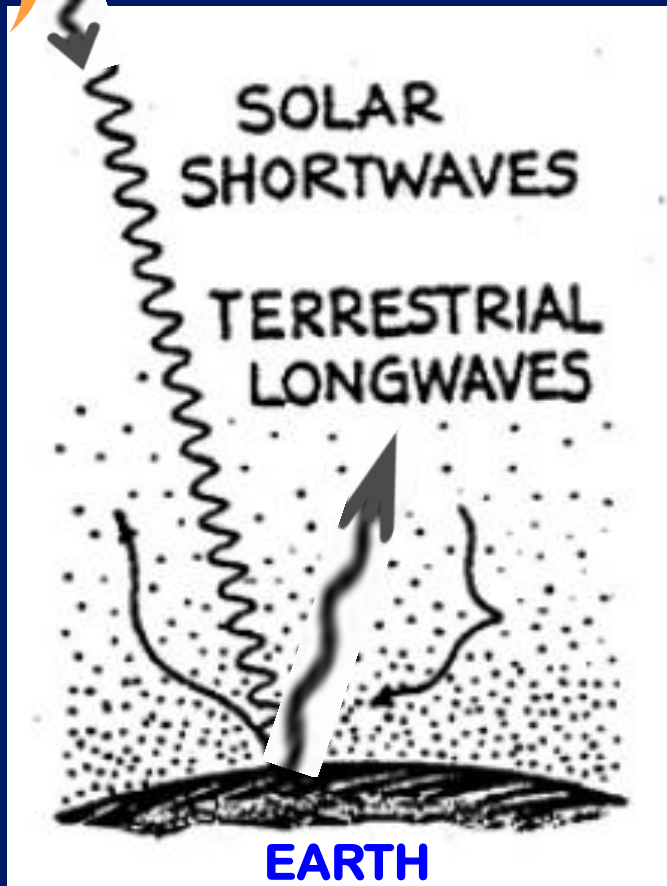
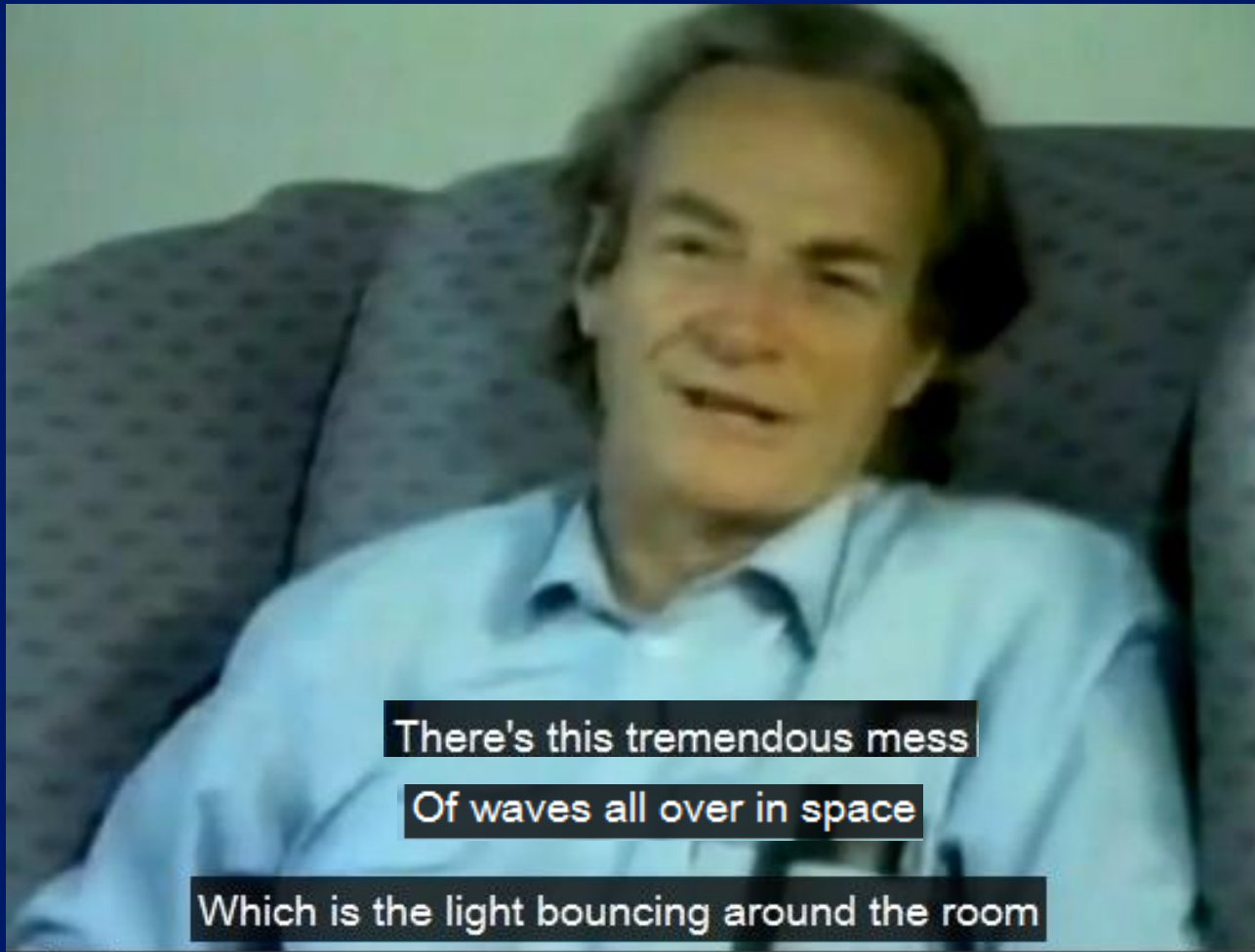


Figure on p 33

Quantum physicist Richard Feynman



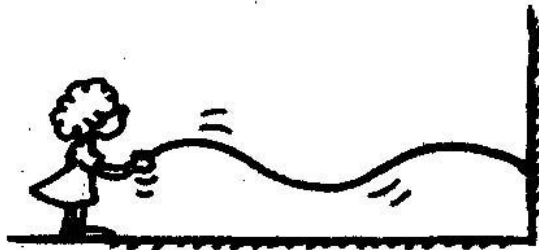
There's this tremendous mess

Of waves all over in space

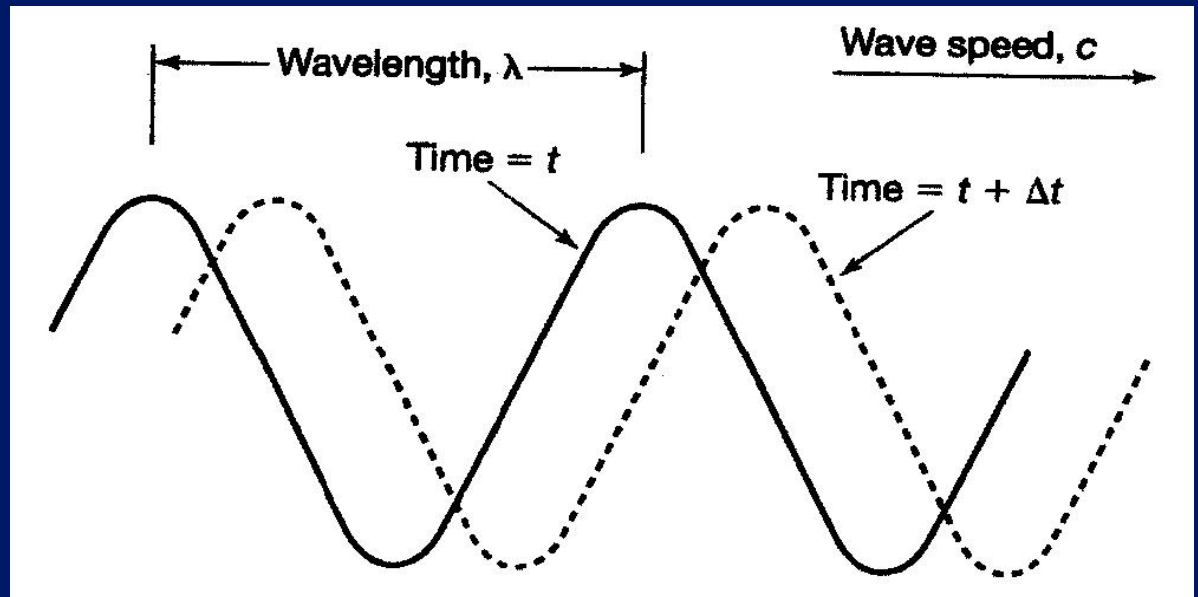
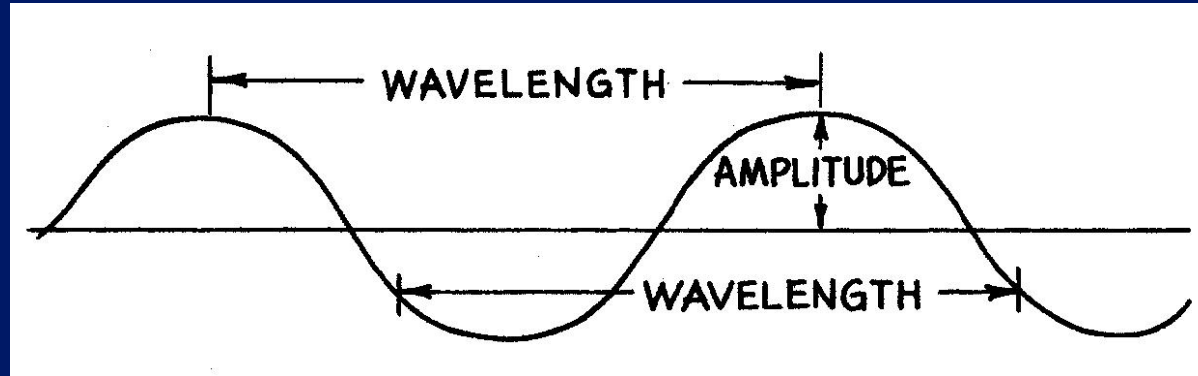
Which is the light bouncing around the room

And going from one thing to the other

Wavelengths



NOTE: Shorter wavelengths are produced when the rope is shaken more vigorously.



Quantifying Frequency & Wavelengths

First we'll talk about the WAVE-like behavior of electromagnetic energy:

Wave terminology:

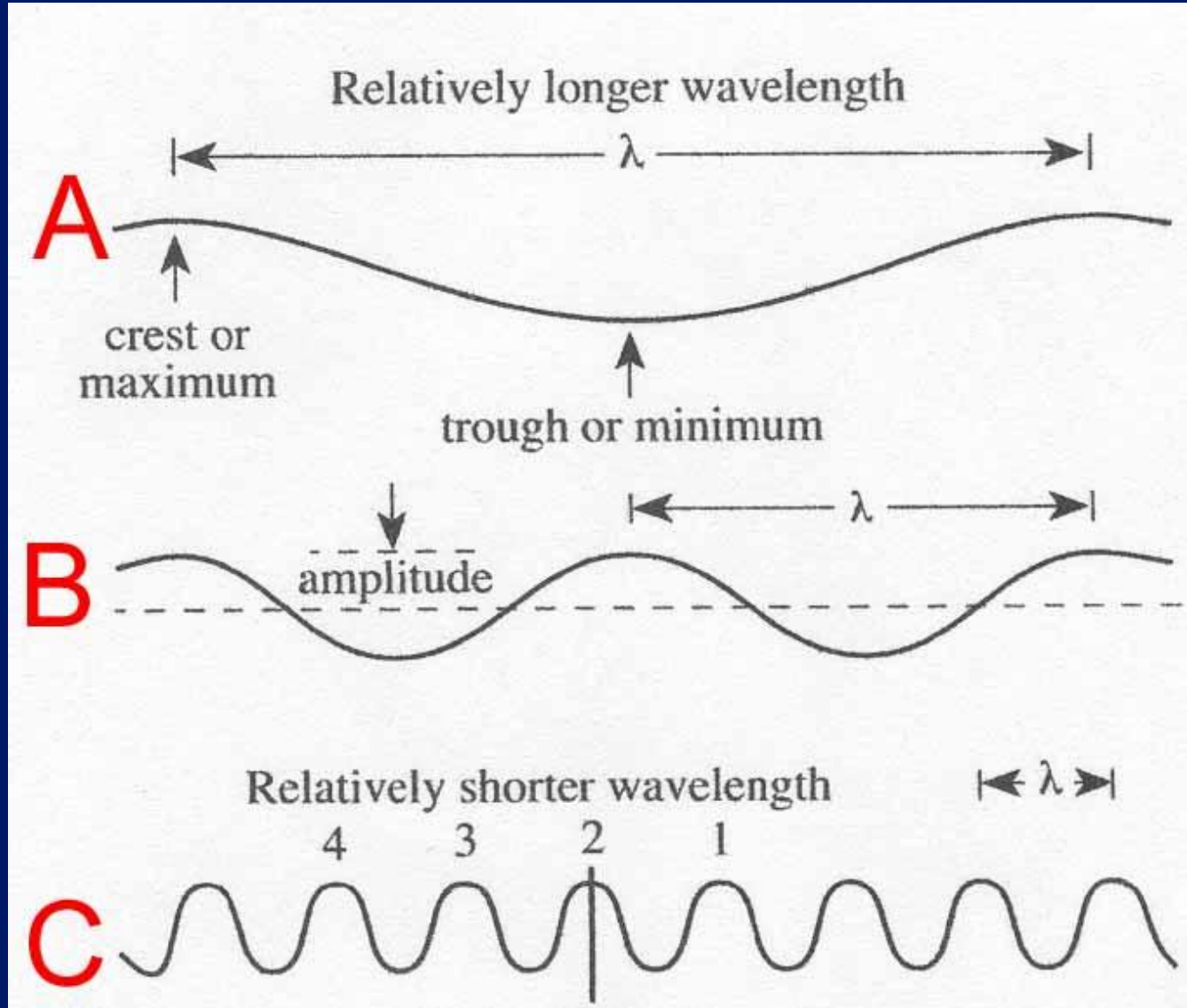
Wavelength = distance between adjacent crests (or troughs) (symbol = **lambda** λ)

Frequency = how fast the crests move up and down (symbol = **nu** ν in SGC)

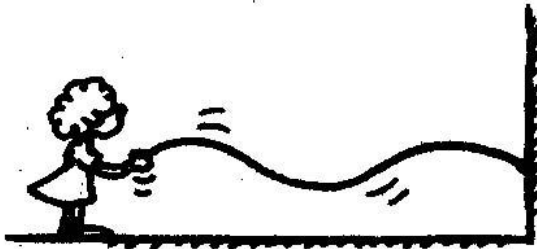
Speed = how fast the crests move forward (symbol = **c** in SGC) the speed of light

Take notes

Another view:



Wavelength & Frequency



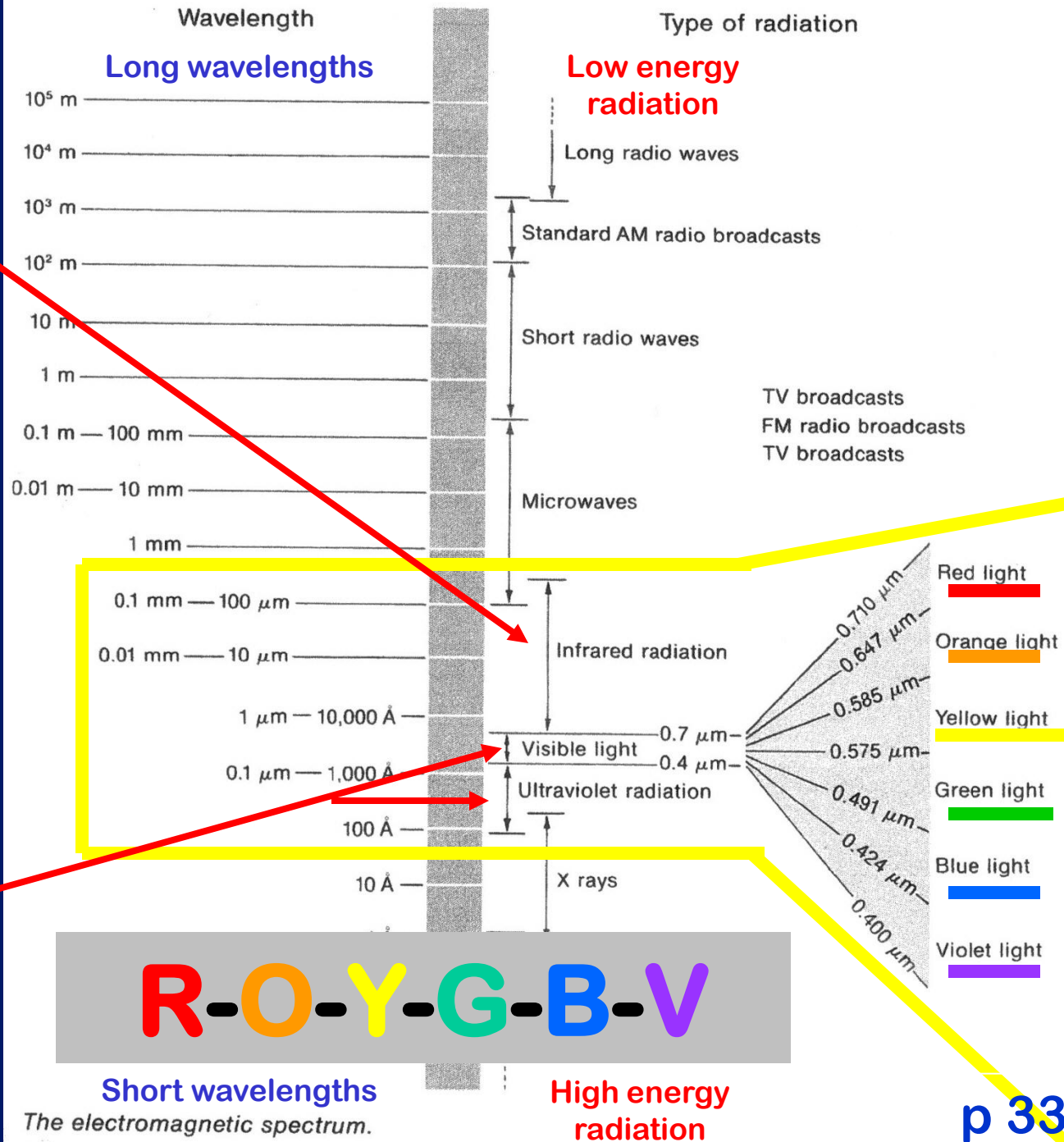
NOTE: Shorter wavelengths are produced when the rope is shaken more vigorously.

*“The shorter the wavelength
the GREATER the energy
&
the HIGHER the frequency”*

The Electromagnetic Spectrum

Longwaves (LW)

Shortwaves (SW)



Another (flipped) view:

Typical Sources That Send out Waves at This Frequency:

High energy radiation

Processes by protons and neutrons in atomic nuclei

Electrons in atoms, high-energy processes

Electrons in atoms, low-energy processes

Thermal vibrations of molecules

Microwave oven
Radar antenna

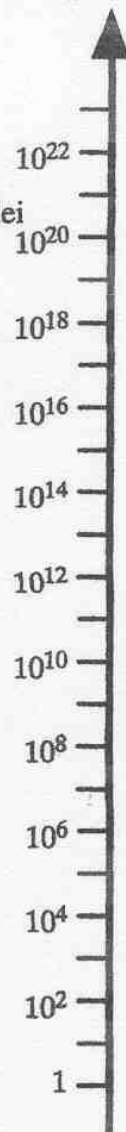
FM radio, TV antenna

AM radio antenna

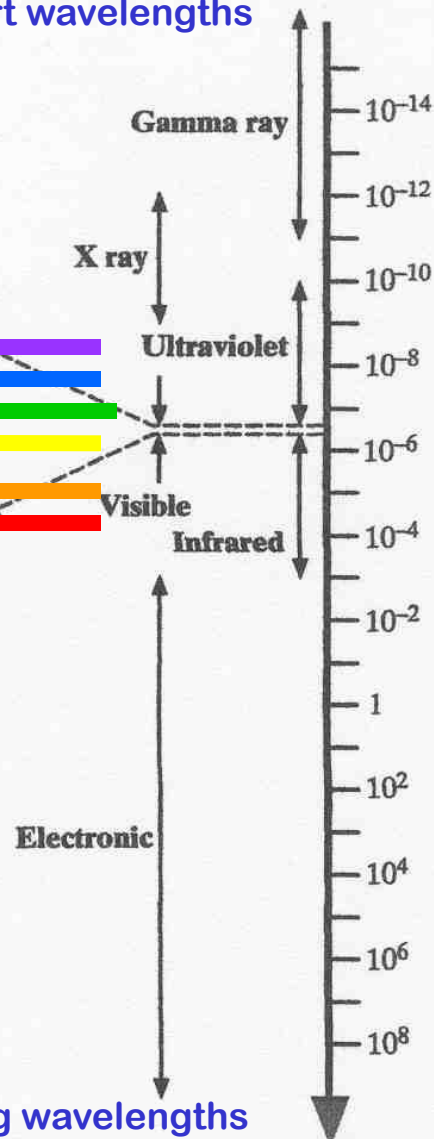
60-Hz power-line radiation

Low energy radiation

Frequency, Hz



Short wavelengths



Long wavelengths

Typical Object Whose Size Is the Same as This Wavelength:

Nucleus
TINY

Atom

DNA molecule
Amoeba

Fine dust particle

Millimeter
Centimeter

Meter

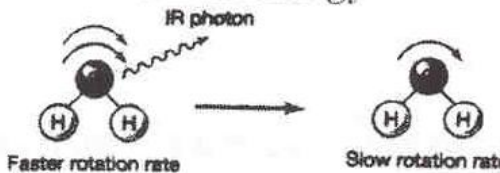
Soccer field
Kilometer

Earth

HUGE

Wavelength, m

What are the “sources” of different wavelengths of electromagnetic radiation?

Type of Electromagnetic Radiation	Range of Wavelengths (in units indicated)	Typical Source
Gamma rays	10^{-16} to 10^{-11} in meters (m) using scientific notation	high-energy processes within nucleus caused by the strong force
Ultraviolet radiation	.0001 to 0.4 in micrometers (μm)	electrons moving (quantum leaps) within individual atoms
Visible light	0.4 to 0.7 in micrometers (μm)	
Infrared radiation	0.7 to ~30 (up to 1000) in micrometers (μm)	
Near Infrared radiation See SGC-II p 197	0.7 - 1.0 in micrometers (μm)	chaotic thermal kinetic motion of molecules due to their thermal energy 
Far Infrared See SGC-II p 197	1.0 - ~30 (up to 1000) in micrometers (μm)	
Microwaves	10^{-4} to 10^{-2} in meters (m) using scientific notation	electronically produced by microwave oven
AM Radio waves	10 to 10^2 in meters (m) using scientific notation	electronically produced -- waves vibrate in human-made electrical circuits

Neat website:

ELECTROMAGNETIC SPECTRUM JAVA APPLET:

[http://lectureonline.cl.msu.edu/~mmp/applist/
Spectrum/s.htm](http://lectureonline.cl.msu.edu/~mmp/applist/Spectrum/s.htm)



***THE RELATIONSHIP BETWEEN
FREQUENCY (ν), WAVELENGTH (λ), &
ENERGY (E) OF PHOTONS:***

KEY CONCEPT #1:

The Energy (E) of photons is directly proportional to their frequency ν .

\propto = “is proportional to”

$$E \propto \nu$$

Take notes

***THE RELATIONSHIP BETWEEN
FREQUENCY (ν), WAVELENGTH (λ),
& ENERGY (E) OF PHOTONS:***

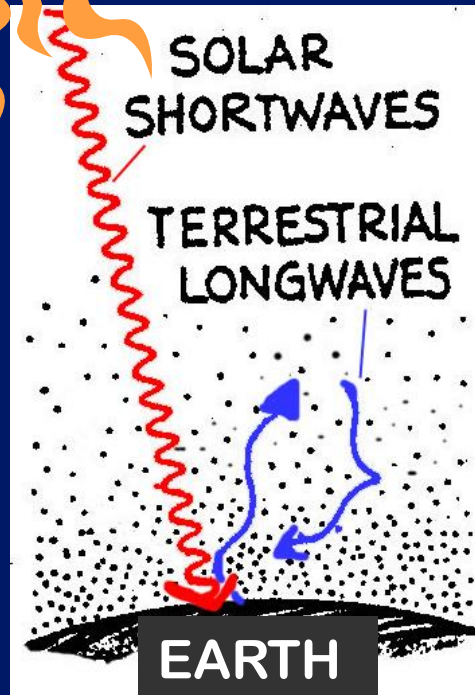
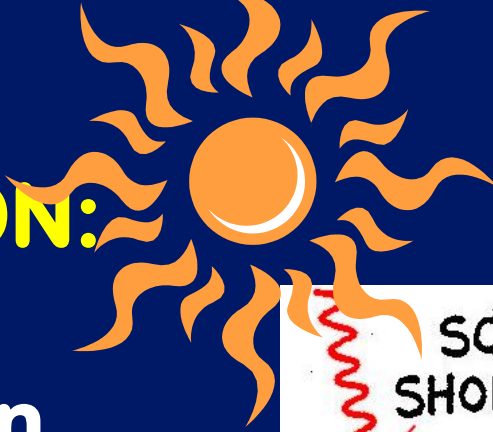
KEY CONCEPT #2:

The **Energy (E)** of photons is inversely proportional to their **wavelength (λ)**

$$E \propto c / \lambda$$

Take notes

SOLAR RADIATION:
greatest intensity in **SHORT** wavelengths
(high energy & frequency)



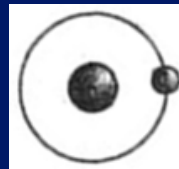
EARTH RADIATION:
entirely in **LONG** wavelengths
(low energy & frequency)

The wavelength determines how the electromagnetic ENERGY (photon) will interact with MATTER !

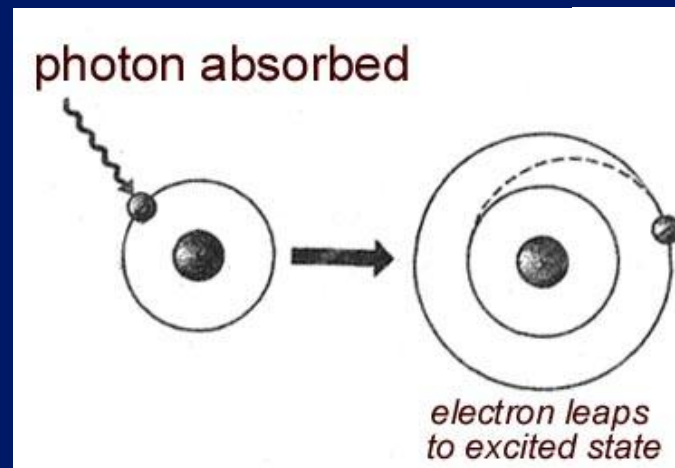
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the *difference* in the energy
of the ground level & the first excited level,
- the electron **ABSORBS** the photon energy and . . .
- the electron is “moved” (quantum leap) to “Level 2”

Hydrogen atom:

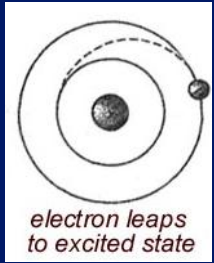


with electron in
ground state
(Level 1 shell)



Review

Photons + ATOMS vs Photons + MOLECULES



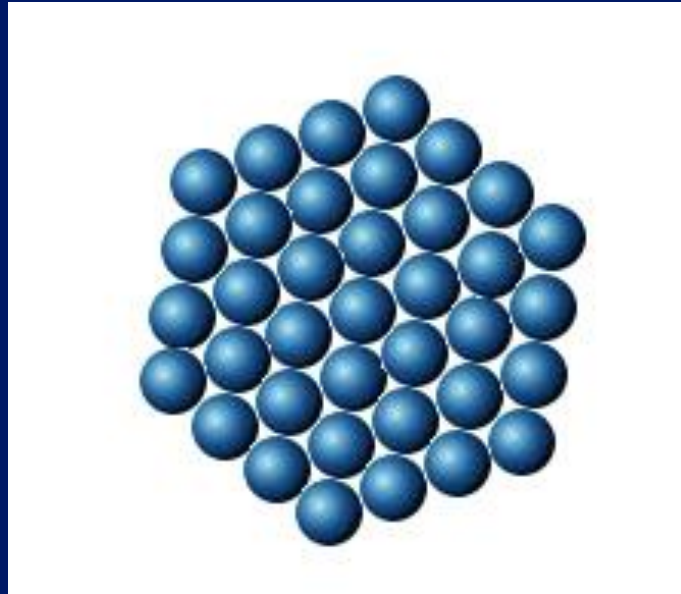
The quantum leap of electrons:
takes place WITHIN an ATOM between
discrete energy levels (shells) when
photons are absorbed or emitted . . .

but

Quantum theory also involves the
behavior of molecules

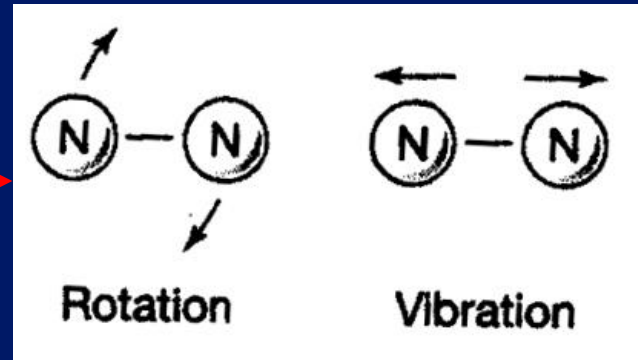


Remember the vibrating molecules?

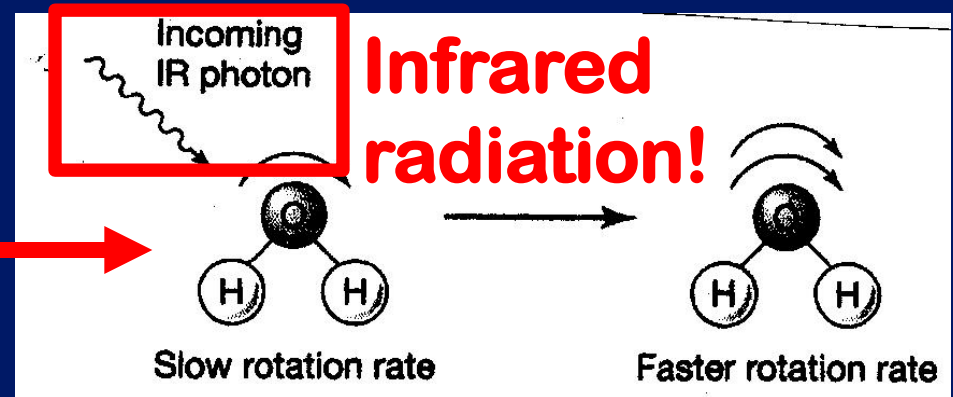


When some molecules absorb and emit certain wavelengths of electromagnetic energy they bend, rotate, and spin in a specific way

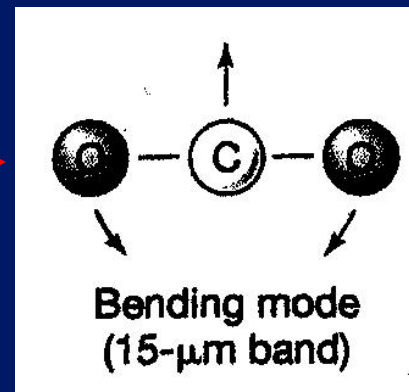
NITROGEN GAS
MOLECULE



WATER VAPOR
MOLECULE



CARBON
DIOXIDE GAS
MOLECULE

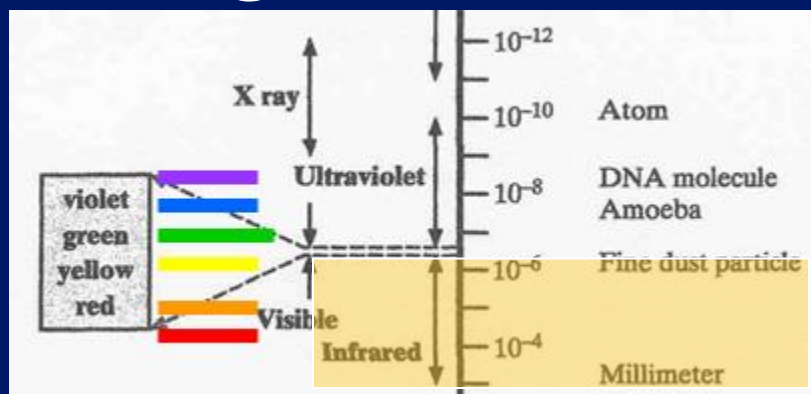


Greenhouse gases!

So what is a **Greenhouse Gas**?

abbreviation we'll use = GHG

GHG = a gas than can absorb and emit (re-radiate) **INFRARED** wavelengths of Electromagnetic Radiation



IR
radiation

0.7 - 1000 micrometers (μm)
(7×10^{-6} to 1×10^{-3} meters)

KEY POINT:

The QUANTUM BEHAVIOR of
CERTAIN MOLECULES
with respect to
INFRARED RADIATION
is the
REASON THAT **GREENHOUSE**
GASES ARE GREENHOUSE GASES!!

More on this later!!!!

ARIZONA  WILDCATS

GO CATS!

Thursday Sep 9th

RECAP OF ANNOUNCEMENTS

- **RQ-1 was cutoff at 30 minutes before class TODAY.**
Missed the cutoff deadline? See FAQ #22 to find out how to submit an **ABSOLUTION FORM** .
- **TEST #1** is a week from TODAY (**Sep 16th**) ! A “Top Ten Things to Study” guide will be posted by Sunday night.
- Don't forget to **register** your clicker online for **THIS CLASS** (even if it's already registered for another class).
Dr H will be matching up your Clicker ID's with your D2L records next week, so you need to be registered .
- **Assignment I-1 PART B** will be posted after we compile your **GROUP AVERAGE FOOTPRINT** results
→ **BRAND NEW DUE DATE: Tuesday night Sep 14th**
before 11:59 pm