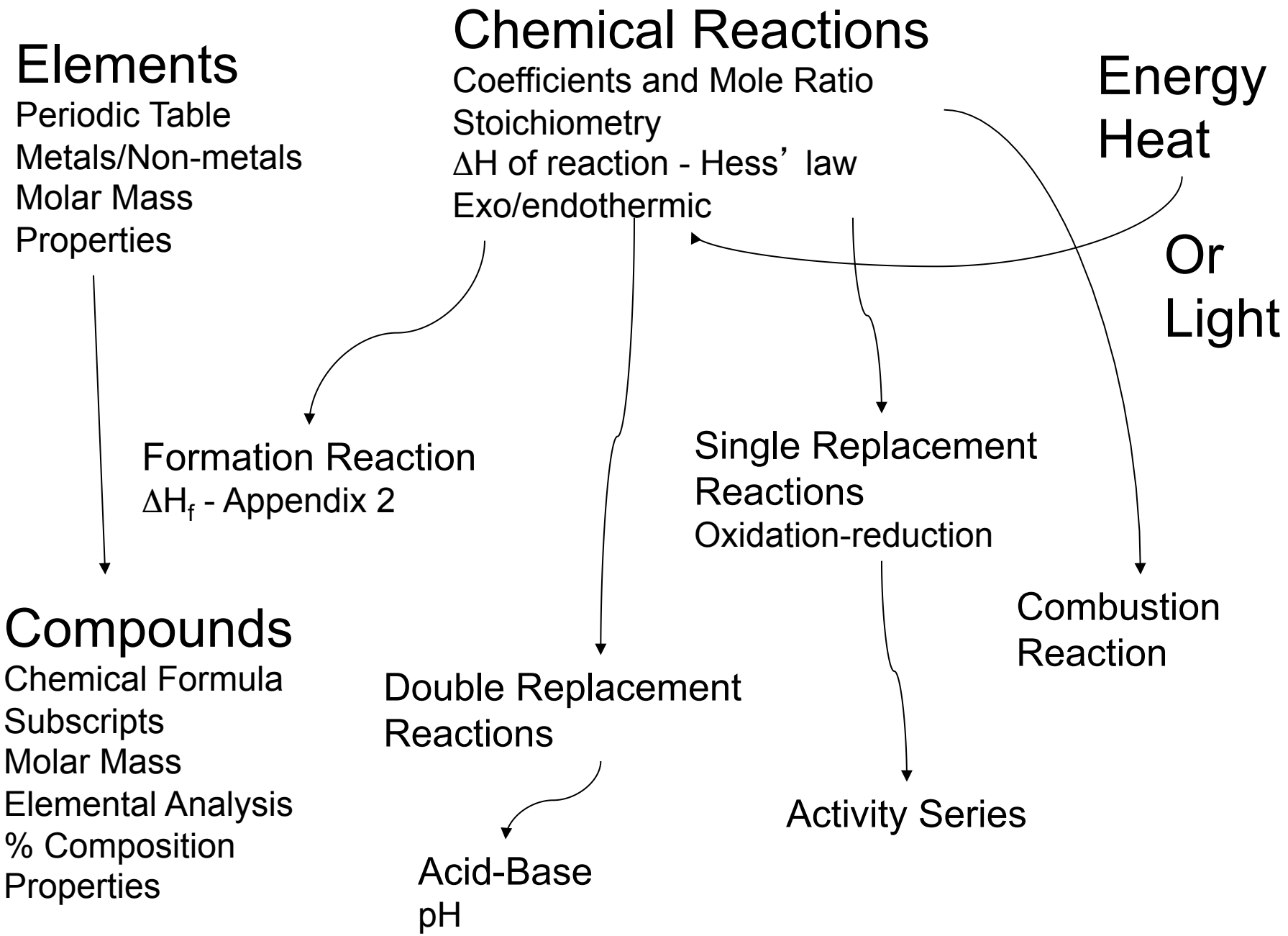
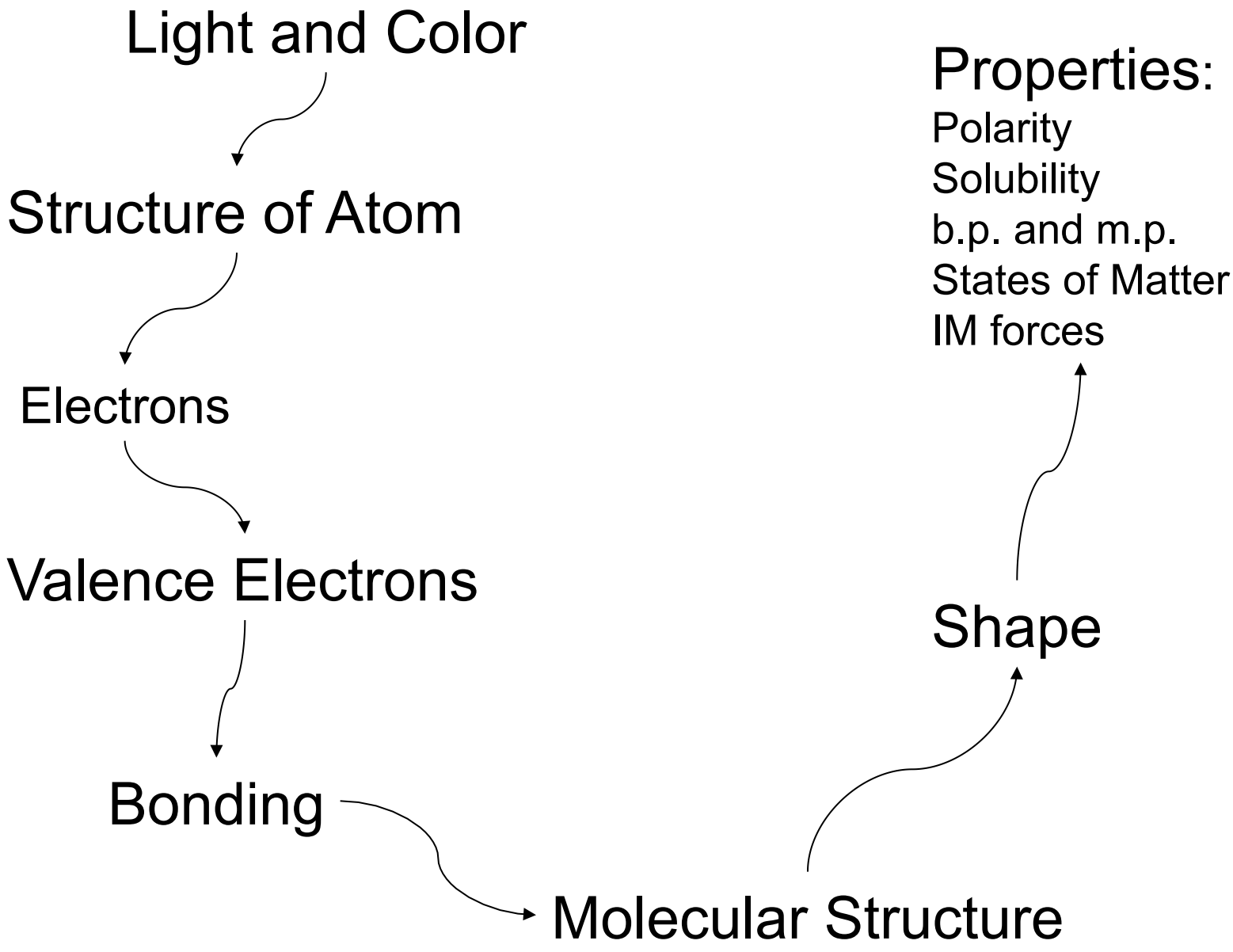
Objective 10

Light and Color
Relate EM radiation properties,
Describe how light is produce with E level diagrams,
Understand quantization.


Elements
Periodic Table
Metals/Non-metals
Molar Mass
Properties
Chemical Reactions
Coefficients and Mole Ratio
Stoichiometry
ΔH of reaction - Hess' law
Exo/endothermic
Energy
Heat
Or
Light
Formation Reaction
ΔH_f - Appendix 2
Single Replacement
Reactions
Oxidation-reduction
Compounds
Chemical Formula
Subscripts
Molar Mass
Elemental Analysis
% Composition
Properties
Double Replacement
Reactions
Combustion
Reaction
Activity Series
Acid-Base
pH


Light and Color
Structure of Atom
Electrons
Valence Electrons
Bonding
Molecular Structure
Shape
Properties:
Polarity
Solubility
b.p. and m.p.
States of Matter
IM forces

Fiat Lux "Let There Be Light"

Light is Electromagnetic (EM) Radiation

EM radiation has Electric and Magnetic Field components

Transmission of energy by ***waves***

Animation: http://dwb4.unl.edu/ChemAnime/atomic_orbits.htm

EM Radiation travels at speed of light ($c = 3.00 \times 10^8$ m/sec)

Energy = E (in J) **= $h\nu$ = hc/λ**

where h = Planck's constant = 6.63×10^{-34} J sec

ν = frequency = c/λ

λ = wavelength

Objective: relate wavelength to frequency to energy

Light is a Wave - quantified by wavelength, frequency, speed, and amplitude.

A

B

Which wave has the longer wavelength?
Which wave has the higher frequency?
Which wave has the higher energy?

More wave properties: Reflection, Refraction, Diffraction

Color is Light We Can See - Visible Light

A supermarket scanner uses a He-Ne laser, which emits 656 nm red light.

Objective: Calculate the energy in J of 656 nm red light.

a. 6.56×10^{7}
b. 4.57×10^{14}
c. 3.03×10^{-19}

http://www.laserfest.org/lasers/innovations.cfm

1974: The first barcode scanner used in supermarkets.
(1st public laser)

Color is Light We Can See - Visible Light

Calculate the energy in J of 656 nm red light.

http://www.laserfest.org/lasers/innovations.cfm

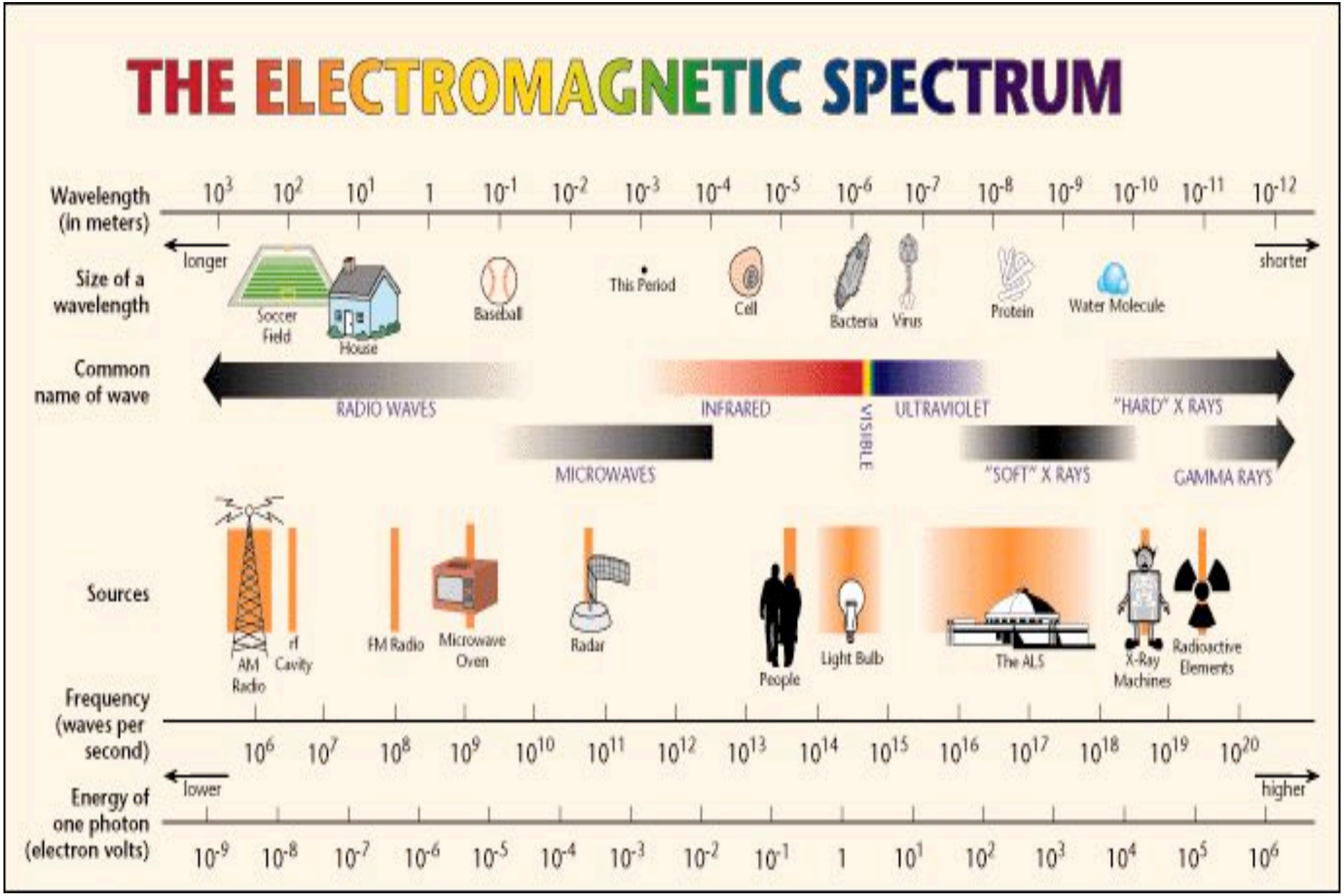
E (in J) **= hν = hc/ λ**

$$= \frac{(6.63 \times 10^{-34}\ \text{J sec})(3.00 \times 10^{8}\ \text{m/sec})}{656 \times 10^{-9}\ \text{m}}$$

$$= 3.03 \times 10^{-19}\ \text{J}$$

Visible light is one slice of the Electromagnetic Spectrum

Where does light (EM radiation) come from?



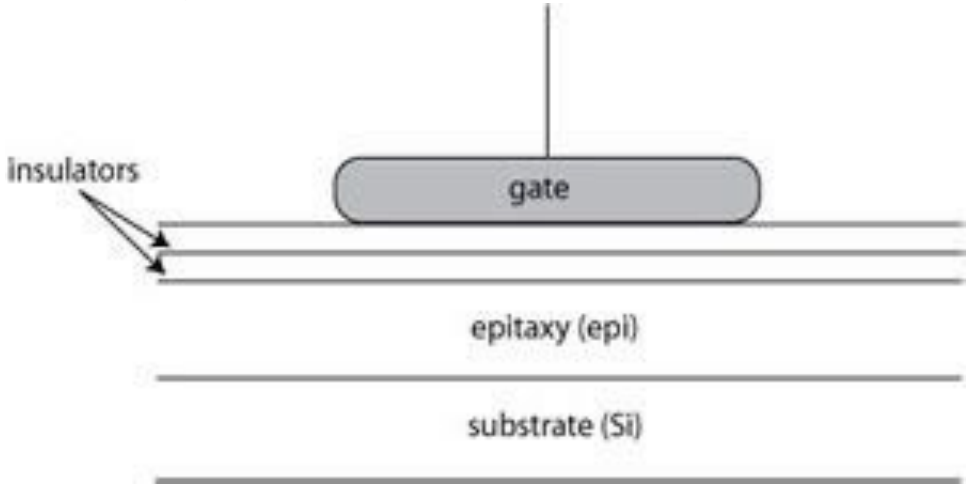
http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

Our Body is a Good Detector of EM Radiation

http://www.eslsmartboard.com/vocabulary_lessons/face_and_body/human_body/

EM Radiation Detectors:

Charge Coupled Device (CCD) – UV, Vis, and IR photon hits doped Si and ejects electron (PE effect) → electrical signal



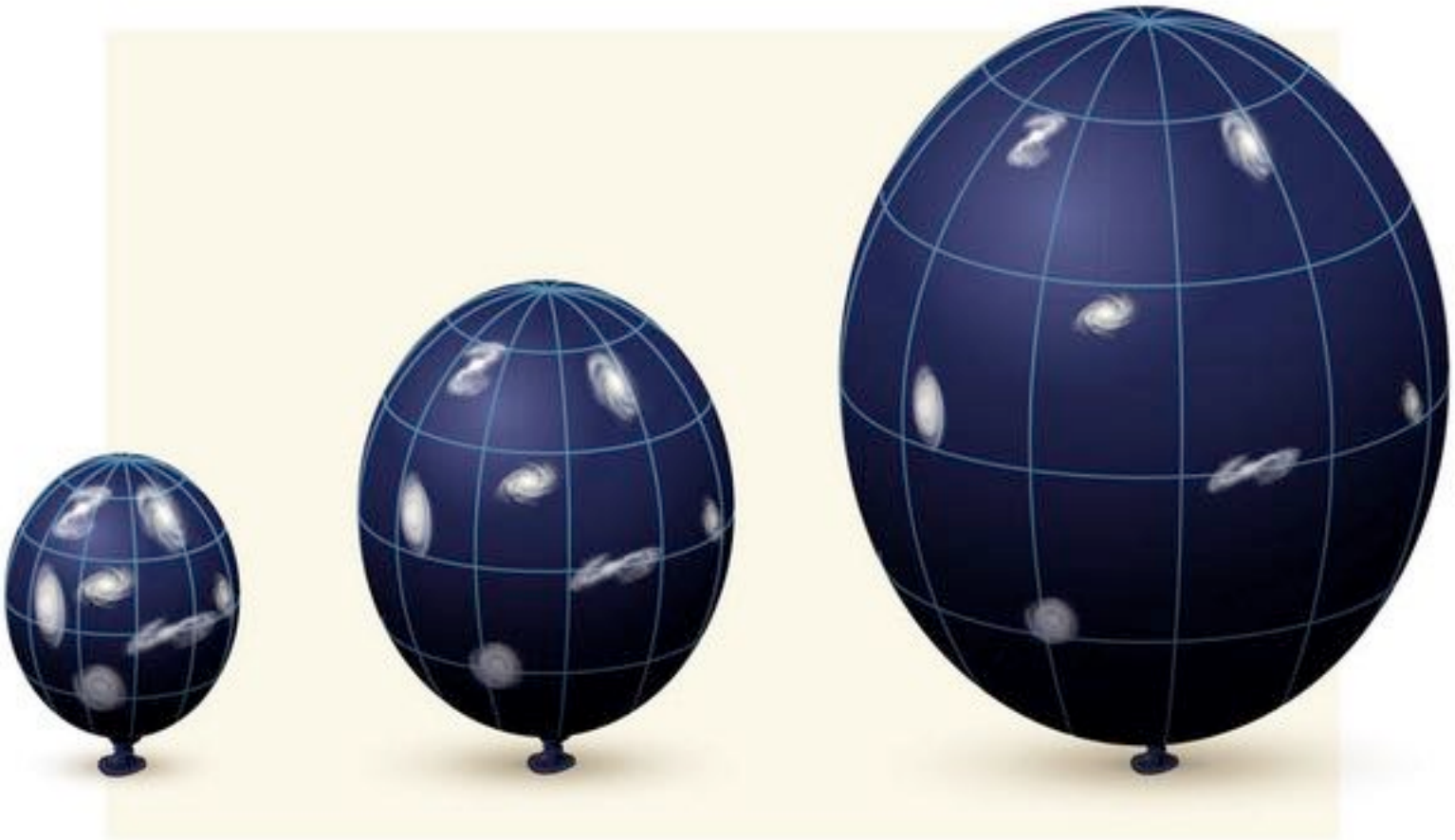
http://www.specinst.com/What_Is_A_CCD.html

Photomultiplier tube, film, CMOS
Photo-conductive cells, e.g., CdS
Photovoltaic cells, e.g., Se

X-rays – photographic film (Ag), semiconductors (Si (Li), CdTe)

Scientists, such as astronomers, like to talk about redshifts and blueshifts.

If the universe is *expanding*, as astronomers believe, would you observe a redshift and blueshift?



http://scienceblogs.com/startswithabang/2011/12/02/dark-energy-accelerated-expans/

The Radiation Type Has a Different Effect on Matter

Microwaves Cause Molecules to **Rotate** (spin)

IR Causes Bonds to **Vibrate**

Visible and **UV** Causes Bonds to **Break**!

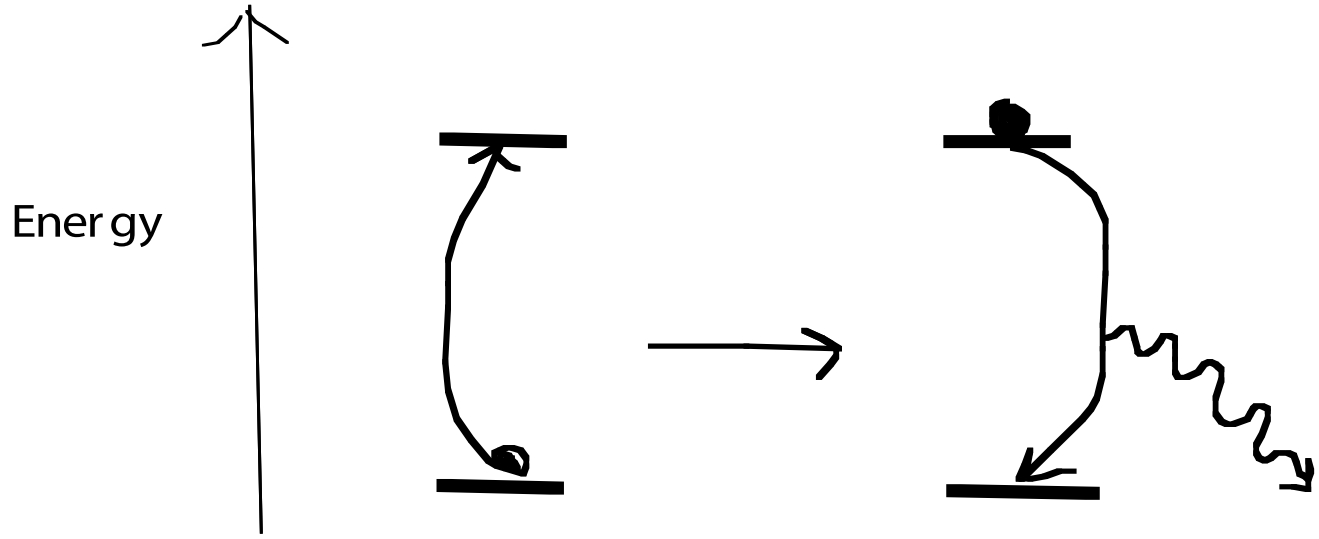
Water boils when placed in a microwave oven but will ice melt in a microwave?

http://www.123rf.com/photo_8416291_hand-drawn-illustration-of-a-microwave-oven-on-white-background.html

Objective: Describe How Light Is Produced

When a _____ absorbs the right amount of E, an _____ undergoes a transition from a _____ energy state to a _____ energy state (excited state).

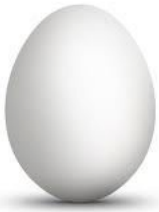
Light is Produced when an _____ undergoes a transition from a _____ energy state to a _____ energy state.



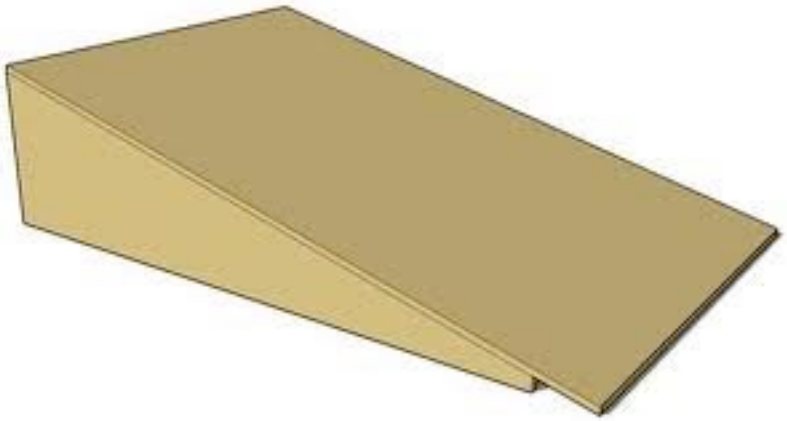
What does "***energy of an electron is quantized***" mean?

What is a Quantum?
What is Quantized?

Egg



Baseball



Ramp

Stairs

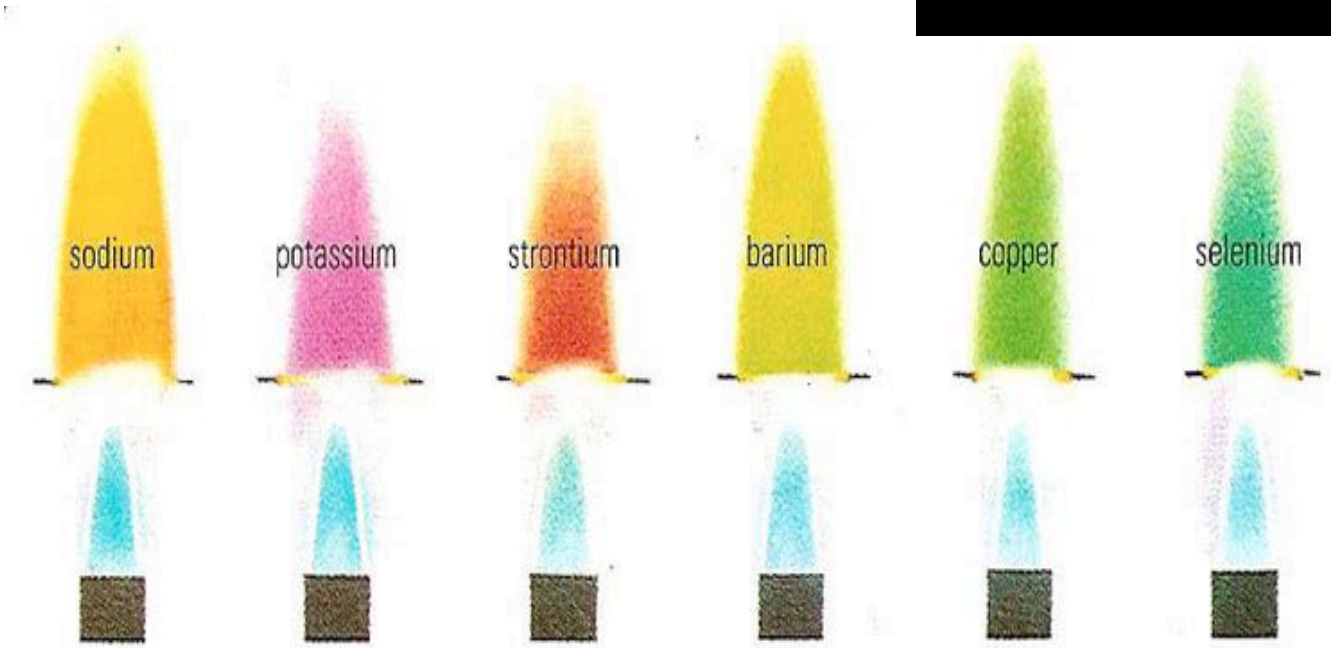
Lab 8: How is light produced in a Ne gas discharge tube?

http://www.m2c3.com/chemistry/VLI/M1_Topic2/M1_Topic2_print.html

Why do ***different*** substances emit ***different*** colors or wavelengths of light?

Fireworks

http://www.conciergepreferred.com/navy-pier-fireworks/4679-fourth-of-july-fireworks-at-navy-pier-2012.html



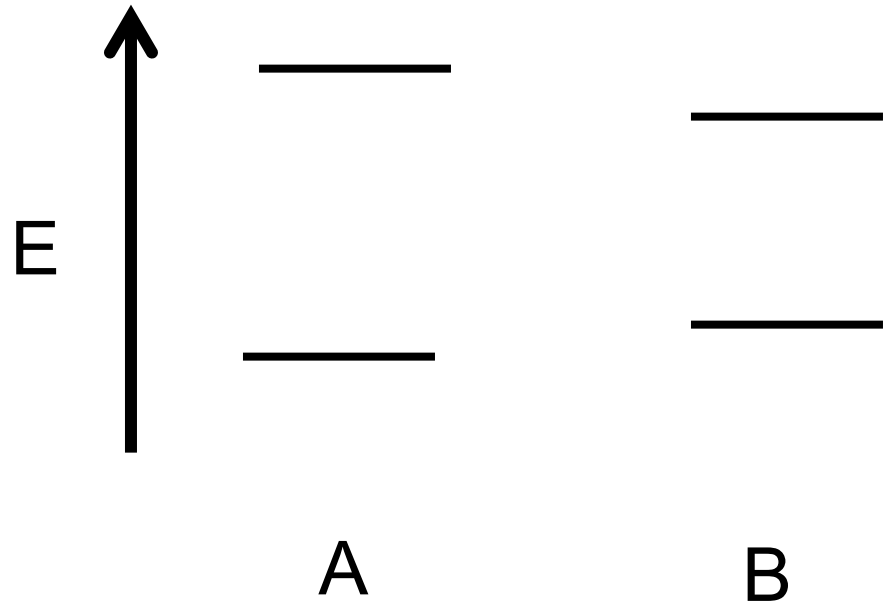
Flame Tests

http://www.daviddarling.info/encyclopedia/F/flame_test.html

Why do ***different*** substances emit ***different*** colors or wavelengths of light?

Fireworks

http://www.conciergepreferred.com/navy-pier-fireworks/4679-fourth-of-july-fireworks-at-navy-pier-2012.html



Which E level diagram, A or B, represents green?
Which E level diagram, A or B, represents red?
Give reasons.

Lab 8. Color (and Light) Is Quantified By _____

The λ's of Light Emitted by a Substance is Measured in an *Emission Spectrum*

An Emission Spectrum is Used to Identify Substances

(like a fingerprint)

Astronomers use emission spectra to identify a star's composition.

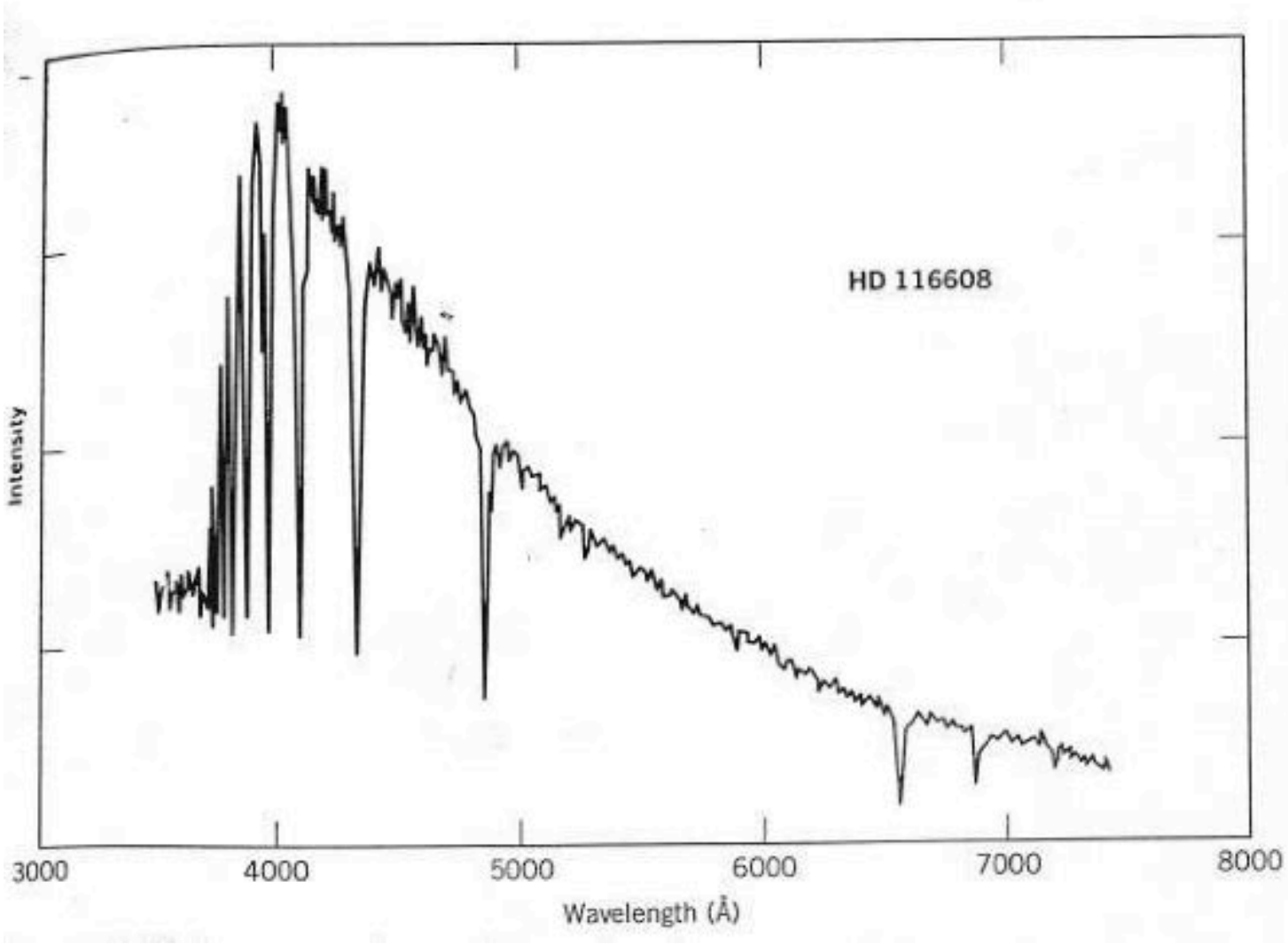
Emission spectrum of sun

H emission spectrum

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/spec.html

A spectrometer is used to measure an emission spectrum.
How does a spectrometer work?

The emission spectrum tells us the composition of this star.

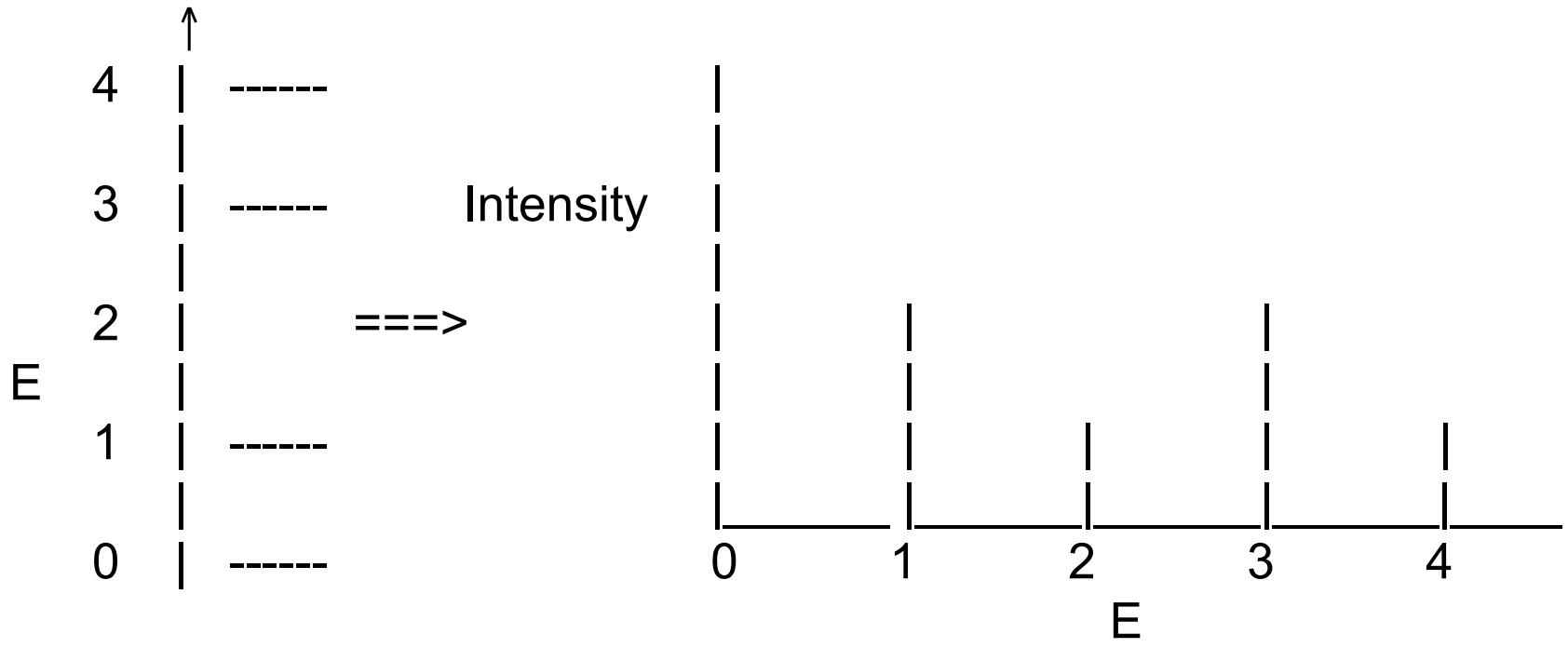


What is the composition of this star?

Objective: relate emission spectrum to electronic structure

An Emission Spectrum tells us about ***Electronic Structure***
(energy states of electrons in an atom or molecule)

Given an energy level diagram, draw an emission spectrum that fits the diagram.

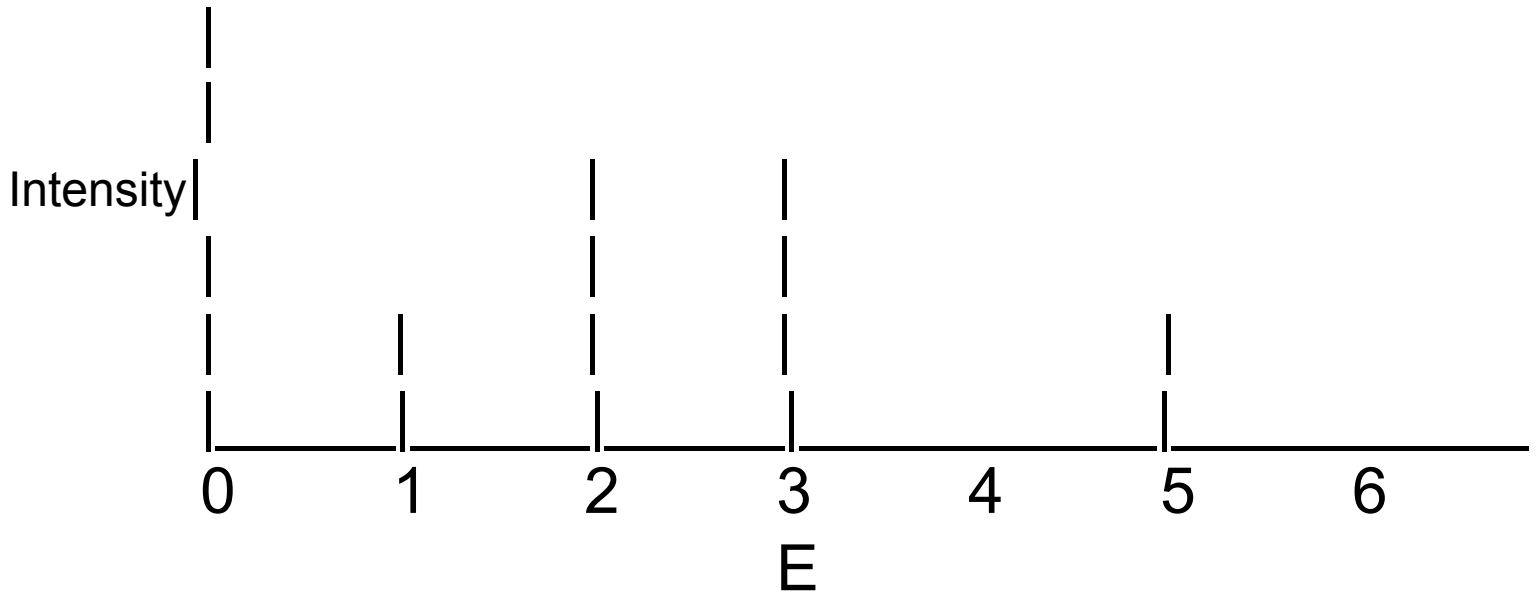


Energy Level Diagram

Emission Spectrum

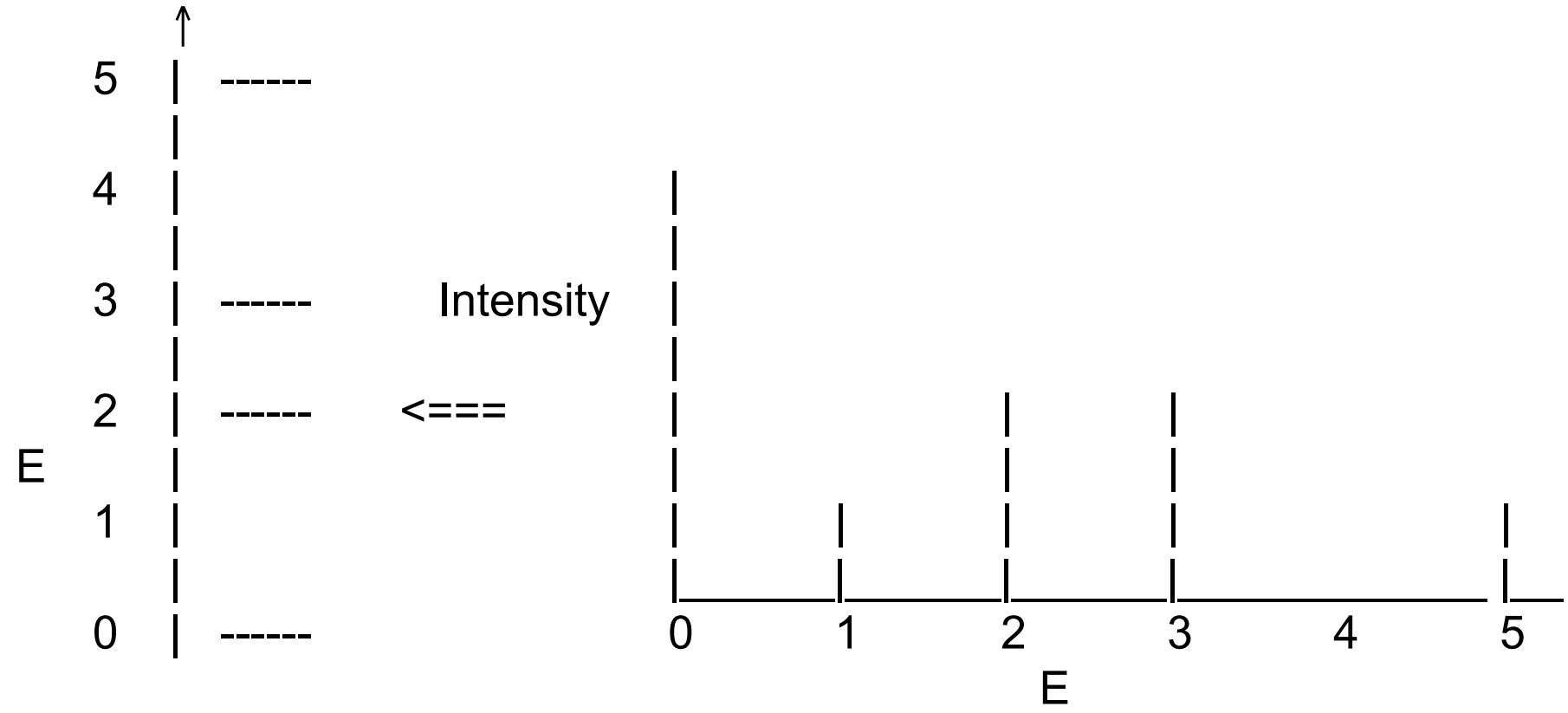
Objective: relate emission spectrum to electronic structure

You measured the emission spectrum of a new substance you have just synthesized. Determine the electronic structure of this substance. In other words, draw an energy level diagram that fits the emission spectrum.



An Emission Spectrum tells us about ***Electronic Structure***

Solution:

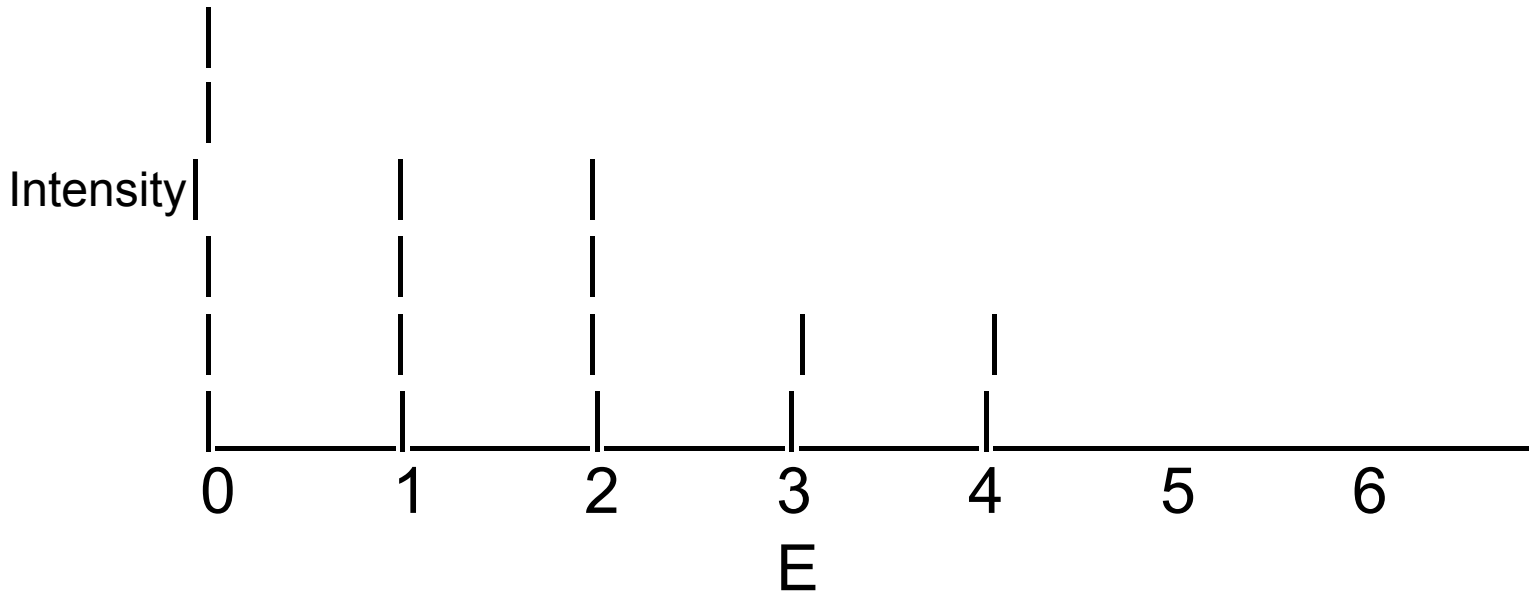


Energy Level Diagram

Emission Spectrum

Objective: relate emission spectrum to electronic structure

You measured the emission spectrum of a new substance you have just synthesized. Determine the electronic structure of this substance. In other words, draw an energy level diagram that fits the emission spectrum. See Practice Problem 3.



The ***Emission Spectrum*** of the ***H atom*** is described by **Bohr's Model**

Postulates:

1. Energy of an electron has specific, not arbitrary, values (energy of an electron is ***quantized***)

$E = -R_H/n^2$ where R_H = Rydberg's constant = 2.18×10^{-18} J and n = 1, 2, 3, …

This Equation Can *ONLY* Be Used for the *H atom*!!

2. Electrons can undergo transitions from one energy state to another:

Lower E state --> Higher E state	absorption
Higher E state --> Lower E state	emission

(2 others)

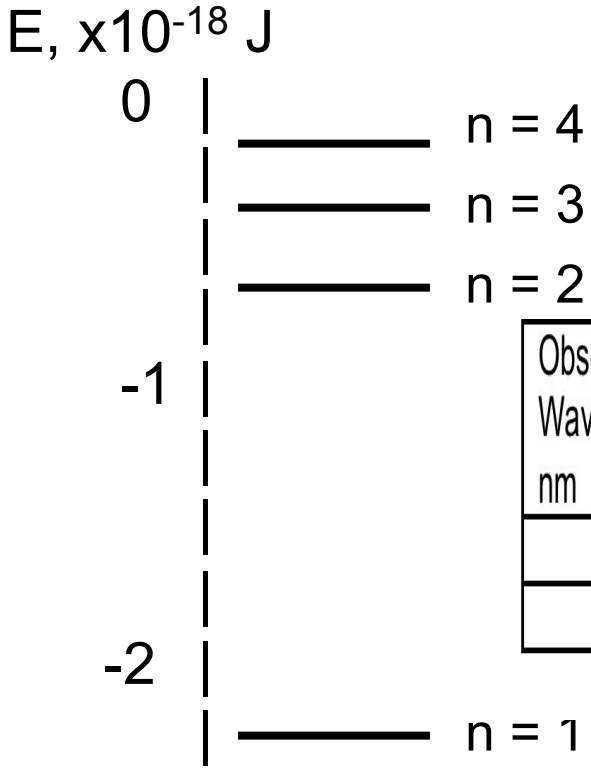
What is E of the n = 1 electron energy state in H?

What wavelength is emitted in the n = 2 to n = 1 transition?

Hydrogen Emission Spectrum

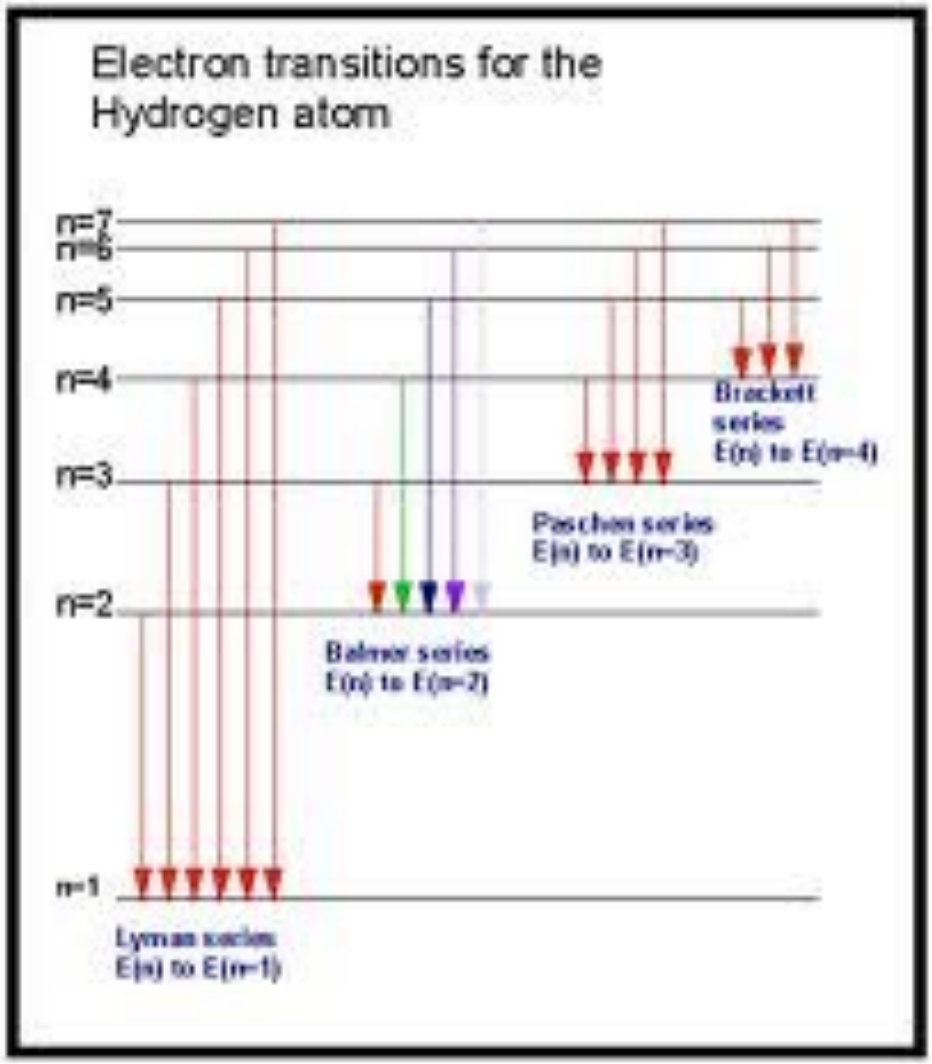
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/spec.html

Lab 8. Identify the electron states that produces each color.



Observed Wavelength, nm	Observed Color	$\frac{1}{\lambda}$R	n_f	n_i	$(\frac{1}{n_f^2} - \frac{1}{n_i^2})$	ΔE, J

E, J



$E = -R_H/9$

$E = -R_H/4$

$E = -R_H$

http://www.files.chem.vt.edu/RVGS/ACT/notes/notes-electronic_structure.html

Light is Used In Many Different Ways and Applications

Fluorescent lights http://home.howstuffworks.com/fluorescent-lamp.htm

Lasers
Supermarket scanners - He/Ne laser

TV http://electronics.howstuffworks.com/tv.htm
Electron gun inside TV
http://electronics.howstuffworks.com/question694.htm

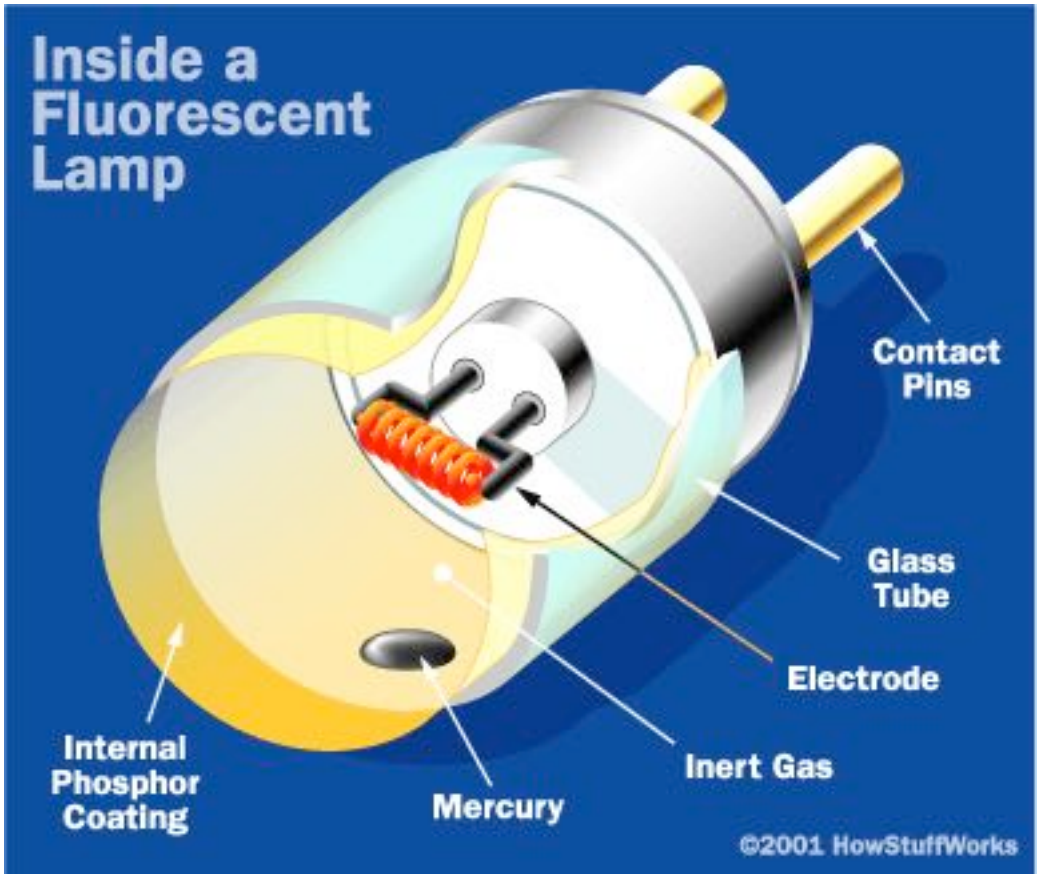
LCD http://electronics.howstuffworks.com/lcd2.htm

LED – see 2014 Nobel Prize in Physics

Reactant in Chemical Reactions - Photochemistry
Cameras - analog and digital

Information transfer (radio, cell phones, fiber optics)

How Fluorescent Lamps Work
(http://home.howstuffworks.com/fluorescent-lamp1.htm)



Hg (l) --> Hg (g)
Hg emits UV.
UV excites phosphor.
Phosphor emits white light.

What excites Hg?

Why do ***different*** substances emit ***different*** colors or wavelengths of light?

Mercury (Hg) Is Used In Fluorescent Lights

which is the reason fluorescent lights should **not** be thrown out with the garbage.

The 546.1 nm line is used to calibrate light detectors and diffraction gratings.

Calculate the frequency and energy in J/photon and kJ/mole.

What Is A ***Photon*****?**

Light as a Reactant in a Chemical Reaction

Dentistry:

Blue light for curing composite resins

http://laserpointerforums.com/f38/blue-ray-whitens-teeth-47683.html

http://science.howstuffworks.com/zoology/question554.htm

Light as a Product in a Chemical Reaction

Fireflies

Light sticks

http://onlyhdwallpapers.com/tag/lightsabers/

Supply Energy to Produce Light

http://iet.jrc.ec.europa.eu/energyefficiency/residential-lighting/european-cfl-quality-charter

Supply Light to Produce Energy

http://www.gizmag.com/low-grade-silicon-solar-cell-efficiency/27426/

Lab 8: Glowing pickle??
What makes the pickle glow this color?

http://www.fotosearch.com/illustration/pickle.html

https://portal.magnet.fsu.edu/lists/announcements/dispform.aspx?id=162

Lasers are used in supermarket scanners, medical and industrial uses.

How does a laser work? See http://science.howstuffworks.com/laser.htm

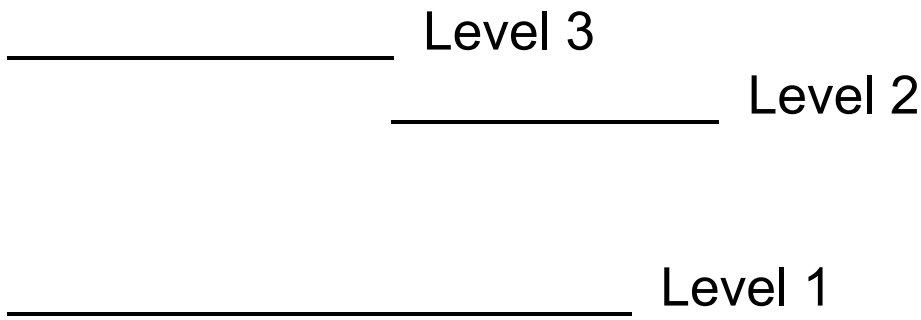
Laser Properties:

1. Directionality (tight beam, strong and focused). Compare to flashlight.
2. High spectral brightness
3. Monochromaticity (spectral purity) – narrow bandwidths. Some lasers have bandwidths < 1 MHz (or 10^{-4} cm^{-1})
4. Coherence (light waves of similar frequency and well defined phase relationships)
5. Short pulses – some lasers have pulse widths < 10^{-13} sec

3 Elements of a Laser:

1. Active medium
2. Energy pump source (to create population inversion)
3. Resonant cavity to contain light

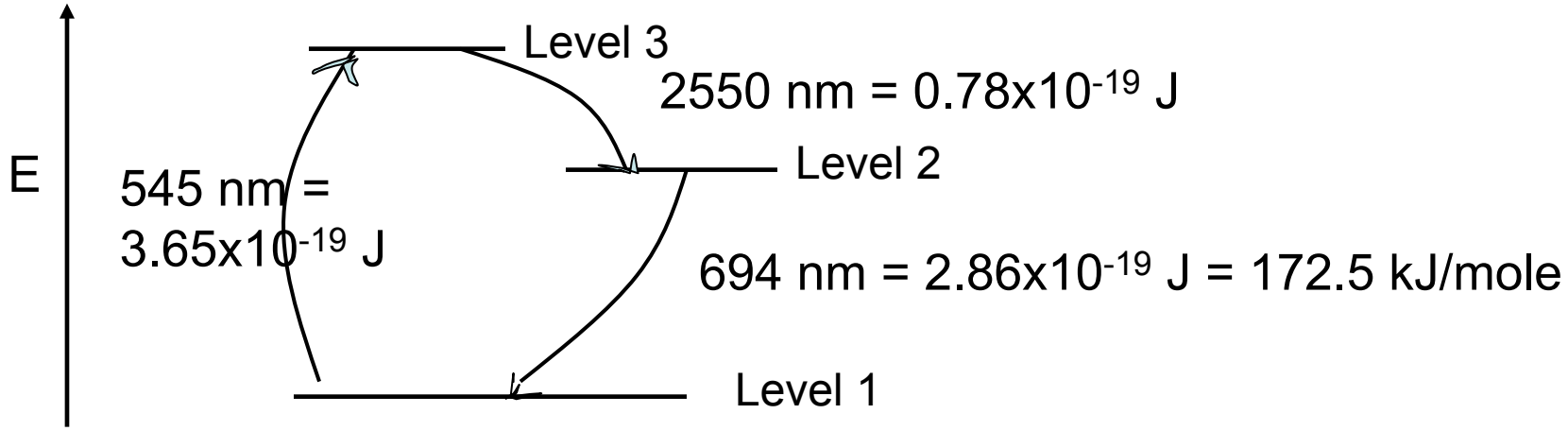
The gemstone ruby is alumina (Al_2O_3) doped with Cr^{3+}. The color of a ruby is due to electron transitions of Cr^{3+} in alumina. These electron transitions can be used in a ruby laser. Three transitions occur: one transition corresponds to a wavelength of 545 nm, another transition corresponds to a wavelength of 694 nm, and a third transition corresponds to a wavelength of 2550 nm. See Practice Problem 5.



a. Rubies are red. Which transition gives ruby its color? Be specific with the initial and final energy levels. Give reasons.
b. In a laser,
(i) a flash tube excites (pumps) electrons in Cr^{3+} from Level 1 to Level 3. Which wavelength corresponds to this transition?
(ii) Electrons from Level 3 undergo a transition to Level 2 to release heat and create a population inversion (high number of excited state electrons). Which wavelength corresponds to this transition?
Confirm that ΔE for the Level 1 to Level 3 transition equals the sum of ΔE for the Level 3 to Level 2 transition and ΔE for the Level 2 to Level 1 transition.

Solution: The color of a ruby is due to electron transitions of Cr^{3+} in alumina. Three transitions occur:

λ, nm	Color	ΔE, J	ΔE, kJ/mole	Transition
545	green	3.65×10^{-19}	219.7	1 --> 3
694	red	2.87×10^{-19}	172.5	2 --> 1
2550	IR	0.78×10^{-19}	47.0	3 --> 2



$\Delta E_{1->3} = \Delta E_{3->2} + \Delta E_{2->1}$

3.65×10^{-19} J = 0.78×10^{-19} J + 2.87×10^{-19} J

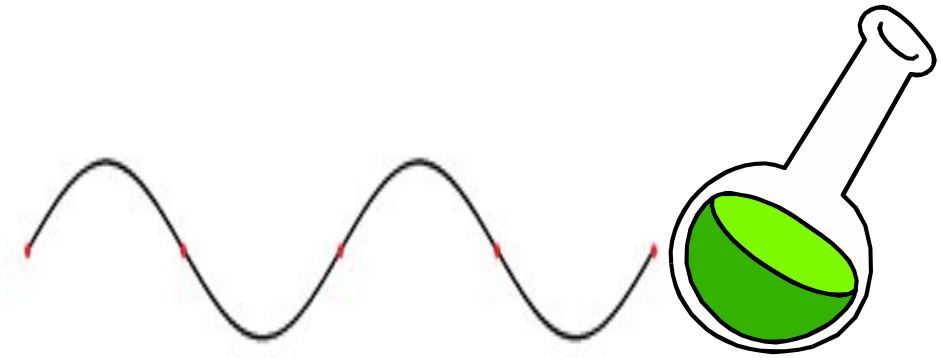
Transition Metals Give Gemstones Their Color

Gemstone	Color	Formula
Ruby	Red	Cr^{3+} in Al_2O_3
Emerald	Green	Cr^{3+} in beryllium aluminum silicate
Sapphire	Blue	Fe^{3+} and Ti^{4+} in Al_2O_3
Garnet	Red	Fe^{2+} in $Mg_3Al_2(SiO_4)_3$
Peridot	Yellow-green	Fe^{2+} in Mg_2SiO_4
Turquoise	Blue-green	Cu^{2+} in $CuAl_6(PO_4)_4(OH)_8 \bullet 4H_2O$
Diamond	Colorless, pale blue or yellow	N atoms trapped in crystal

Reference: http://scifun.chem.wisc.edu/chemweek/PDF/Gemstones.pdf

Spectroscopy Is The Interaction of Light With Matter

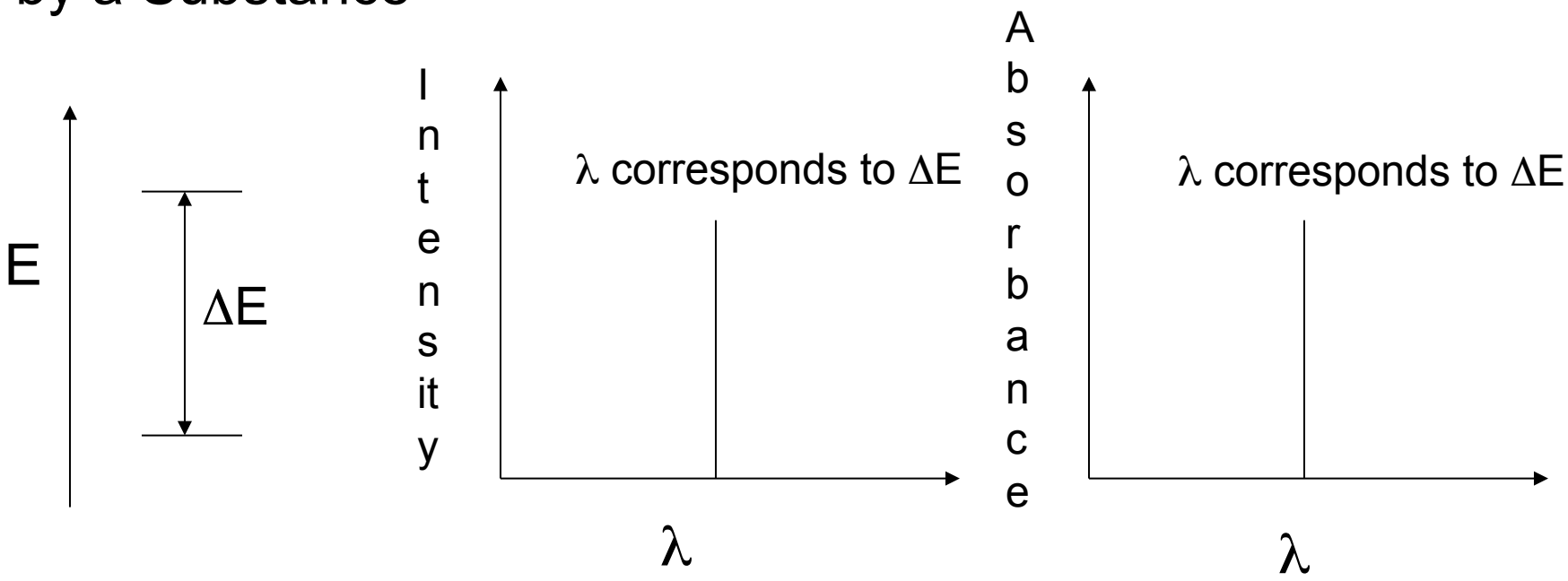
What happens when light comes in contact with a substance?



Light is reflected off of substance.
Light is transmitted through substance.
Light is absorbed by the substance.
Light is absorbed by the substance, then emitted by substance.

An Emission Spectrum Measures the λ ‘s of Light Emitted by a Substance

An Absorption Spectrum Measures the λ ‘s of Light Absorbed by a Substance



E Level Diagram
Shows the energy of electron energy states

Emission Spectrum
λ ‘s emitted is color you see

Absorption Spectrum
λ ‘s absorbed is not color you see ==> complementary color is color you see
Color Wheel

Objective: relate absorbed color to observed (complementary) color

http://trehautecouture.blogspot.com/2012/06/how-to-mix-colors-in-your-wardrobe.html

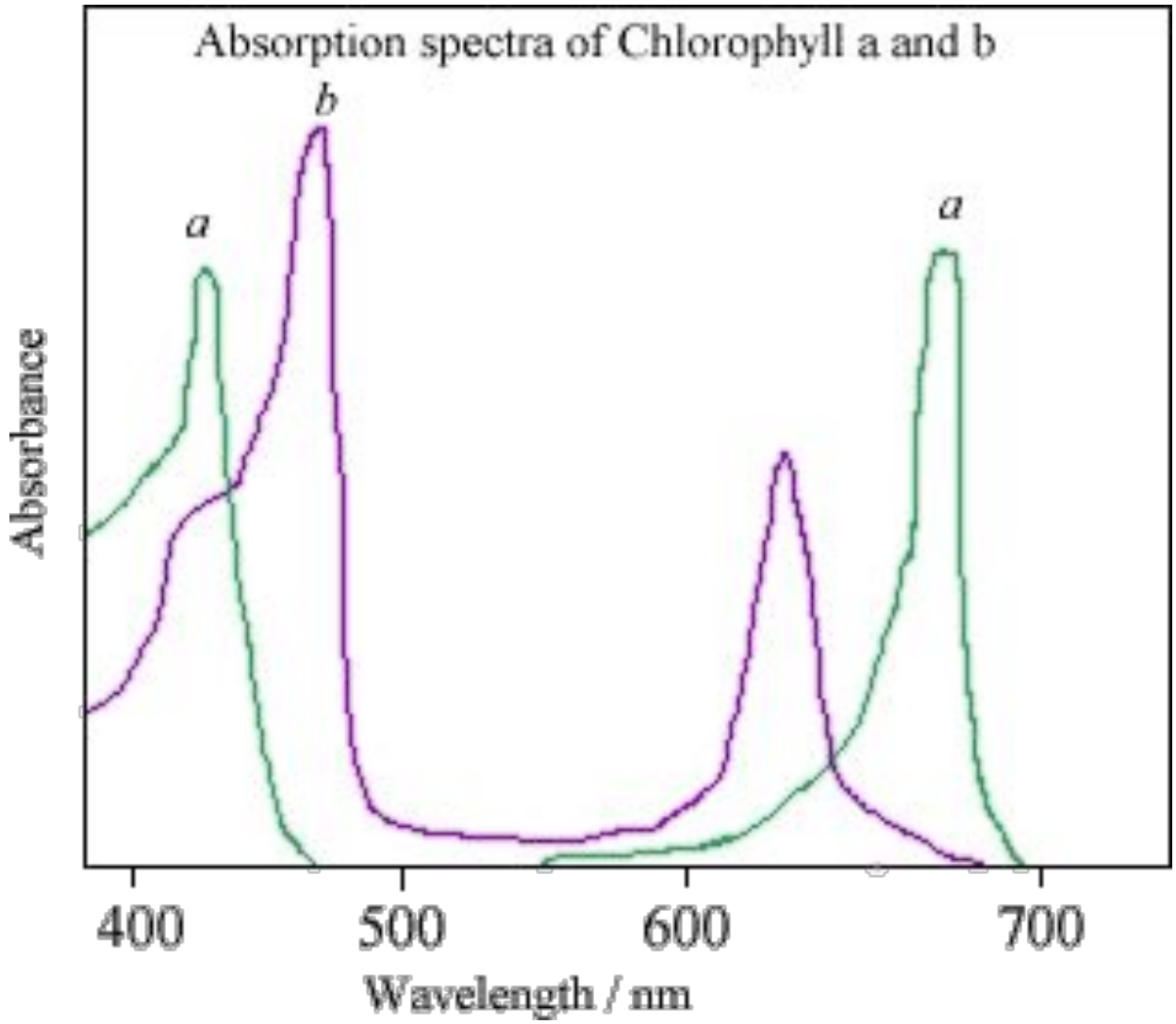
http://technorati.com/lifestyle/green/article/levis-jeans-reduces-carbon-footprint/

If a substance absorbs red, it appears ____.

If a substance appears blue, it absorbs _____.

Chlorophyll is the Green pigment in plants

What color is absorbed by chlorophyll? See Practice Problem 6.



http://www.webexhibits.org/causesofcolor/7A.html

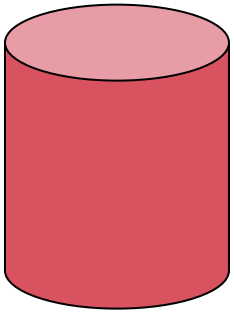
A Substance Absorbs a Specific Wavelength of Light

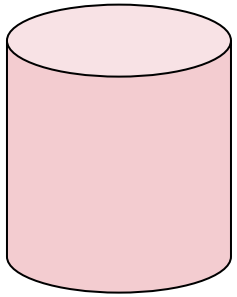
The Amount of Light Absorbed by the Substance (chromophore) is Proportional to Concentration

Beer's law: A α C

where A = Absorbance

and C = concentration





Which solution absorbs more light? What color is absorbed?
Which solution is less concentrated?

Beer's law is used to determine the concentration of a substance in a solution.
E.g., breath analyzer

http://luxfashiontrends.com/ysl-sunglasses-spring-summer-collection-for-you.html

Sunglasses are designed:

- to protect your eyes from glare (polarized)
- UV light (DNA damage)
- to make you look cool.

Some sunglasses claim "***100% UV protection***" but …
"*Sunglasses Carry Shady UV-Protection Claims, Study Reveals*"
(http://www.livescience.com/6524-sunglasses-carry-shady-uv-protection-claims-study-reveals.html)

Lab 8: How would you test sunglasses?

Bring A Pair Of Sunglasses To Lab!

Sunscreens Are Chemicals That Absorb UV Light

Sun Protection Factor (SPF) tells you how much UV light is absorbed:

$$SPF = \frac{1}{T} = \frac{1}{1 - A}$$

where T = transmittance (light of specific λ transmitted through sample)
and A = Absorbance (light of specific λ absorbed by sample)

SPF	A
15	0.933
20	0.95
30	0.967
50	0.98

Is it worth getting an SPF over 30?

Lab 8. Absorption Spectra applications

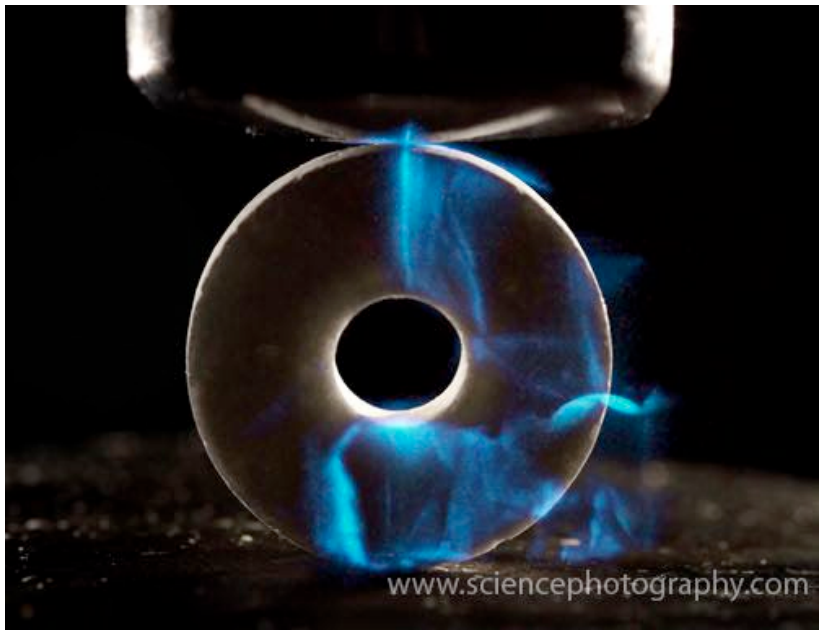
Measure the Absorption Spectra of 2 food colors.

Mix 2 food colors to get a new color.
Measure the Absorption Spectrum.
Did a chemical reaction occur?

Bring A Colored Food To Lab.
Extract the color from the food.
Measure the Absorption Spectrum.
Is the color from the food a food coloring?

Wint-O-Green Lifesavers: See Practice Problem 7.

http://familyembellishments.blogspot.com/2011/06/wintergreen-lifesavers-spark-great.html



http://scienceblogs.com/photosynthesis/2009/09/23/luminescent-candy/

Light and Color

Where does light come from?

How is light produced?

Why do different substances have different color?

How is light studied?

What does the study of light tell us?

TiO_2 is a White Pigment used in Paint and Food coloring

Nano-sized TiO_2 added to concrete keeps concrete white

http://cen.acs.org/articles/89/i24/Building-Small.html

Self-cleaning property:

TiO_2 + UV light --> excited TiO_2*

TiO_2* works as a catalyst for oxidizing organic grime and "eats" smog (NO_x, SO_x, carbon monoxide, aromatics, ammonia, and aldehydes)

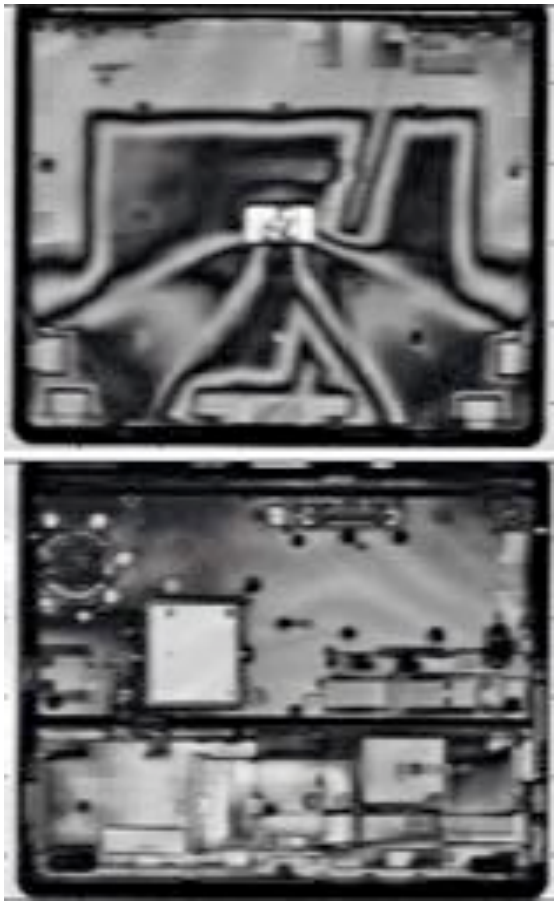
Add TiO_2 to surfaces to reduce air pollution.

Application: Far IR is used in chemical analysis and

1 Terahertz (THz) = 10^{-12} Hz)

Development of instrumentation for THz spectroscopy.

Detects small amounts of C-4 explosives hidden in sealed envelopes (590 cm^{-1}). C-4 cannot be detected by X-rays or metal detectors.



Imaging in medical, security, and other applications that capitalize on the light's ability to penetrate plastics, paper, and textiles

Burning of Fossil Fuels ==> Global Warming

2007: **World oil demand = 85 million barrels/day**

US oil demand = 20 million barrels/day,

approx 10 million barrels/day for gasoline,

141 billion gallons gas/year

California = 16 billion gallons gas/year

Gasoline is a mixture of hydrocarbons.

One gallon of burned octane produces 8250 g of CO_2.

CO_2 absorbs IR radiation ==> IR = heat

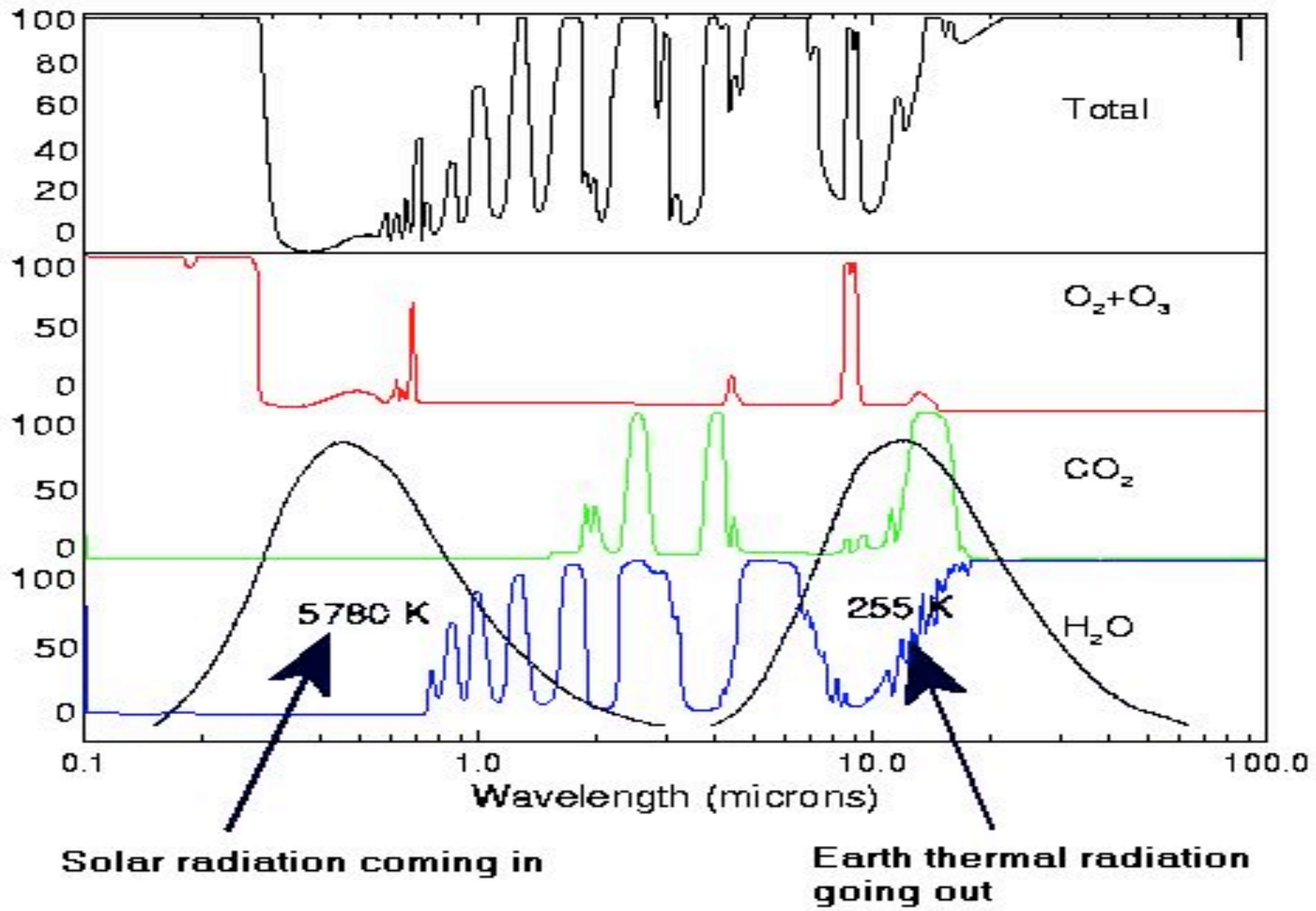
The amount of IR radiation (heat) absorbed by CO_2 is proportional to the CO_2 concentration. *(Beer's law: A α C)*

Atmospheric [CO_2] = 380 ppm

References:

Greenhouse gases explained
http://tonto.eia.doe.gov/energyexplained/index.cfm?page=environment_about_ghg
CO_2 absorption spectrum
http://www.iitap.iastate.edu/gccourse/forcing/images/image7.gif
Solar radiation in and earth's thermal radiation out
http://www.te-software.co.nz/blog/augie_auer.htm
Global warming potential table http://unfccc.int/ghg_data/items/3825.php
CO_2 and T data http://www.geocraft.com/WVFossils/temp_vs_CO2.html
CO_2 and T data last 800,000 years
http://en.wikipedia.org/wiki/File:Co2-temperature-plot.svg
Cold facts on global warming http://brneurosci.org/co2.html
Global warming: a chilling perspective
http://www.geocraft.com/WVFossils/ice_ages.html#anchor2117056
Iowa State global change course http://www.iitap.iastate.edu/gccourse/units01.html

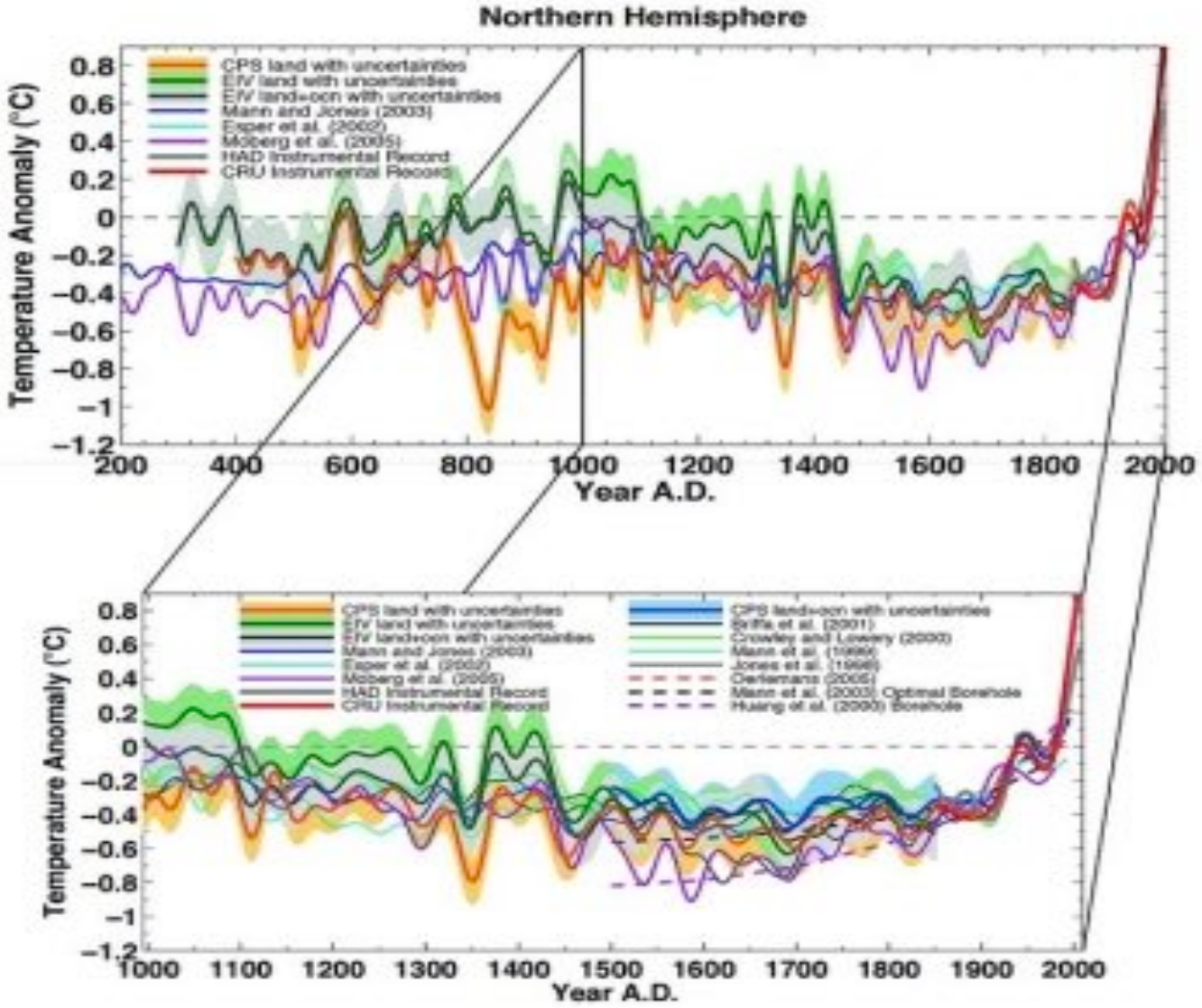
Absorption Spectra of Atmospheric Gases and Solar/Earth Radiation



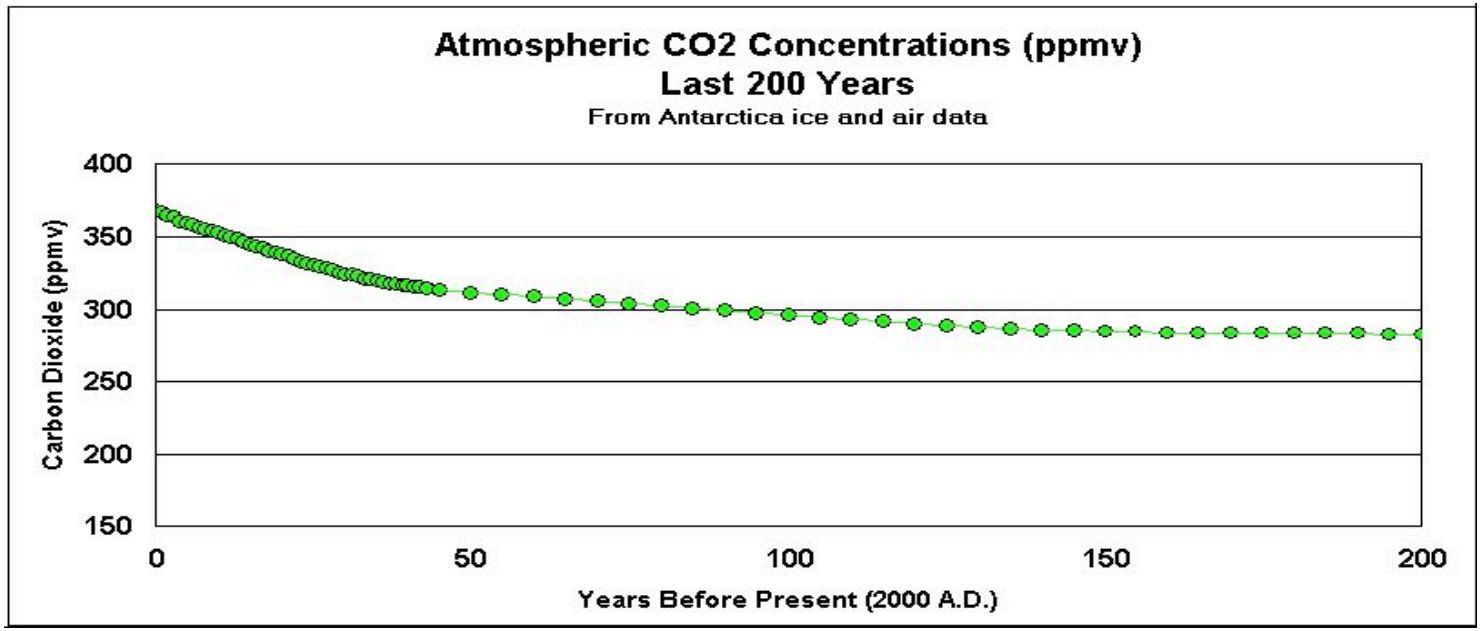
http://noconsensus.wordpress.com/2010/04/19/radiative-physics-yes-co2-does-create-warming/

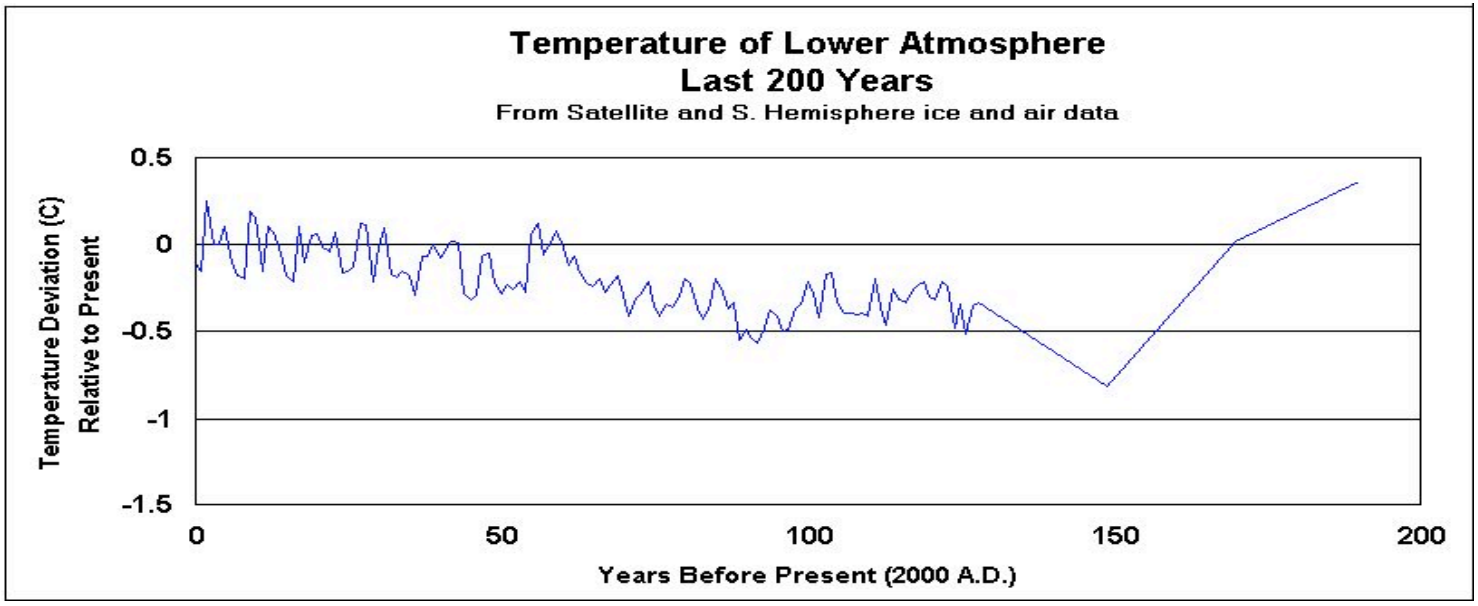
http://cen.acs.org/articles/90/i50/Michael-Manns-Hockey-Stick.html

12/10/12, CEN, p. 52 Book Review: "The Hockey Stick And The Climate Wars: Dispatches From The Front Lines", by Michael E. Mann

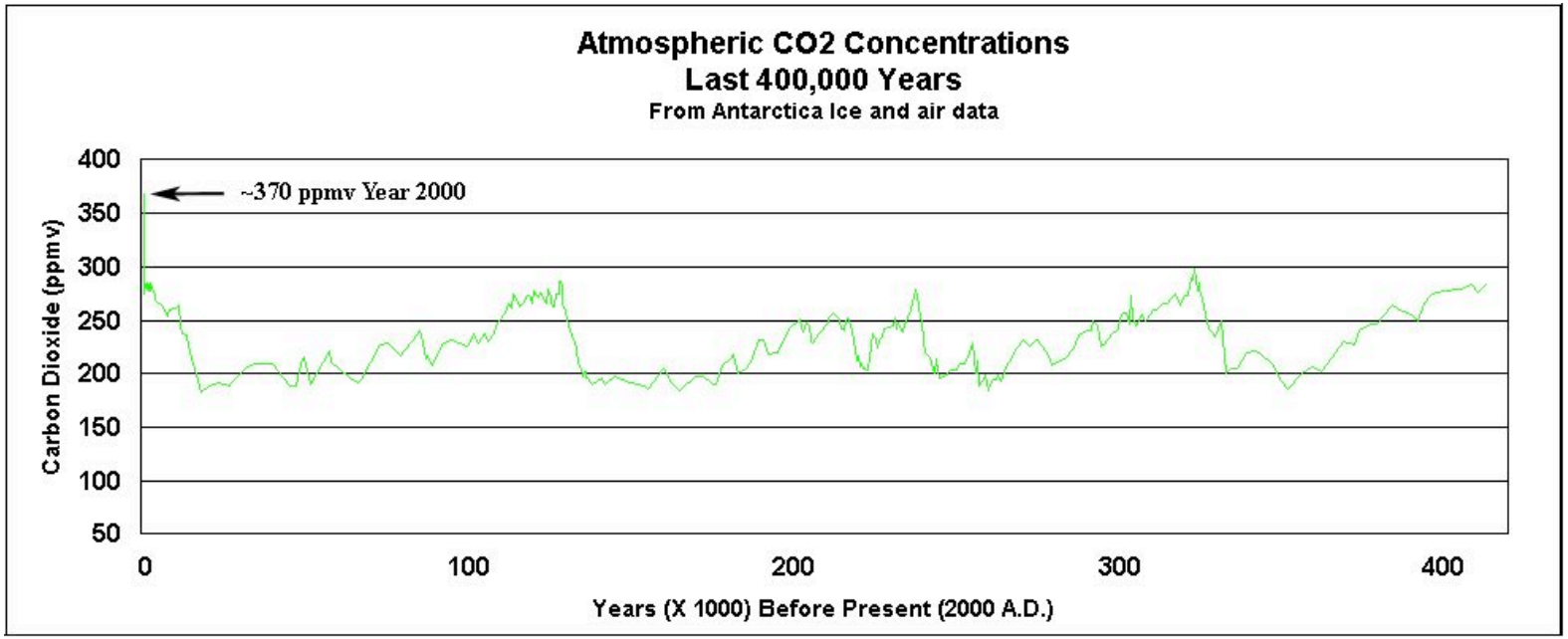


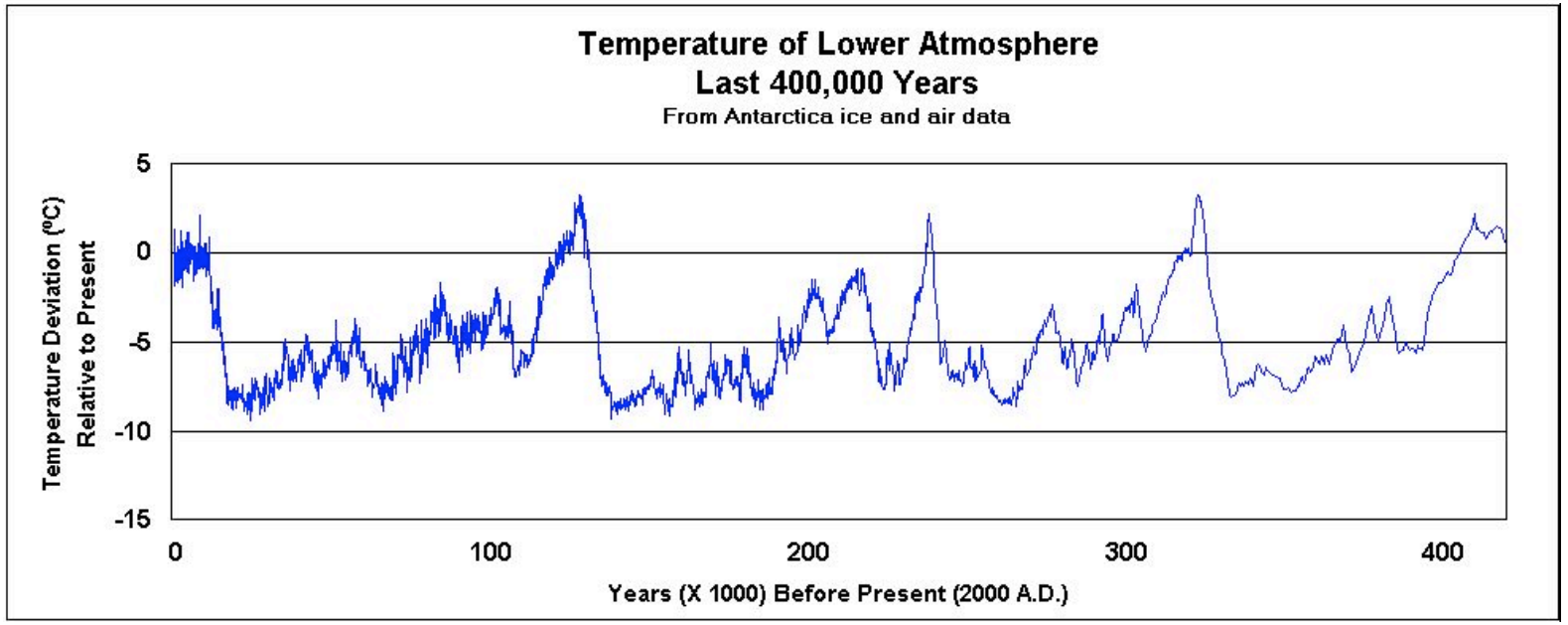
More than a dozen independent temperature reconstructions affirm the conclusion that Earth's temperature has risen sharply in the past century.



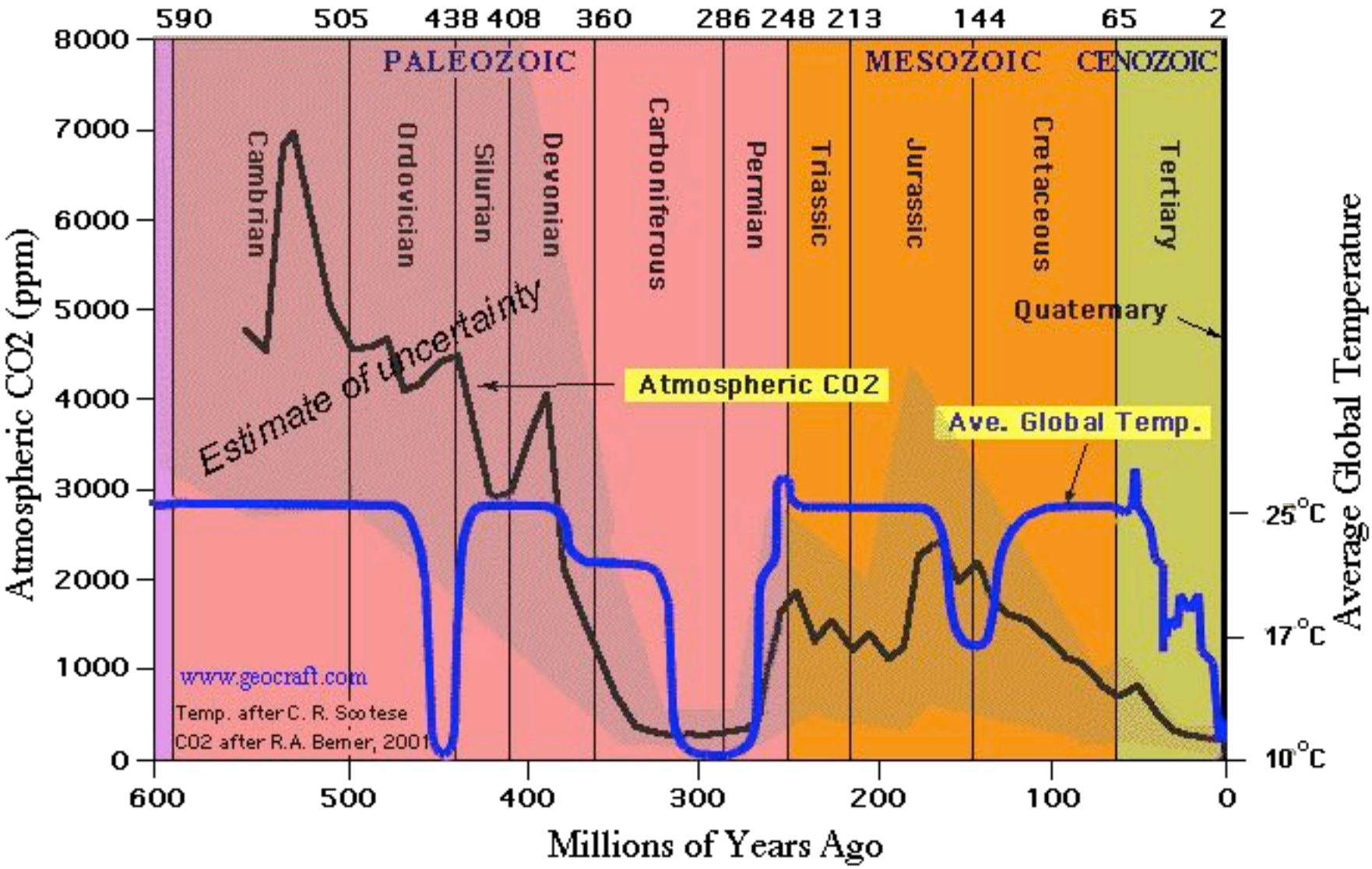


http://www.geocraft.com/WVFossils/last_200_yrs.html





http://www.geocraft.com/WVFossils/last_400k_yrs.html



http://www.geocraft.com/WVFossils/Carboniferous_climate.html#anchor147264

Carbon Cycle: Life on earth is carbon-based
Plants absorb CO_2 and emit oxygen as a waste product.
Humans and animals breathe oxygen and emit CO_2 as a waste product.

All sources: Approx. 200 billion tons of carbon from CO_2 that enter earth's atmosphere each year (½ from oceans, ½ from volcanoes and decaying plants)
Human activity: 6 billion tons of carbon from CO_2.

CO_2 that goes into the atmosphere is recycled by terrestrial plant life and earth's oceans

CO_2 concentration: 380 parts per million (ppm) = less than 4/100ths of 1% of all gases present. Compare to former geologic times.

Is CO_2 is an essential ingredient.
Is CO_2 is a nutrient or a pollutant?
Is plant growth stimulated by more CO_2?
http://www.geocraft.com/WVFossils/ice_ages.html

Australian sheep and cattle to be vaccinated to reduce CH_4 emissions.

http://spudcomics.com/tag/farting-sheep/

Sheep and cattle in Australia produce 14% of Australia's total greenhouse emissions (measured in CO_2 equivalents).

Vaccine will reduce CH_4 emissions by 20% in these animals (approx. 300,000 metric tons of CO_2).

$CH_4 \approx 21$ x more potent than CO_2 as a greenhouse gas.
(Chemical and Engineering News, 6/18/01, p. 104)

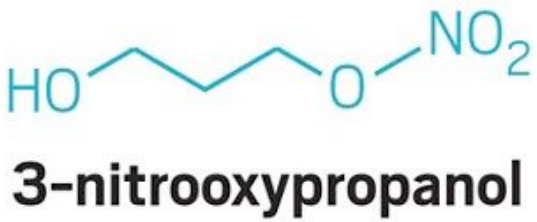
CEN, 7/29/19, “Minimizing methane from cattle”

https://cen.acs.org/business/food-ingredients/DSM-seeks-approval-additive-minimizing/97/i30

A cow releases 70-120 kg of methane annually, mostly by burping. Cow’s digestive system has microbes that produce methane.

Livestock accounts for 15% of global greenhouse emissions of which more than ½ from cattle.

3-nitrooxypropanol is a cattle feed additive that can reduce methane emissions by 30%. DSM Co. (Europe) has applied to European regulators to see this additive.



3-nitrooxypropanol

1.3 billion cows in the world (2011)

U.S. Livestock produces 139.8 units of $TgCO_2$ equivalent
(teragram carbon dioxide equivalent)
≈ 20% of all human methane production and second only to natural gas systems

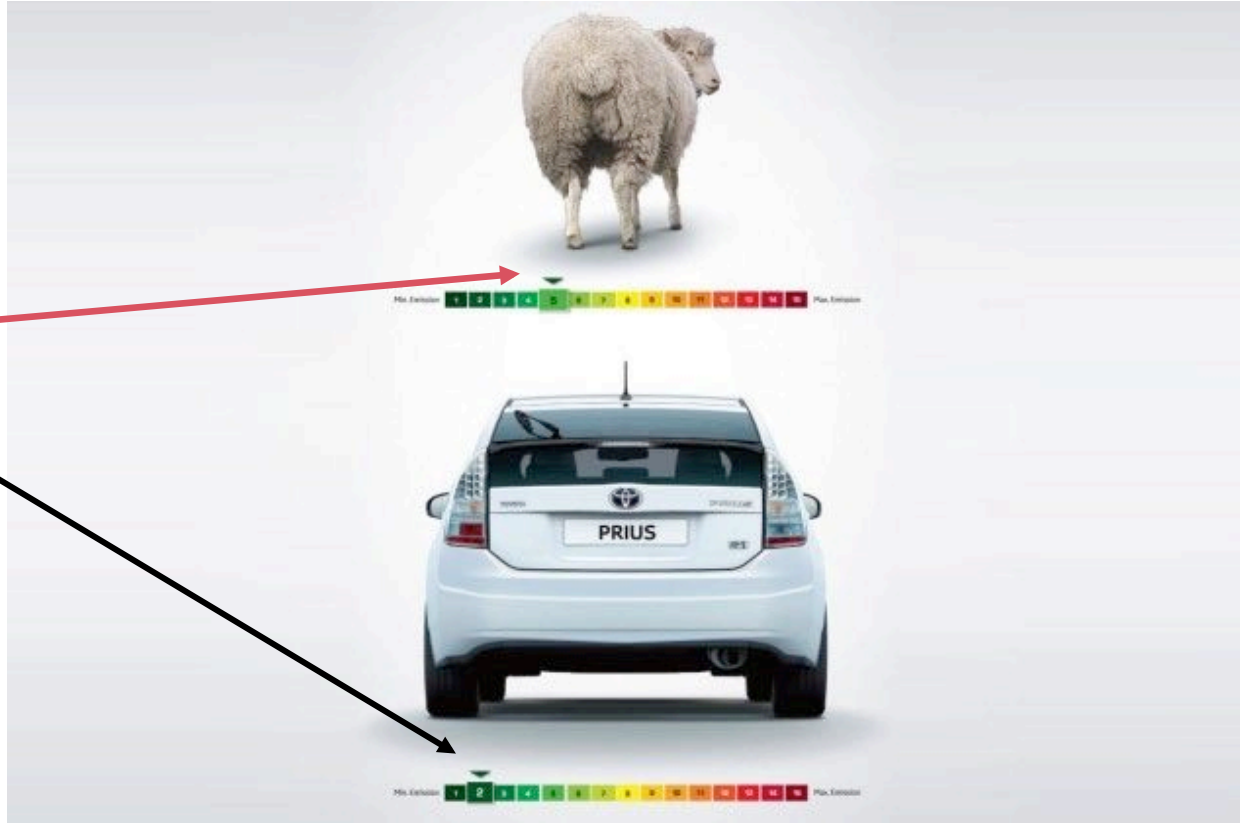
U.S. produces 5,637.9 units of $TgCO_2$ equivalent per year by burning fossil fuels

http://bigkingken.wordpress.com/2011/07/05/finally-a-post-on-cow-farts/

Toyota: Prius exhaust less harmful than sheep emissions

http://www.autoblog.com/2011/01/04/toyota-prius-exhaust-less-harmful-than-sheep-emissions/

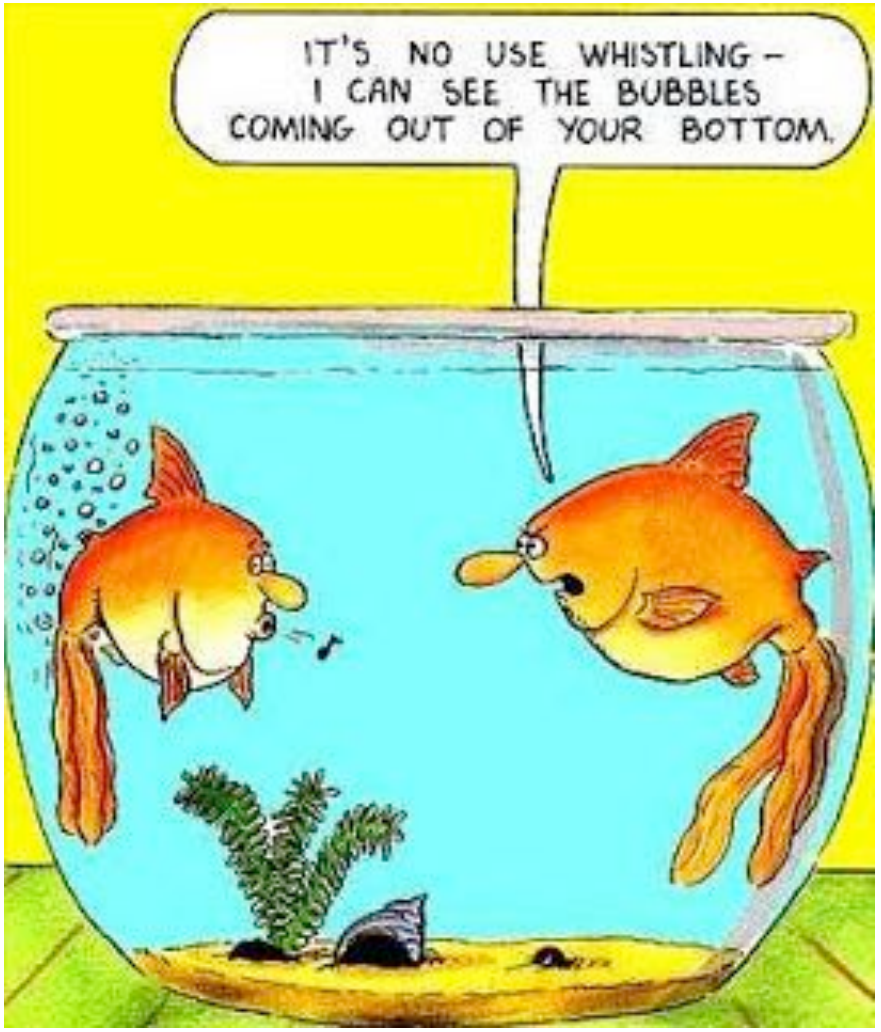
See scale



Question: Does one sheep emit more global warming CH_4 than one Prius emit global warming CO_2?

Seen in SF

http://www.freerepublic.com/focus/f-news/1864014/posts



http://dotsnodds.blogspot.com/2011/02/when-in-malawi-do-not-fart.html

Search for greenhouse gas emitters by facility, type of factory, amount and type of greenhouse gas, facility location, plant name

http://ghgdata.epa.gov/ghgp/main.do

HEATED EXCHANGE

HCFCs and HFCs remain in the atmosphere longer than CFCs

GAS	GLOBAL WARMING POTENTIAL[a]	LIFETIME (YEARS)
CO_2	1	100+
Chlorofluorocarbons (CFCs)		
CFC-12	10,200 +/– 3,750	100.0
CFC-114	9,880 +/– 3,460	300.0
CFC-113	6,030 +/– 2,110	85.0
CFC-11	4,680 +/– 1,640	45.0
Hydrochlorofluorocarbons (HCFCs)		
HCFC-142b	2,270 +/– 800	17.9
HCFC-22	1,780 +/– 620	12.0
HCFC-124	599 +/– 210	5.8
HCFC-123	76 +/– 27	1.3
Hydrofluorocarbons (HFCs)		
HFC-23	14,310 +/– 5,000	270.0
HFC-125	3,450 +/– 1,210	29.0
HFC-134a	1,410 +/– 490	14.0
HFC-245fa	1,020 +/– 360	7.6
HFC-152a	122 +/– 43	1.4

a Referenced to CO_2. Global warming potential is a measure of relative ability to affect the global climate.

SOURCES: Intergovernmental Panel on Climate Change and Economic Assessment Panel

CEN, October 3, 2005, pp. 23-24
Hot Times Ahead For Refrigerants
As worry over refrigerants' threat to the ozone layer recedes, concern over global warming rise.

Energy for refrigeration = 1/6 of global energy usage

http://www.nytimes.com/2014/07/27/magazine/what-do-chinese-dumplings-have-to-do-with-global-warming.html?_r=0