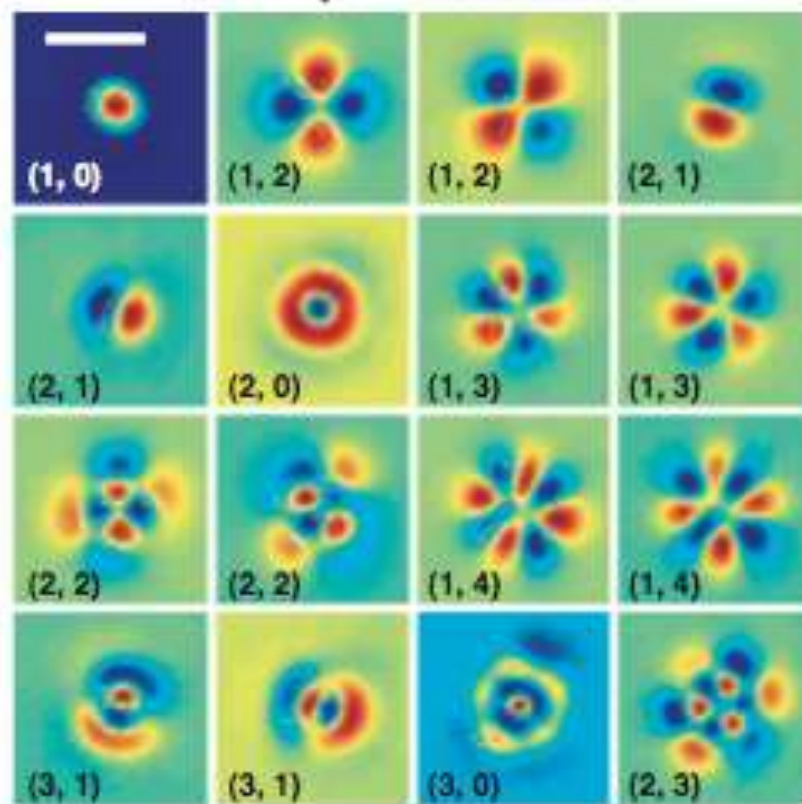
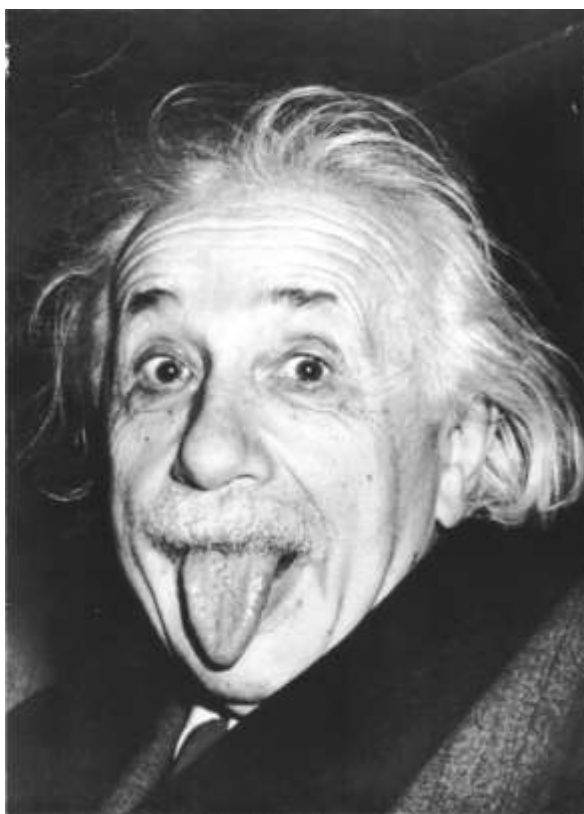


Pre-AP Chemistry

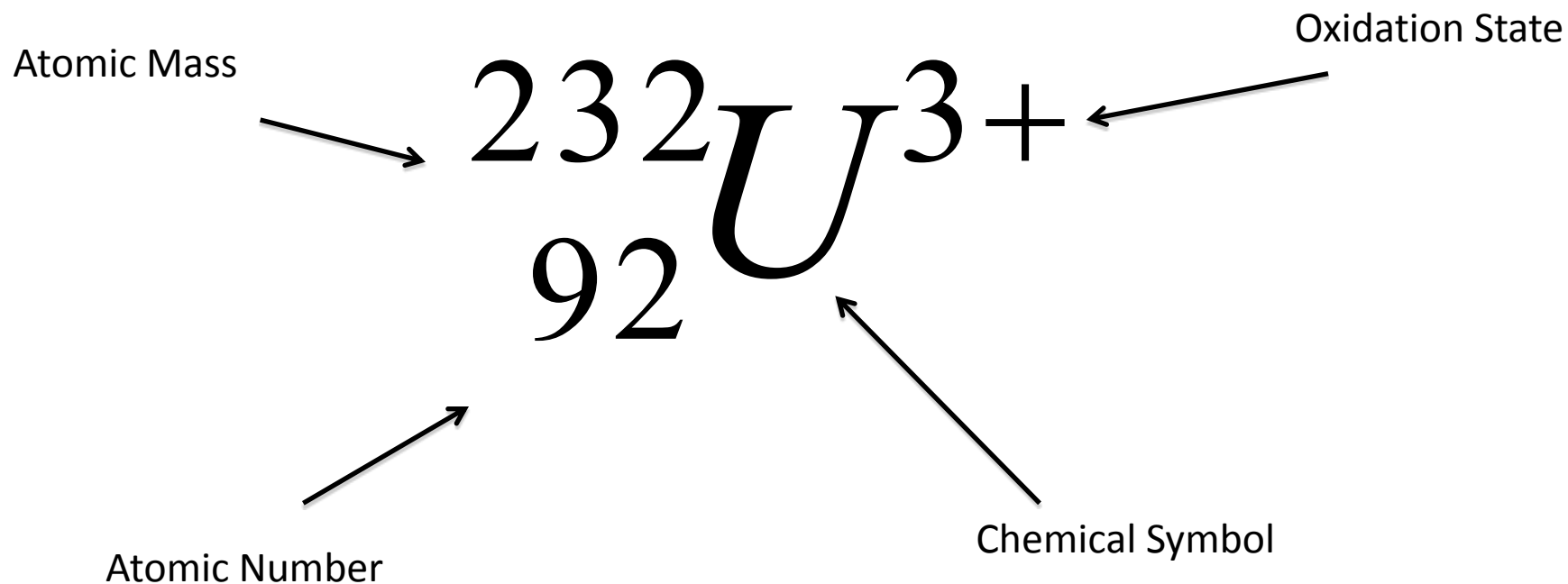
September 4, 2011

7. Electrons in Atoms I



Review

- Atomic symbols allow you to count the total number protons, neutrons, and electrons in an atom
- The atomic mass tells you about the percent relative isotopic abundance



Periodic Table

- Special Groups: What properties do the elements in each have in common? What is the origin of these common properties?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																		
1 H Hydrogen 1.00794	Atomic # Symbol Name Atomic Mass																2 He Helium 4.002602																		
3 Li Lithium 6.941	4 Be Beryllium 9.012182	C Solid Hg Liquid H Gas Rf Unknown										Metals Alkali metals Alkaline earth metals Lanthanoids Actinoids Transition metals Poor metals			Nonmetals Other nonmetals Noble gases			5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0064	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797												
11 Na Sodium 22.98976928	12 Mg Magnesium 24.304	13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.796										
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29	55 Cs Cesium 132.9054519	56 Ba Barium 137.327	57-71 Lanthanoids	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.227	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3853	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209)	85 At Astatine (209)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89-103 Actinoids	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (289)	117 Uus Ununseptium (289)	118 Uuo Ununoctium (294)																		

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

Periodic Table Design and Interface Copyright © 1997 Michael Dayah. <http://www.ptable.com/> Last updated: May 27, 2008



57 La Lanthanum 138.90547	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Electron configuration!

Chemistry IS the transfer of electrons between atoms.

Outline

- Electromagnetic Radiation
- Introduction to Quantum Mechanics
- Chemistry?

- Electromagnetic Radiation
 - Waves
 - Electromagnetic Spectrum
- Introduction to Quantum Mechanics
 - Atomic Spectra
- What does this have to do with chemistry?

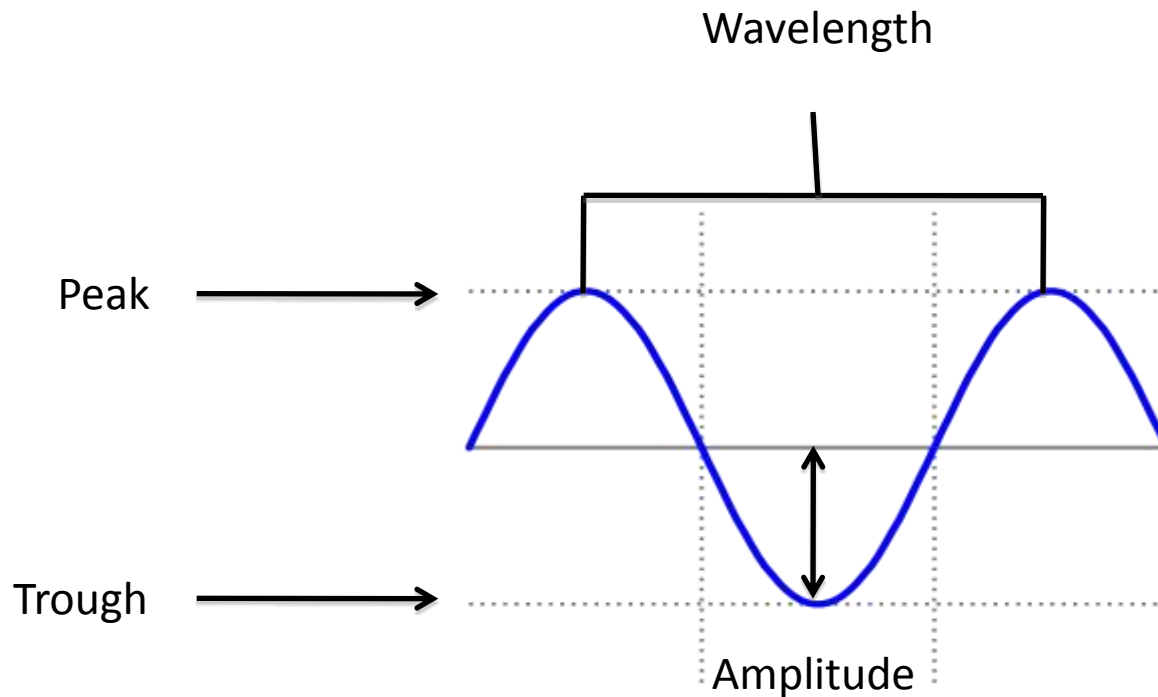
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Waves

- Peak / Trough: the highest / lowest points on a wave.
- Wavelength (λ): the distance between two consecutive peaks
- Amplitude (A): the height of a peak relative to the middle of a wave



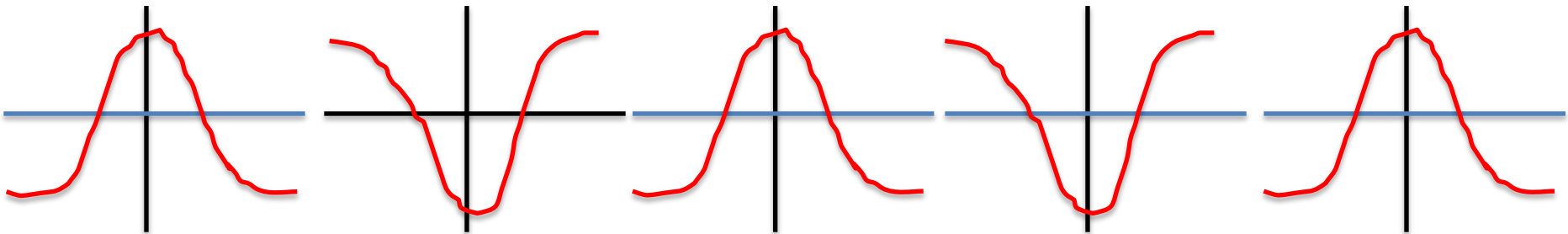
Waves

- Frequency (f): number of times a peak passes a point in a given time
- Velocity (v): the product of a wave's wavelength and frequency

0.00 s

0.50 s

1.00 s



Peak passes black line twice in 1 second \rightarrow frequency is 2 cycle s^{-1} (Hz)

In vacuum

Speed of Light

In media

$$c = \lambda f$$

$$c \approx 3 \times 10^8 \text{ m/s}$$

$$v = \lambda f$$

Waves

- Do the units in the velocity equation make sense?
- Let's do some dimensional analysis ...

Property		Units
Velocity	v	$\frac{m}{s}$
Wavelength	λ	m
Frequency	f	$\frac{1}{s}$

$$v = \lambda f$$

$$\left[\frac{m}{s} \right] = [m] \times \left[\frac{1}{s} \right]$$

$$\left[\frac{m}{s} \right] = \left[\frac{m}{s} \right]$$



In vacuum

$$c = \lambda f$$

Speed of Light

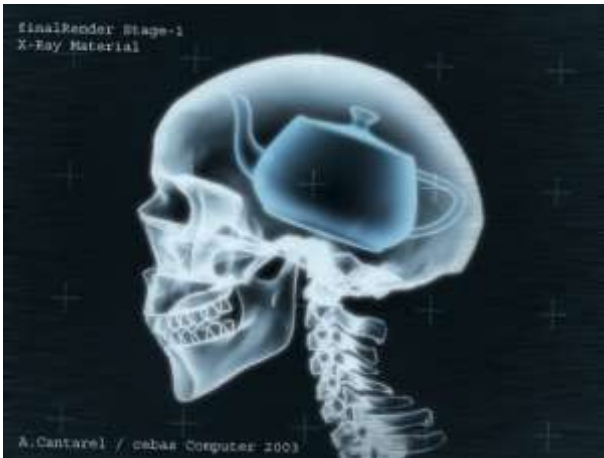
$$c \approx 3 \times 10^8 \text{ m/s}$$

In media

$$v = \lambda f$$

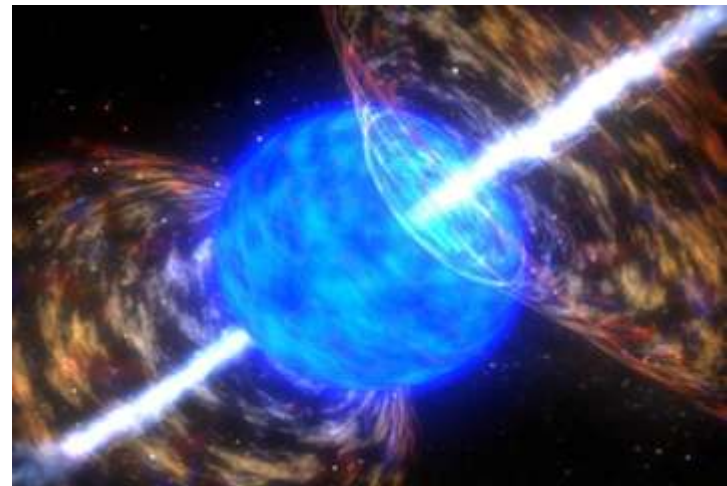
Mini Quiz

- Microwaves produce waves with a wavelength of 1 cm. What is the frequency of these waves?



- X-rays have a frequency of $3\text{E}+16$ Hz. What is their wavelength?

- What is the velocity of gamma rays (in vacuum)?



Mini Quiz

- It's the night before a big chemistry test, and I forgot the speed of light! The internet doesn't work, my book is at school, and all of my friends are asleep. I remember the formula $c = \lambda f$ and I have access to the following two things:
 1. A microwave operating at a frequency of 2450 MHz
 2. A bag of marshmallows
 3. A glass pan
- Can you find the speed of light before tomorrow's test?

Mini Quiz



2450 MHz

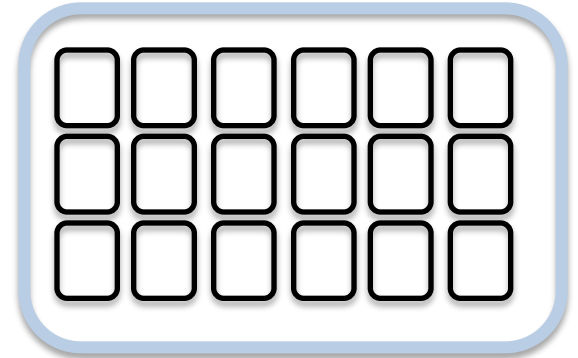


$$c = \lambda f$$

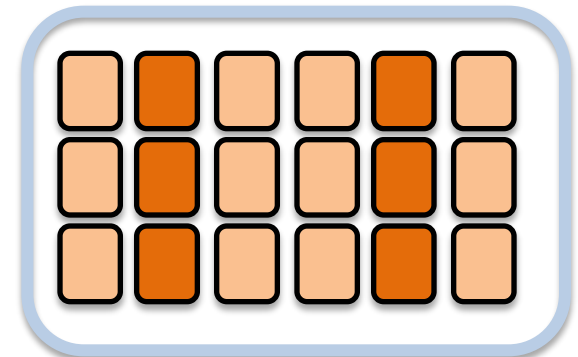
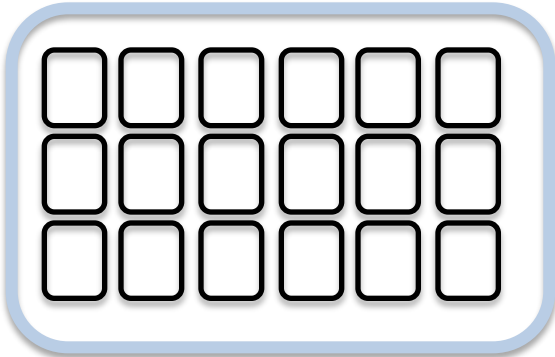
$$C = ?$$

Mini Quiz

1. Arrange marshmallows in rows in glass pan.



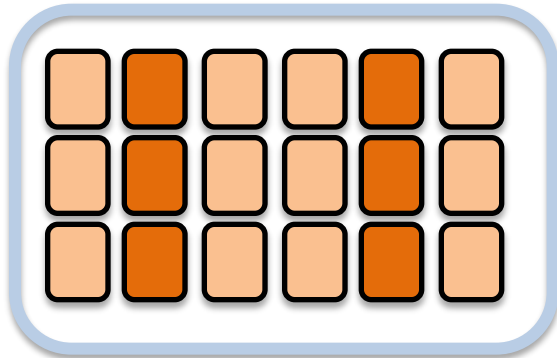
2. Cook pan of marshmallows in the microwave.



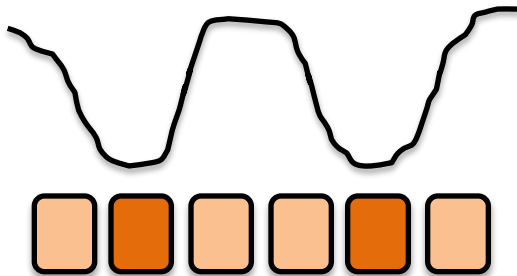
2450 MHz

Mini Quiz

3. Measure distance between darkest marshmallows.



12.2 cm



4. Find speed of light.

Frequency of
microwaves

$$c = \lambda f$$

$$c = 12.2 \text{ cm} \times 2450 \text{ MHz}$$

$$c = 12.2 \times 10^{-2} \text{ m} \times 2450 \times 10^6 \text{ Hz}$$

$$c = 2.989 \times 10^8 \frac{\text{m}}{\text{s}}$$

Outline

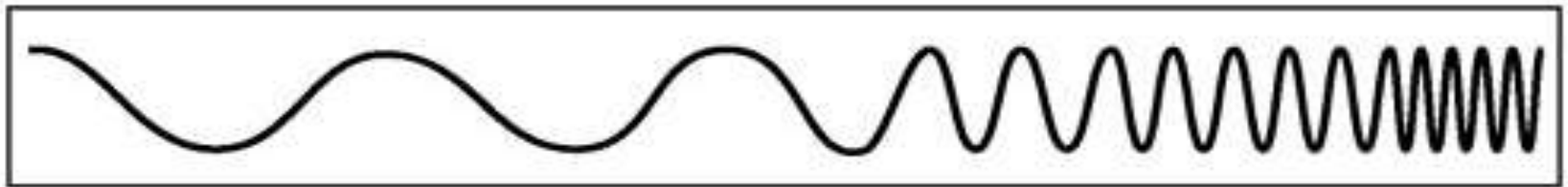
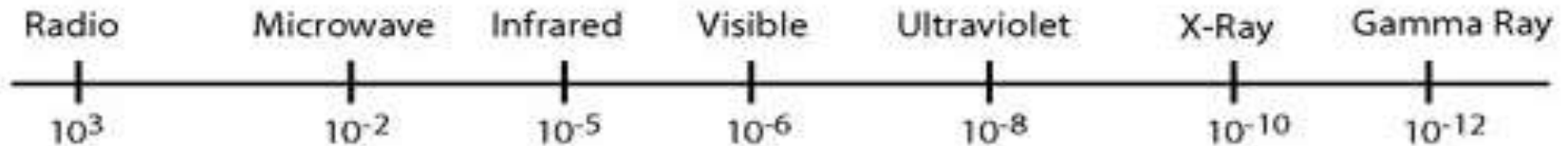
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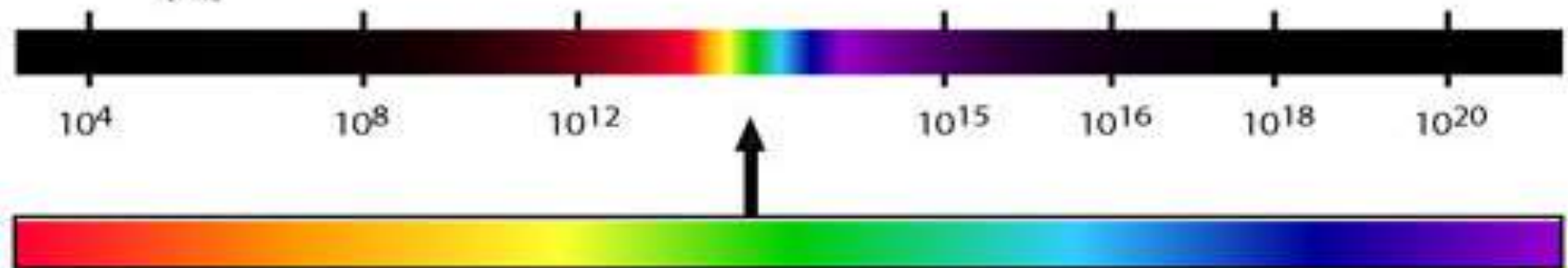
Electromagnetic Spectrum

- We have different names for electromagnetic waves of different wavelengths / frequencies

Wavelength
(metres)



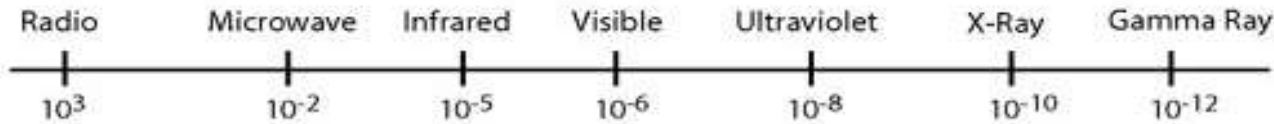
Frequency
(Hz)



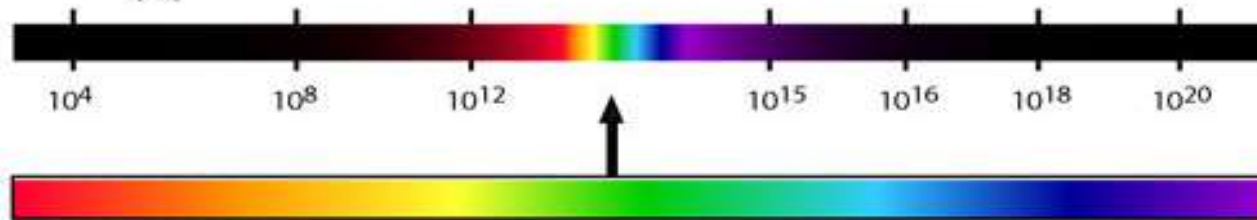
Electromagnetic Spectrum

- The energy of a wave is given by $E = hf$

Wavelength
(metres)



Frequency
(Hz)



$$E = hf$$

$$c = \lambda f$$

$$E = \frac{hc}{\lambda}$$

- Which color wave has more energy, red or blue?

Outline

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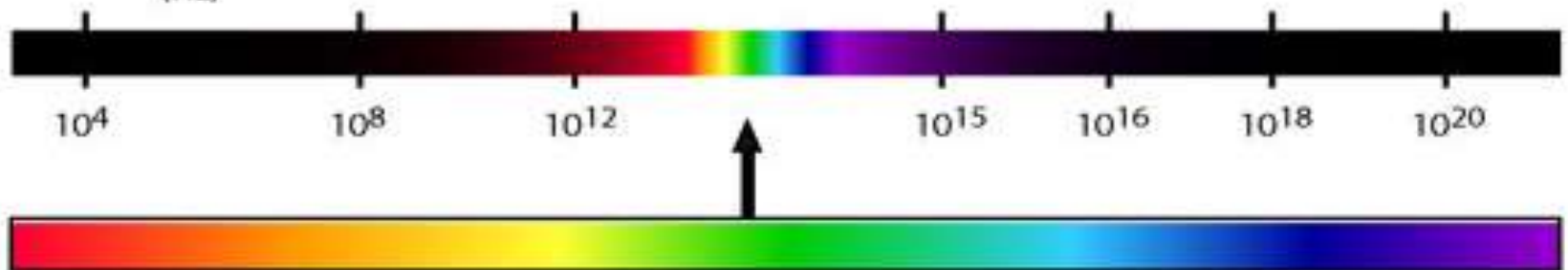
Blackbody Radiation

- Almost all frequencies of light are radiated from a heated body
- We observe their radiation as a **continuous** spectrum

Color Temperature of a Black-Body Radiator

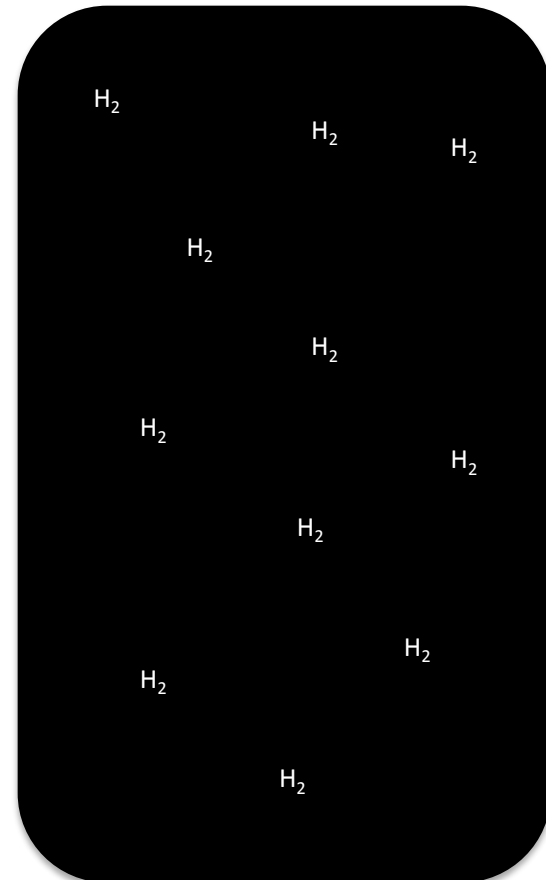
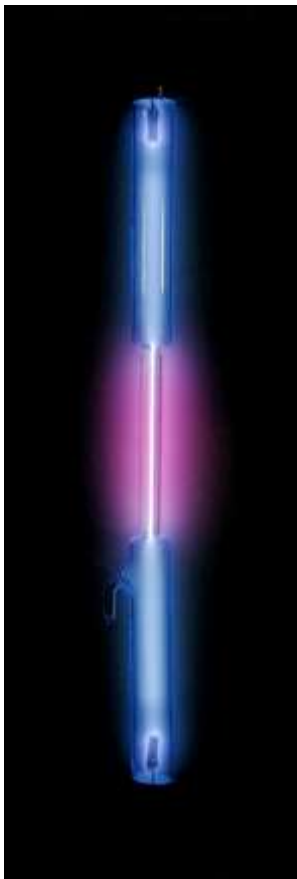


Frequency
(Hz)



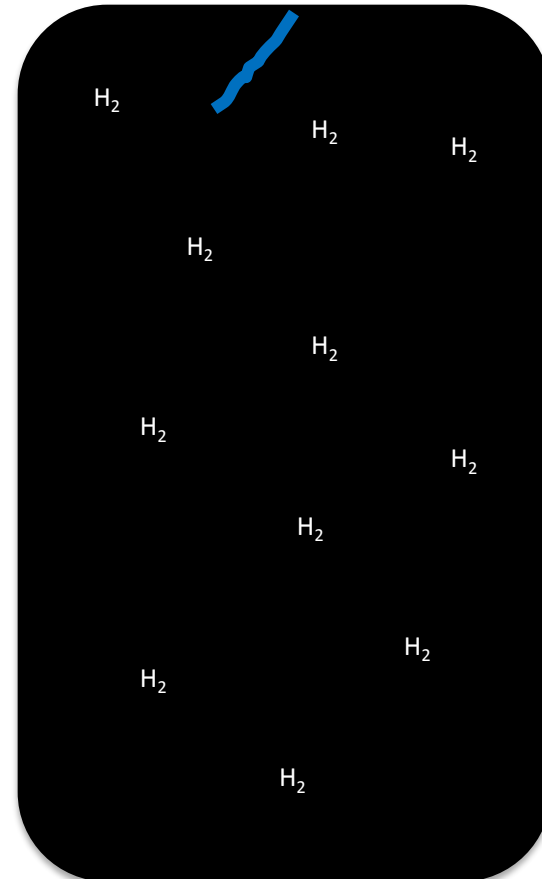
Atomic Radiation

- Light can also be generated by sending electricity through an atomic gas
- Spectra from atomic light sources are **discrete**, NOT continuous



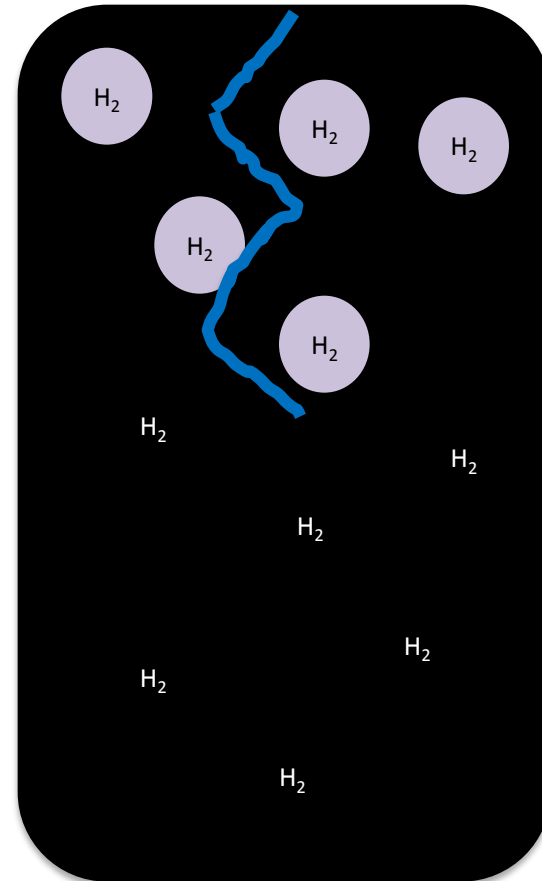
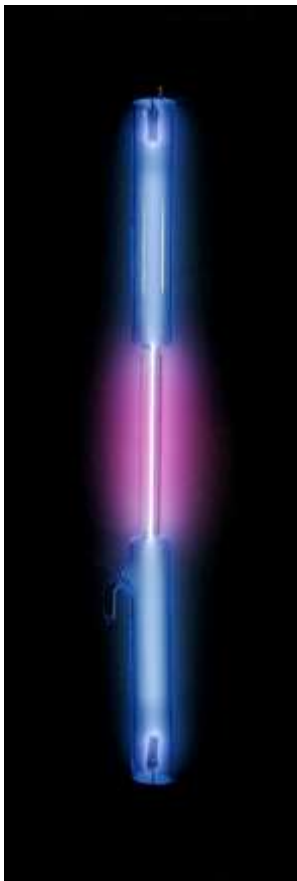
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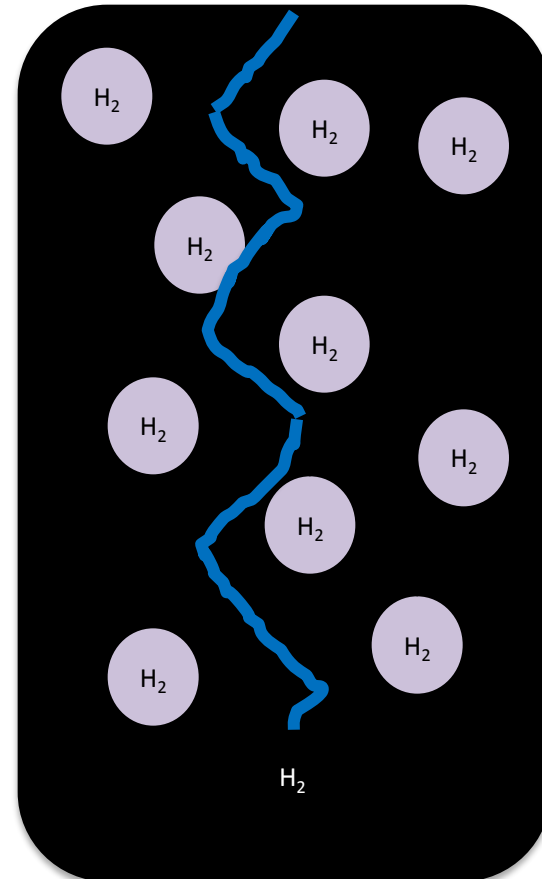
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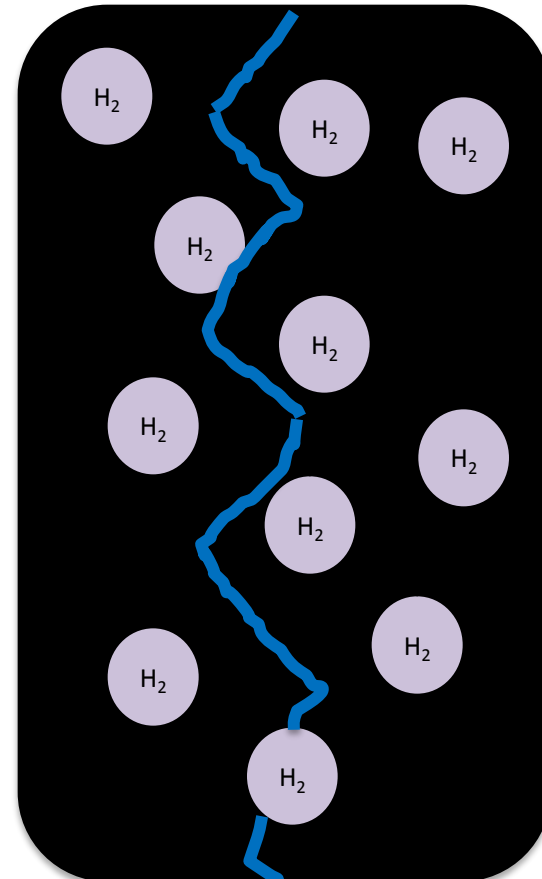
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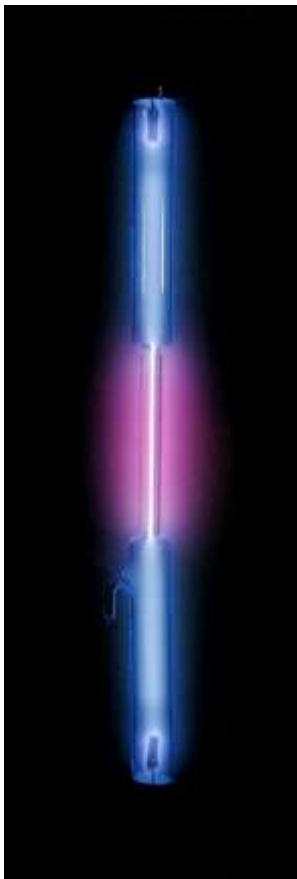
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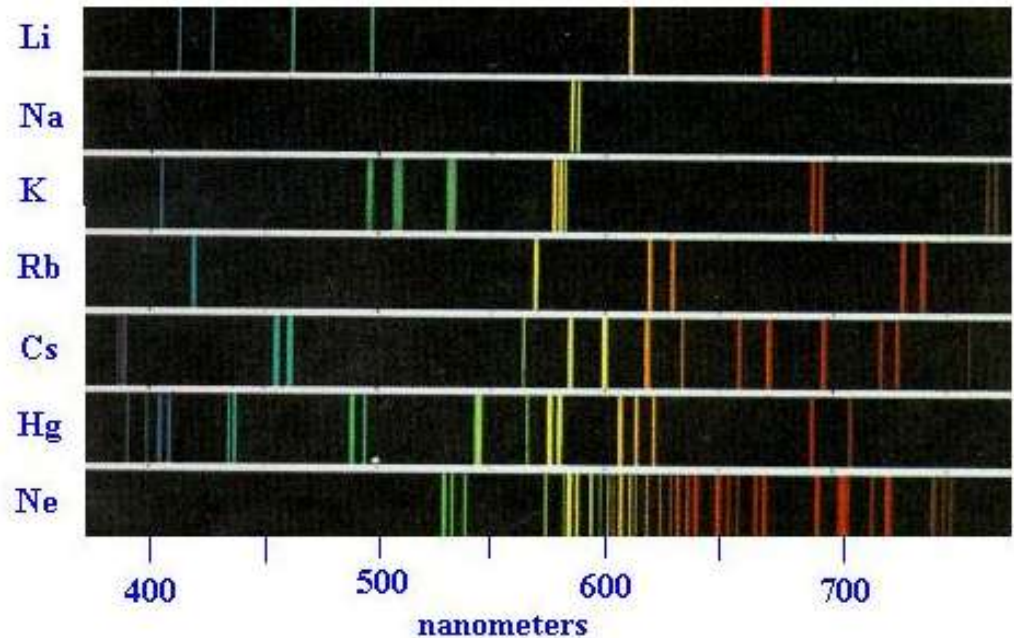


Atomic Radiation

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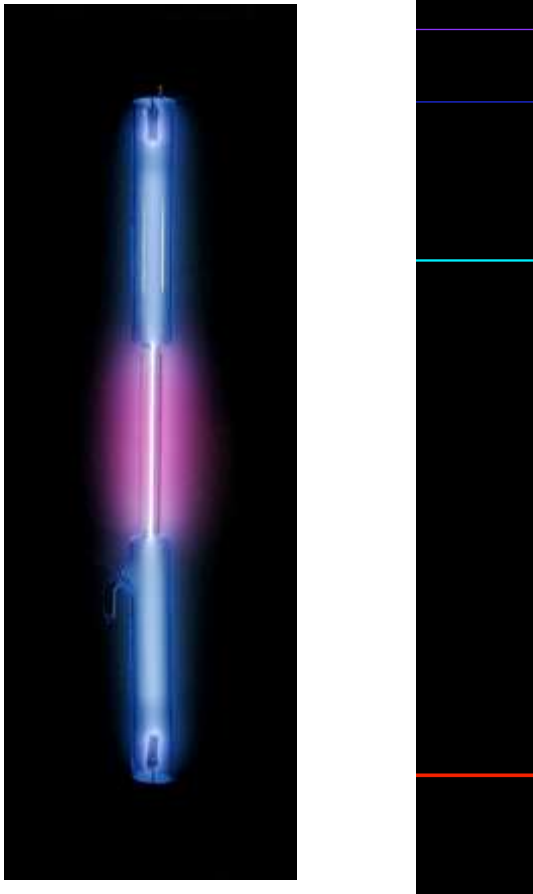


Black Body



Rydberg Equation

- Rydberg discovered that light emitted from atomic hydrogen followed a simple formula
- Possible **wavelengths** were **quantized** – n could ONLY be an integer!



Rydberg Equation

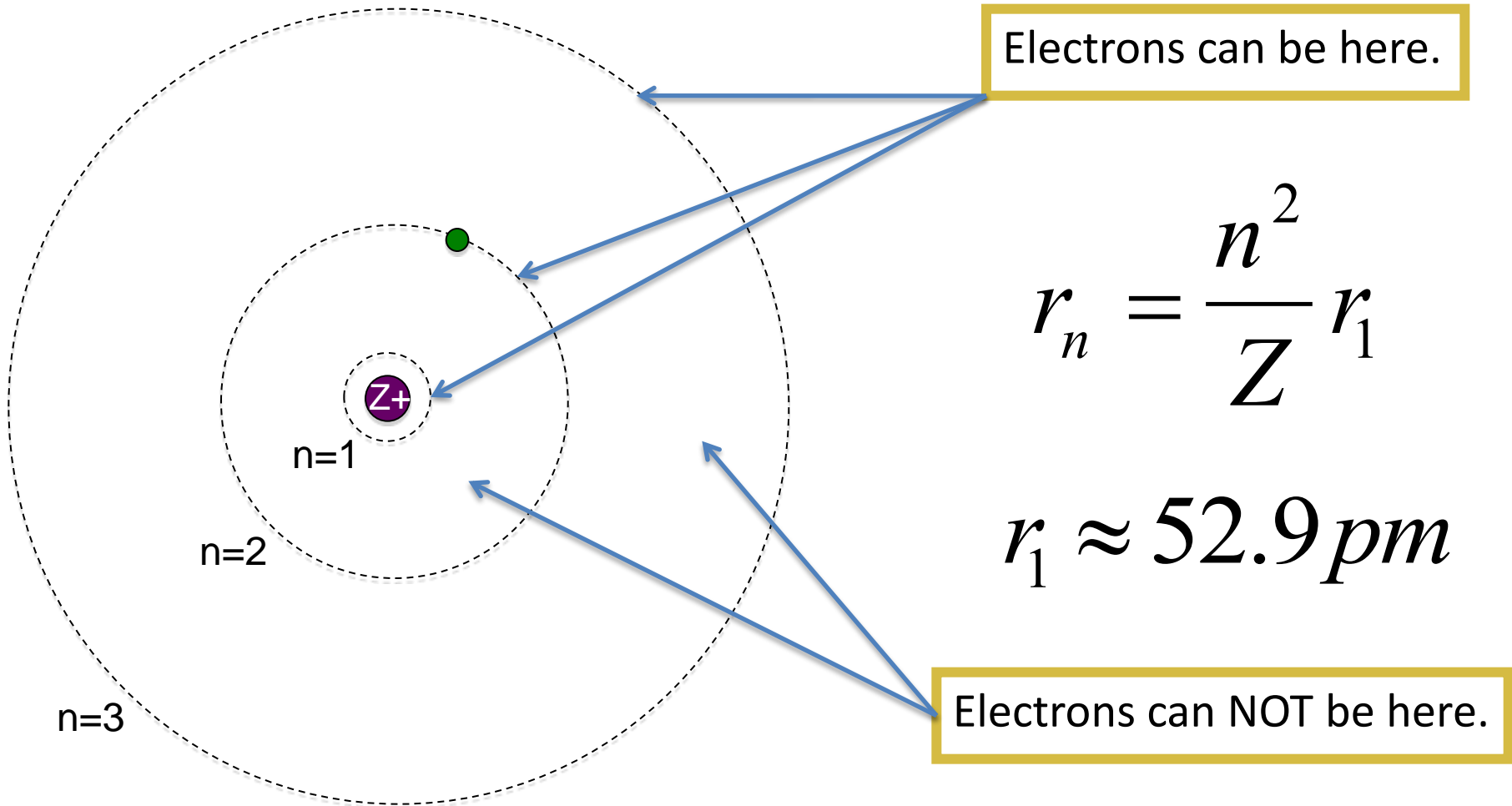
$$\lambda = \frac{n^2}{R_H} \quad E = \frac{hcR_H}{n^2}$$

$$n = 1, 2, 3, \dots$$

We need a model of the atom that explains this equation!

Bohr Atom

- Electrons travel around nucleus in specific **orbitals**
- Only specific **radii** are allowed – they are **quantized!**



Quantization of Electron Energy Levels

- Electrons can only 'sit' on specific orbits ...
- ... just like pandas can only sit on the branches of a tree.

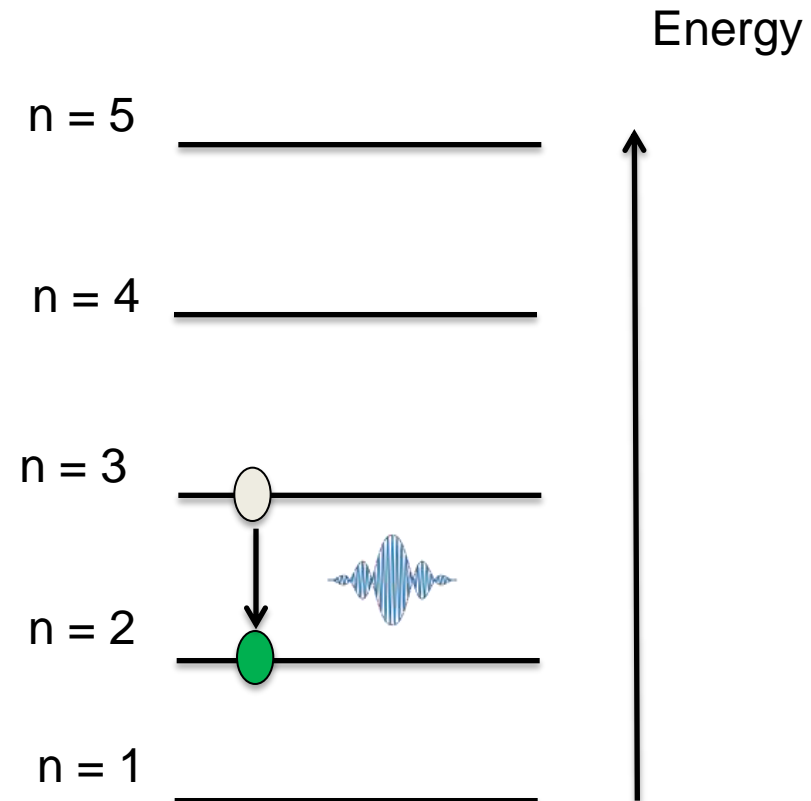
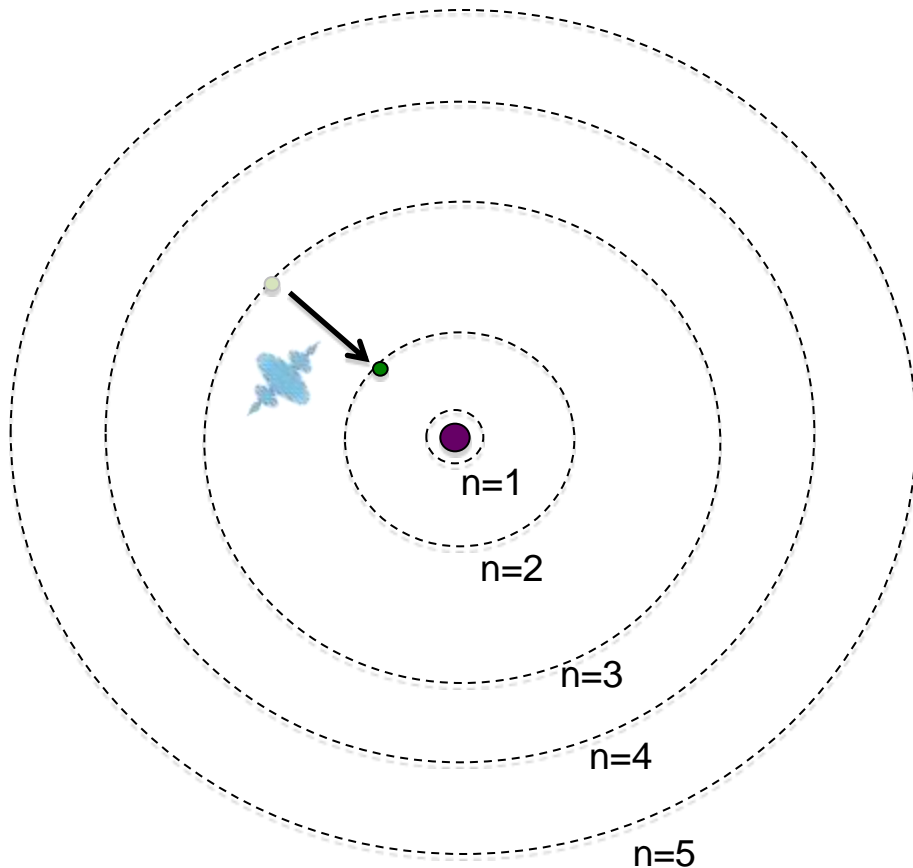


NO pandas between branches

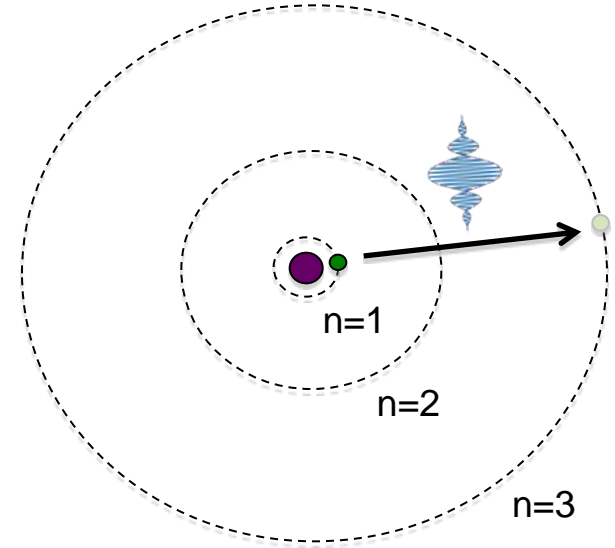
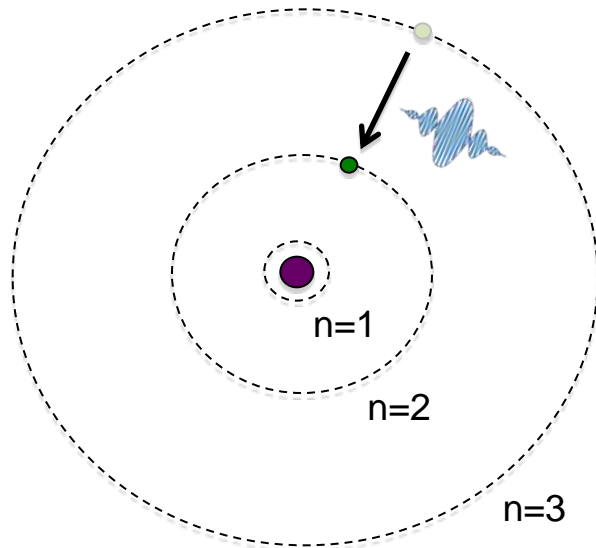
Pandas on branches

Quantization of Electron Energy Levels

- When an electron moves between **specific (quantized) orbits**, it emits or absorbs light of a **specific (quantized) wavelength**



Emission and Absorption



We say radiation (energy) is ...

emitted

absorbed

relax

... when electrons ...

are excited

... to an orbital ...

closer to the nucleus

farther away from the nucleus

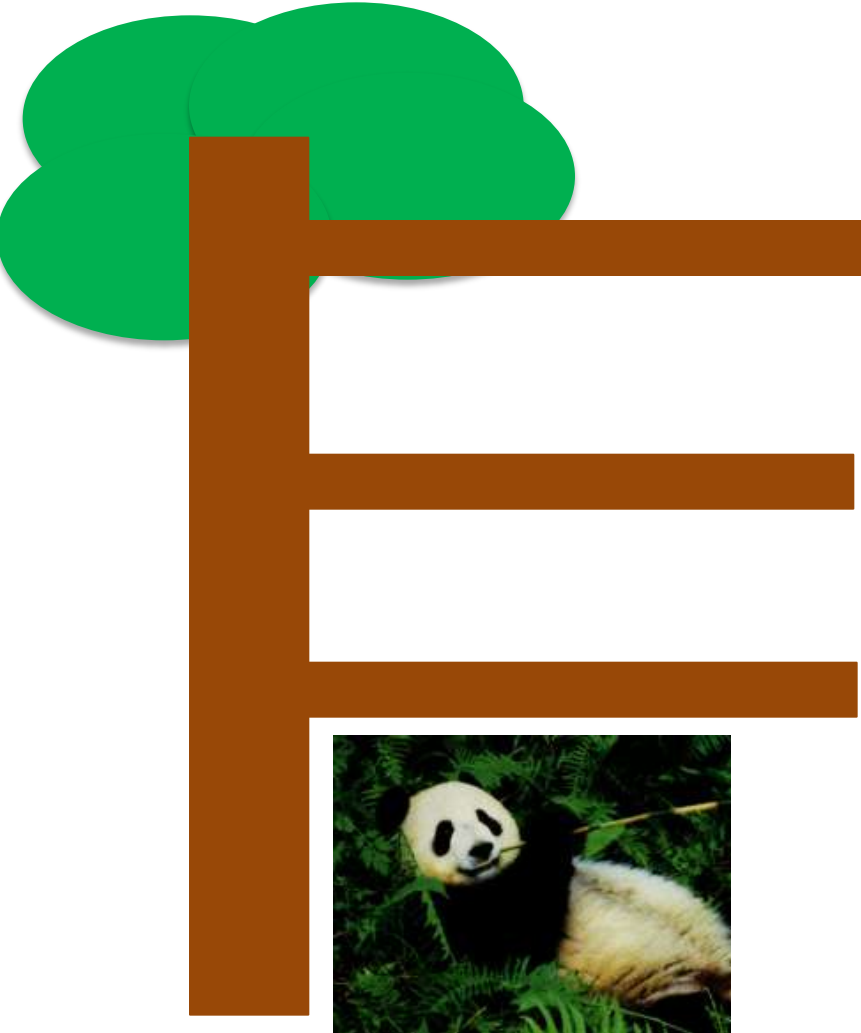
... which has ...

lower n.

higher n.

Quantization of Electron Energy Levels

- An electron is excited away from the nucleus by light ...
- ... just like a panda is excited away from the ground by a tiger.



Quantization of Electron Energy Levels

- An electron is excited away from the nucleus by light ...
- ... just like a panda is excited away from the ground by a tiger.



Mini Quiz

- The Rydberg Equation and the Bohr model helped explain why electron orbits are _____.

- Consider an electron that jumped from an $n = 1$ to an $n = 2$ orbital. Fill in the blanks below:

This electron was _____ (excited / relaxed)

to a _____ (higher / lower)

energy orbital that is _____ (closer to / farther from)

the nucleus by _____ (emitting / absorbing)

radiation (light).

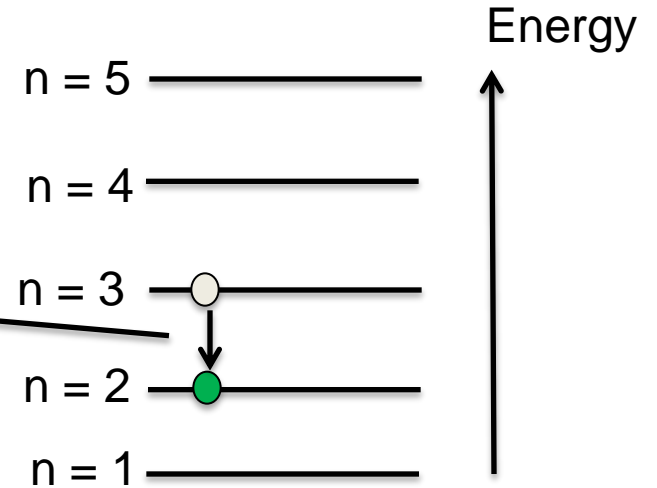
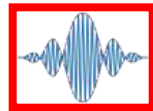
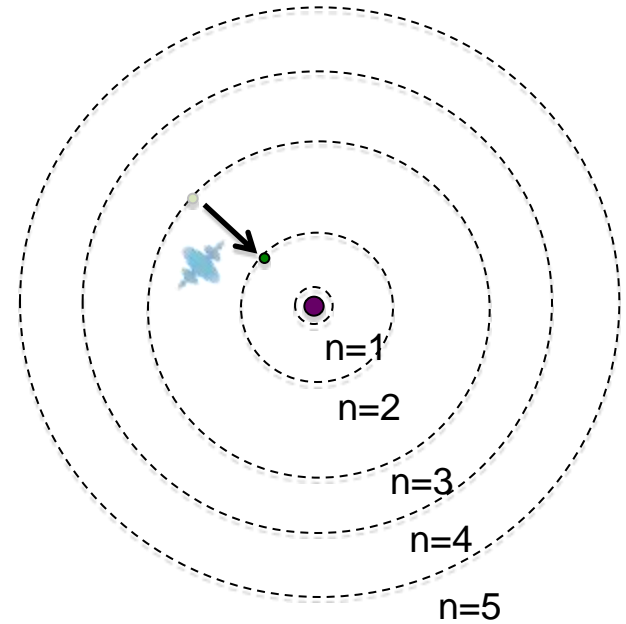
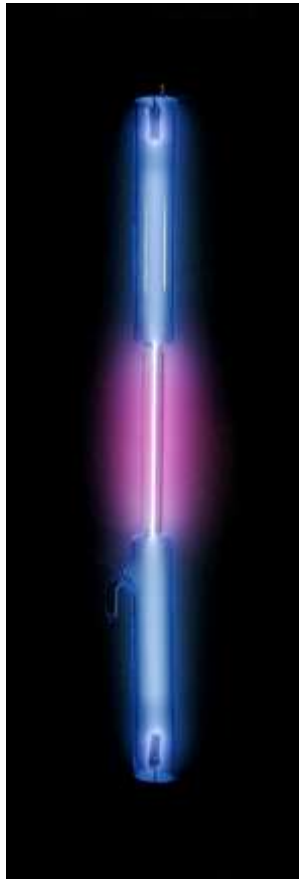
Mini Quiz

- The Rydberg Equation and the Bohr model helped explain why electron orbits are **quantized**.

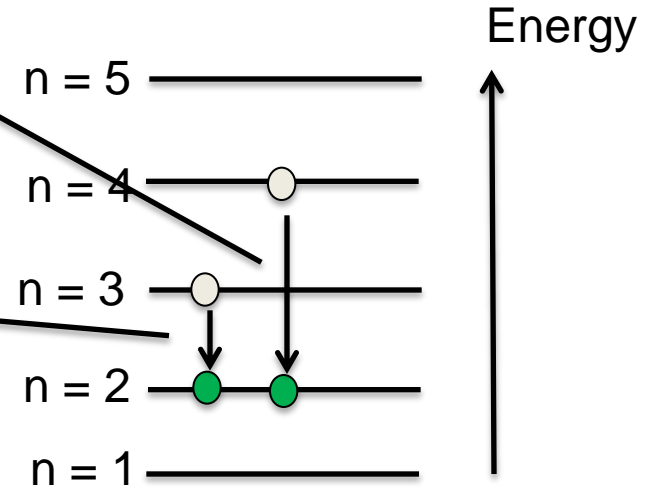
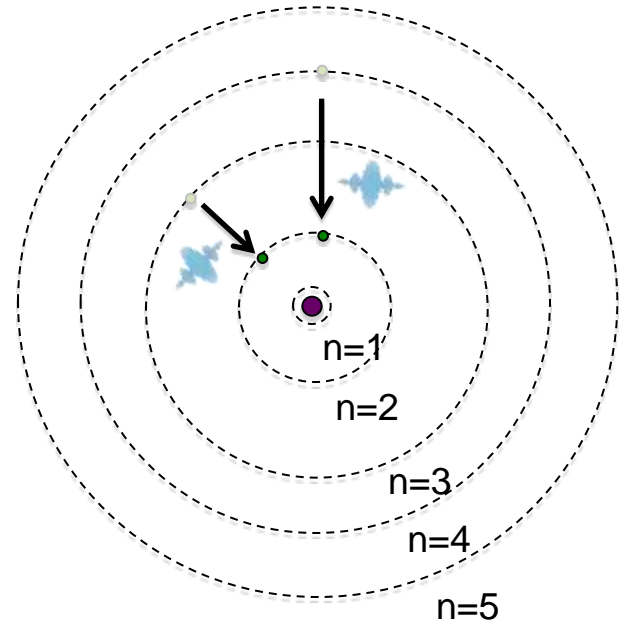
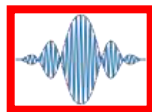
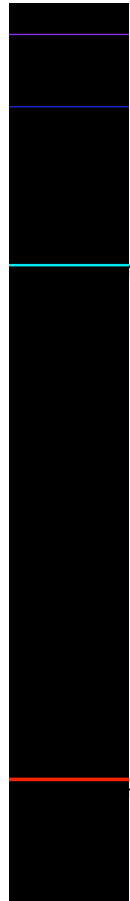
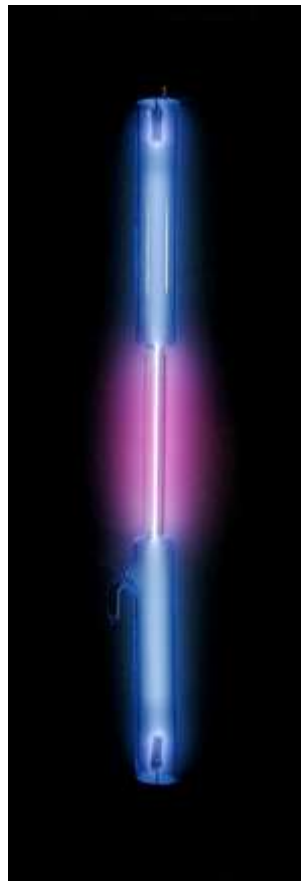
- Consider an electron that jumped from an $n = 1$ to an $n = 2$ orbital. Fill in the blanks below:

This electron was **excited**
to a **higher**
energy orbital that is **farther from**
the nucleus by **absorbing**
radiation (light).

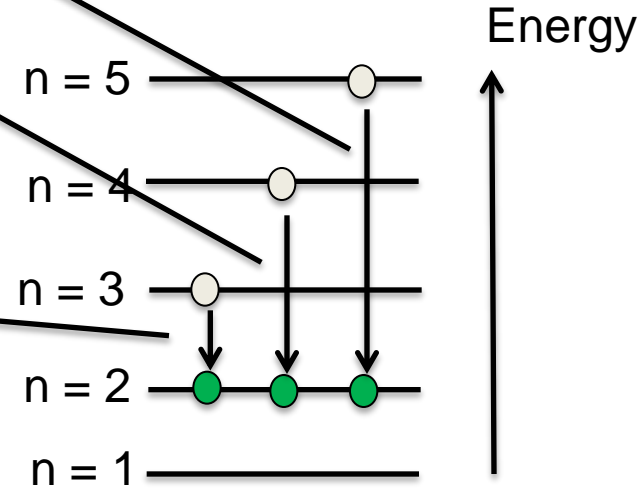
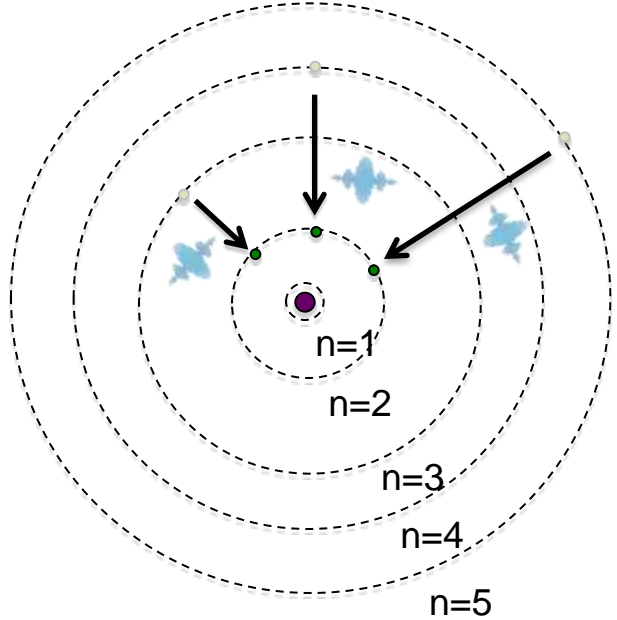
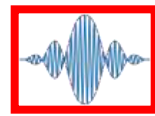
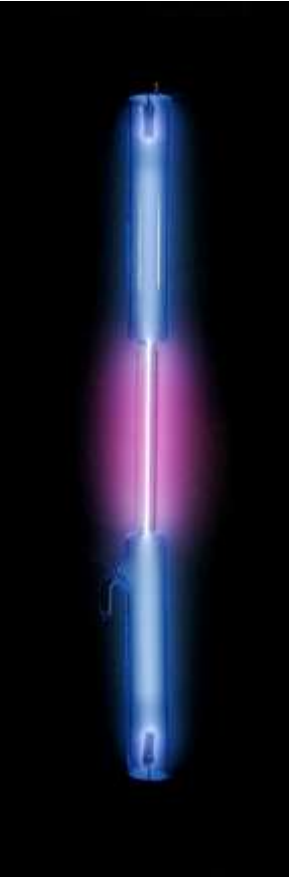
Quantization of Electron Energy Levels



Quantization of Electron Energy Levels

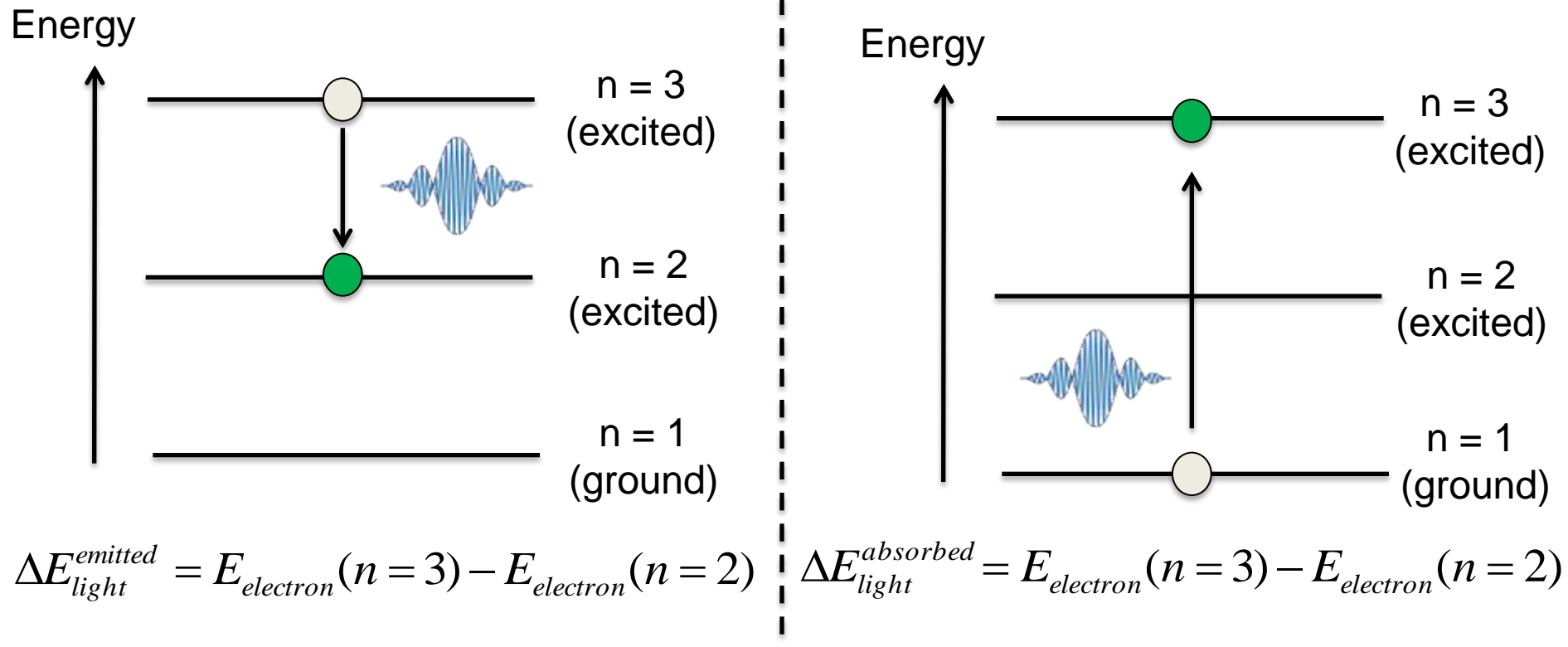


Quantization of Electron Energy Levels



Emission and Absorption

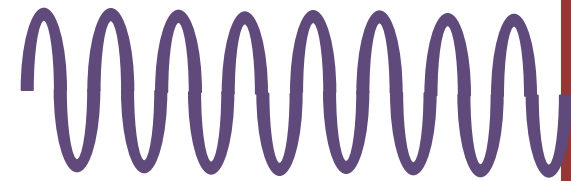
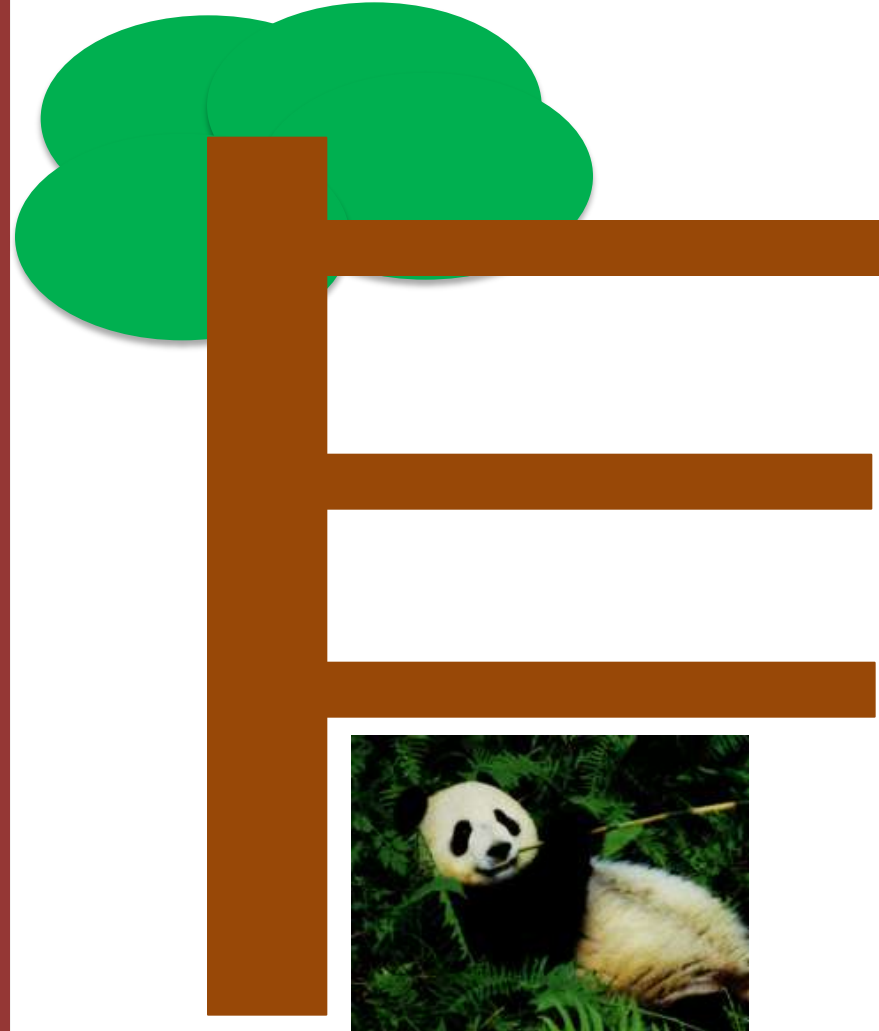
- Light is **emitted** or **absorbed** with an **energy** equal to the difference in energy between the **initial** and **final states** of the electron



- We call the lowest-energy state ($n = 1$) the **ground state**
- All other states are called **excited states**

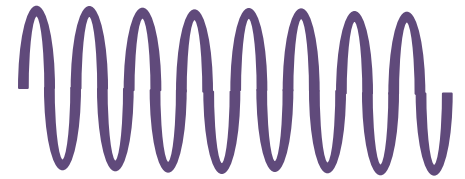
Quantization of Electron Energy Levels

- The closer the tiger is (the shorter the wavelength of light) ...
- ... the more excited the panda becomes (the higher the electron jumps / the farther it falls)



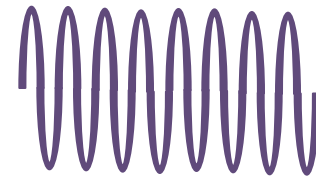
Quantization of Electron Energy Levels

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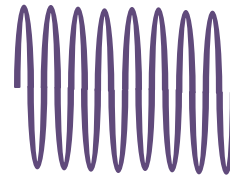
Quantization of Electron Energy Levels

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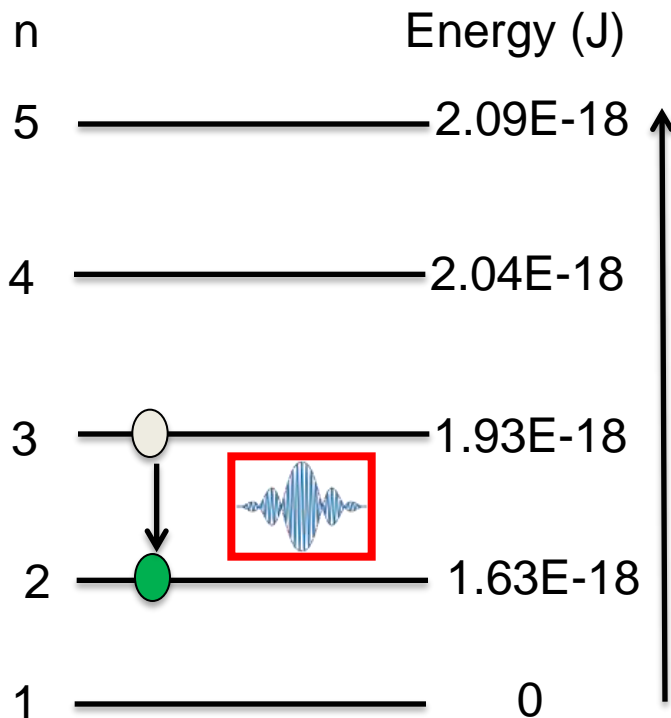
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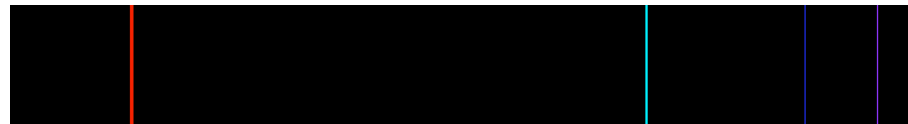


Emission and Absorption

- Light is **emitted** or **absorbed** with an **energy** equal to the difference in energy between the **initial** and **final states** of the electron

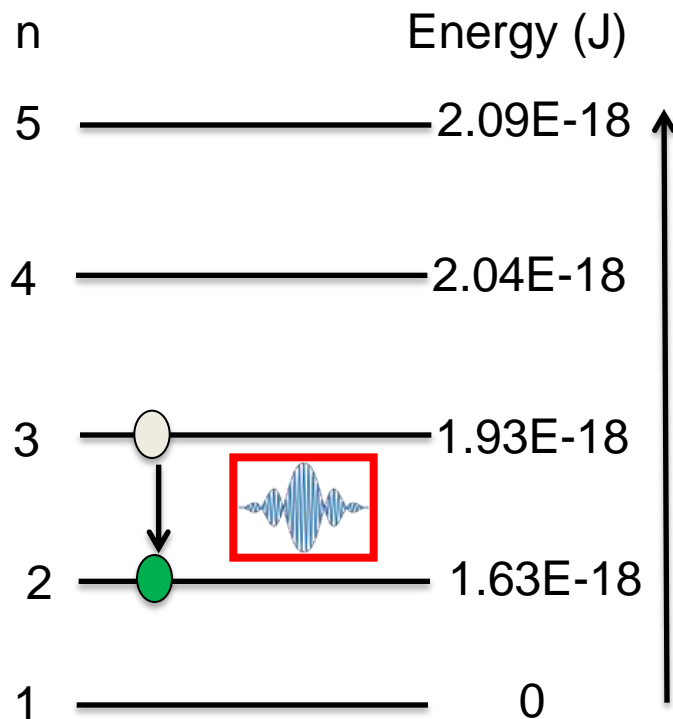


$$\Delta E_{light}^{emitted} = E_{electron}(n=3) - E_{electron}(n=2)$$



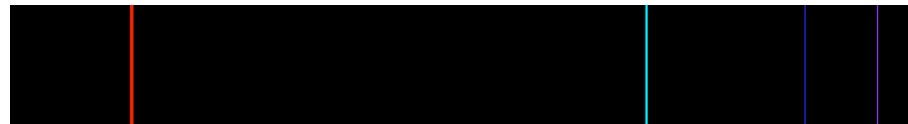
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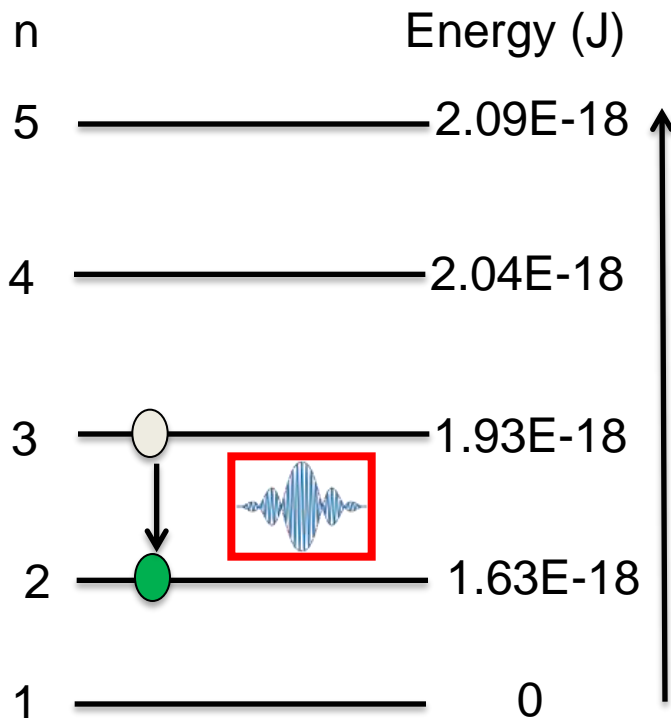
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Emission and Absorption

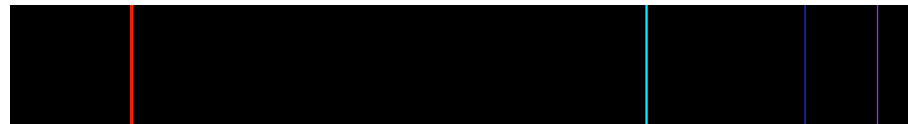
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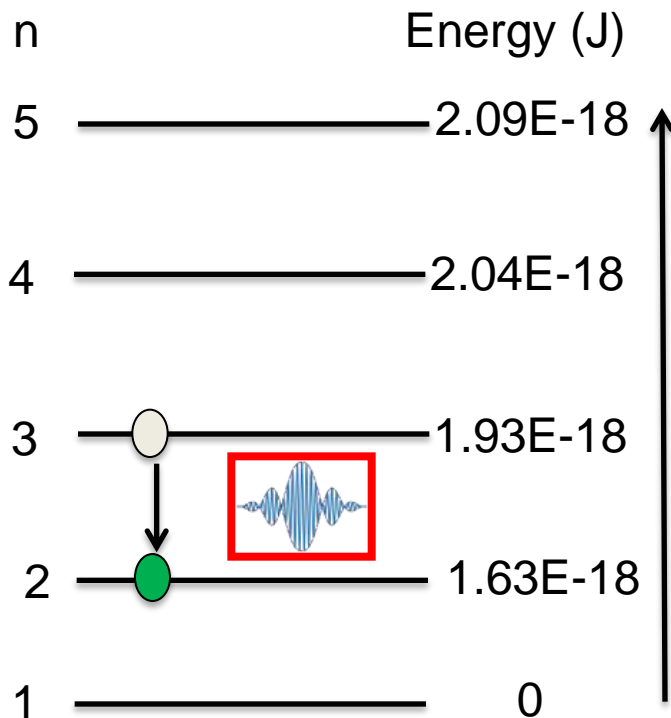
$$\Delta E_{light}^{emitted} = \frac{hc}{\lambda_{emitted}}$$

$$\frac{hc}{\lambda_{emitted}} = 1.93 \times 10^{-18} J - 1.63 \times 10^{-18} J$$



Emission and Absorption

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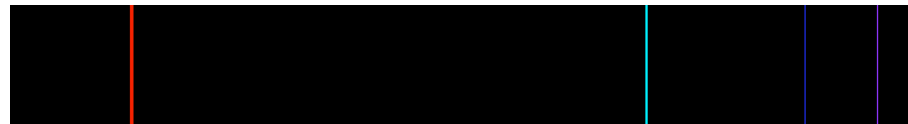


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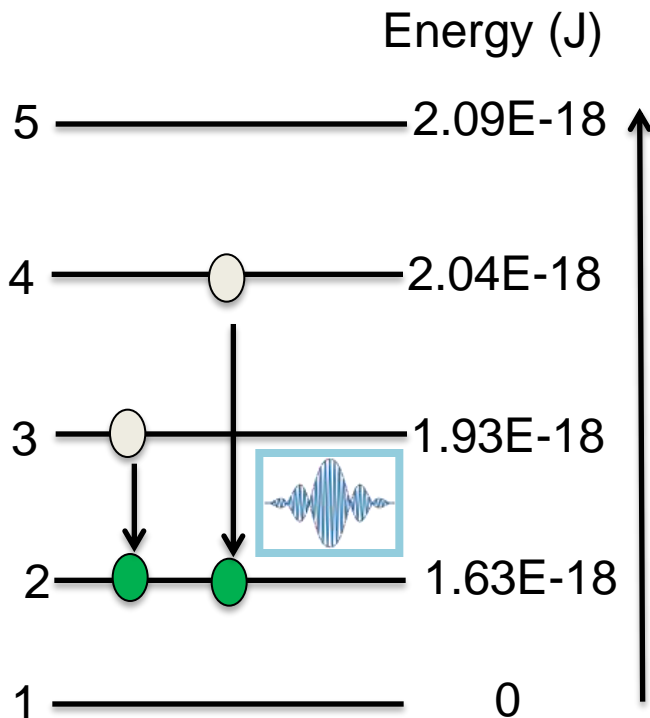
$$\frac{hc}{\lambda_{emitted}} = 1.93 \times 10^{-18} J - 1.63 \times 10^{-18} J$$

$$\lambda_{emitted} \approx 656 nm \quad (\text{Red Light})$$



Emission and Absorption

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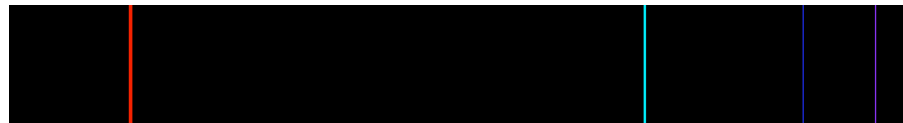


$$\Delta E_{light}^{emitted} = E_{electron}(n=4) - E_{electron}(n=2)$$

$$\Delta E_{light}^{emitted} = \frac{hc}{\lambda_{emitted}}$$

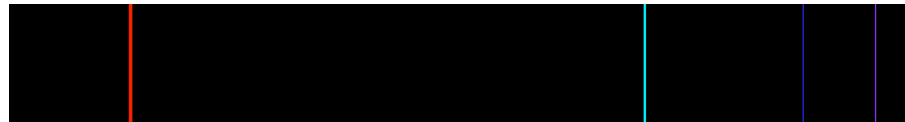
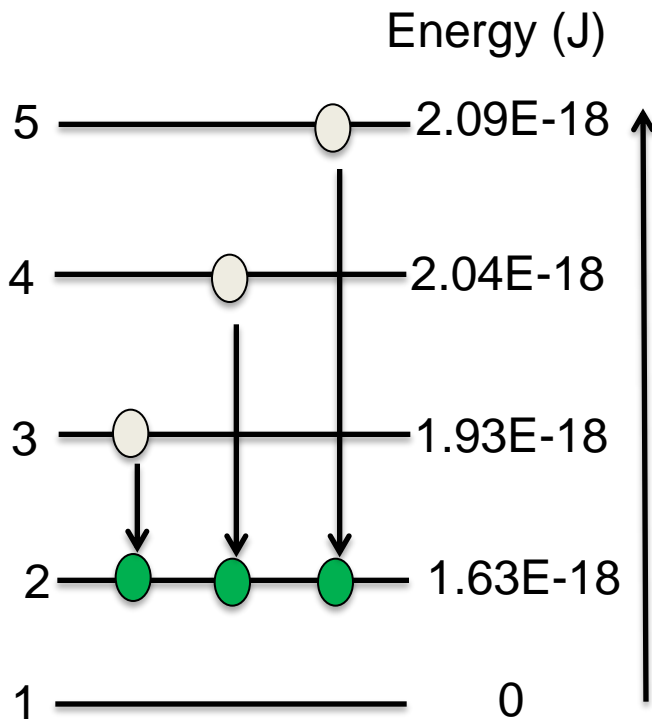
$$\frac{hc}{\lambda_{emitted}} = 2.04 \times 10^{-18} J - 1.63 \times 10^{-18} J$$

$$\lambda_{emitted} \approx 486 nm \quad (\text{Blue-Green Light})$$



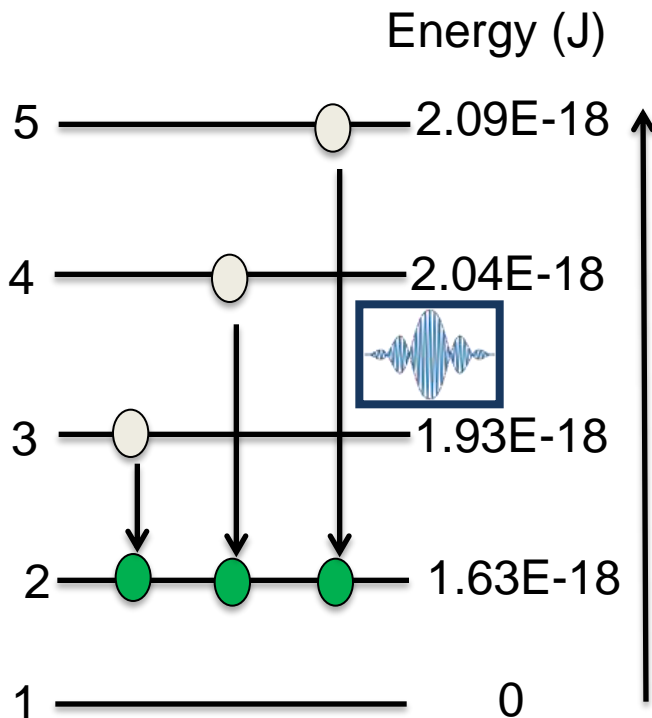
Mini Quiz

- What wavelength of light is emitted when an electron relaxes from $n = 5$ to $n = 2$?



Mini Quiz

- Light is **emitted** or **absorbed** with an **energy** equal to the difference in energy between the **initial** and **final states** of the electron

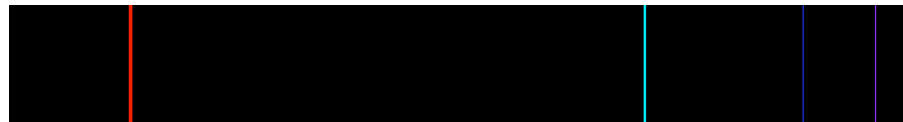


$$\Delta E_{light}^{emitted} = E_{electron}(n=5) - E_{electron}(n=2)$$

$$\Delta E_{light}^{emitted} = \frac{hc}{\lambda_{emitted}}$$

$$\frac{hc}{\lambda_{emitted}} = 2.09 \times 10^{-18} J - 1.63 \times 10^{-18} J$$

$$\lambda_{emitted} \approx 434 nm \quad (\text{Blue Light})$$



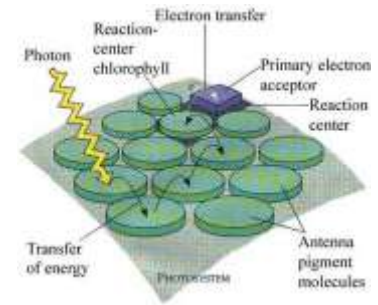
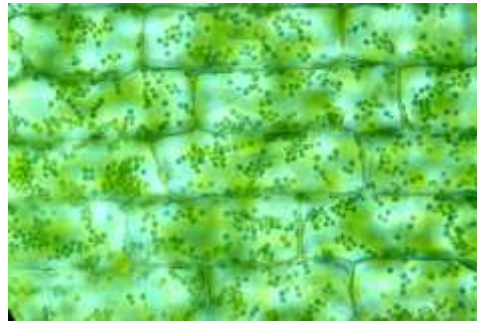
Outline

- Electromagnetic Radiation
- Introduction to Quantum Mechanics
- Chemistry?

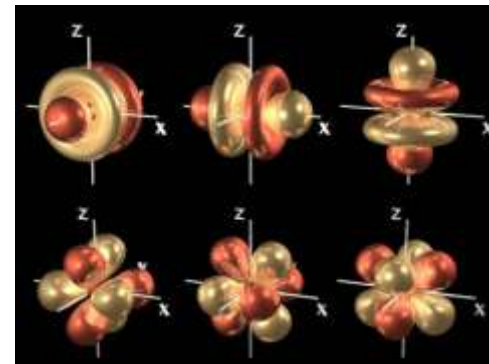
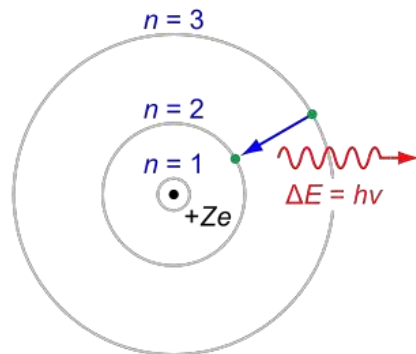
- Electromagnetic Radiation
 - Waves
 - Interference
 - Electromagnetic Spectrum
- Introduction to Quantum Mechanics
 - Atomic Spectra
- What does this have to do with chemistry?

Where Is The Chemistry?

- The interaction of light with matter is responsible for all of life on Earth
- To appreciate life, we must understand both atoms and light



- The shapes and energies of electron orbitals explain known chemical reactions and help us predict new ones
- We will build on Bohr model in upcoming lectures



Summary

- Electrons can only jump between orbitals with **very specific** energies. We call these energies **quantized**.
- Electrons jump to higher-energy orbitals when light of sufficient energy is **absorbed**.
- Light is **emitted** when electrons relax to lower-energy orbitals.

Homework

- Read Ch. 11 (pp. 323 – 326, 327 – 332)
- Problems: p. 353, # 11 - 24
- HW due tomorrow (Tuesday)
- Quiz tomorrow (Discovery of the Atom and Mass Spec)