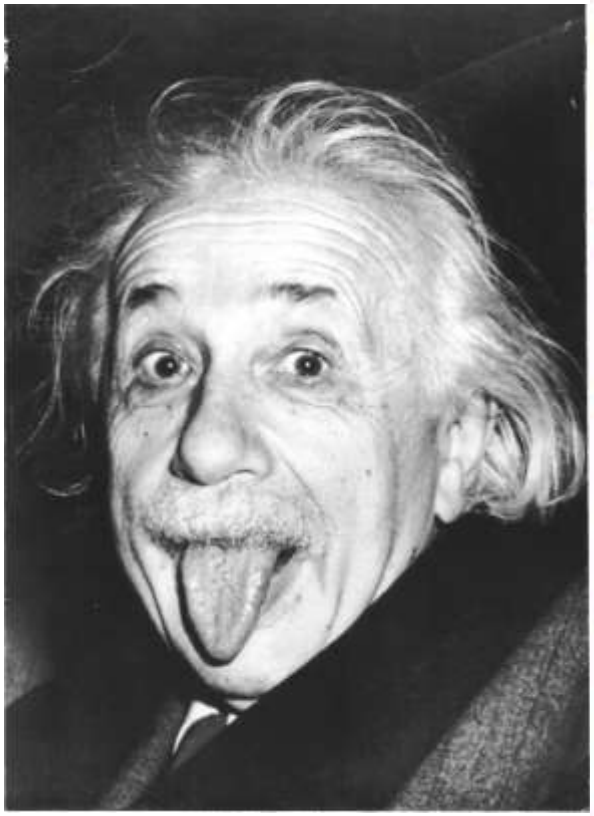
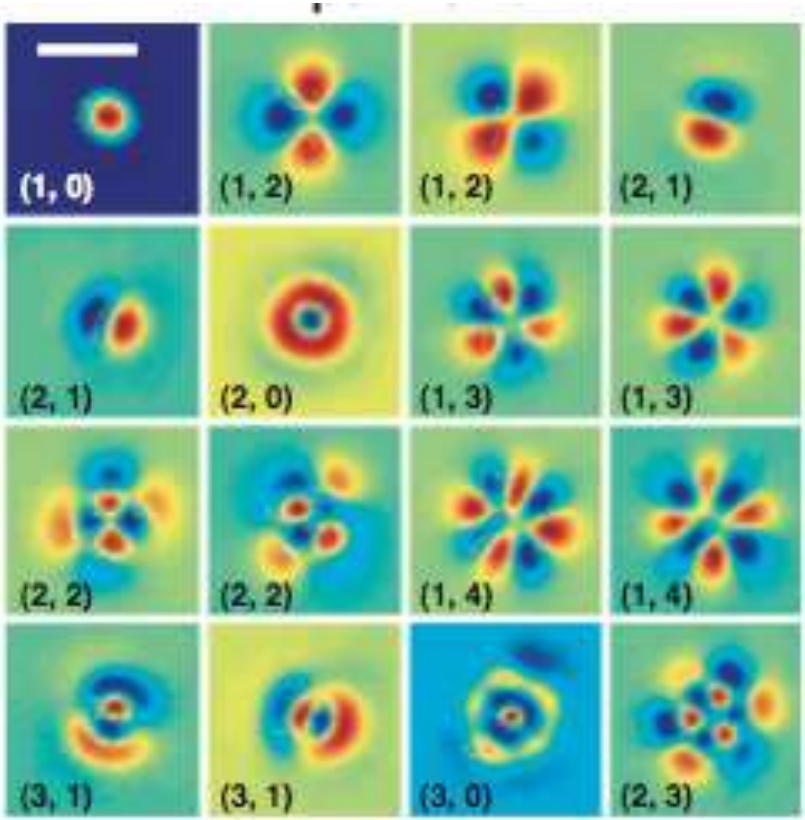
Pre-AP Chemistry

September 4, 2011

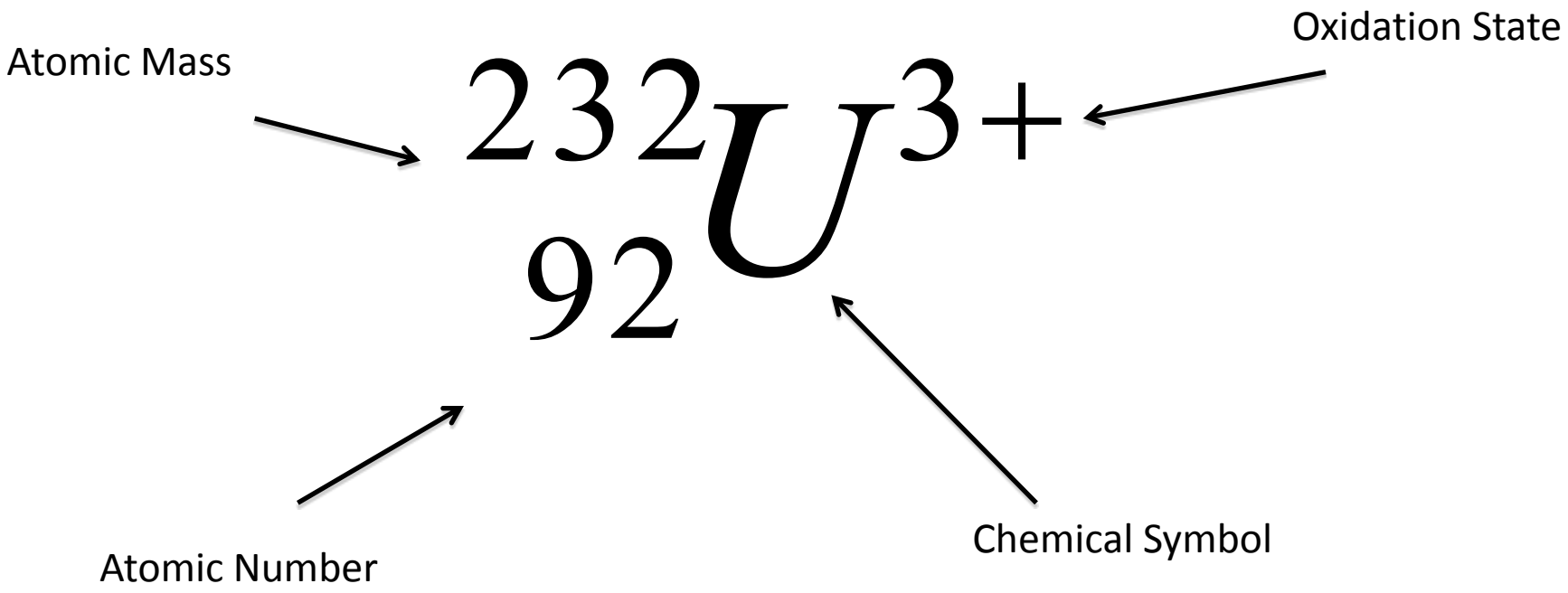
7. Electrons in Atoms I





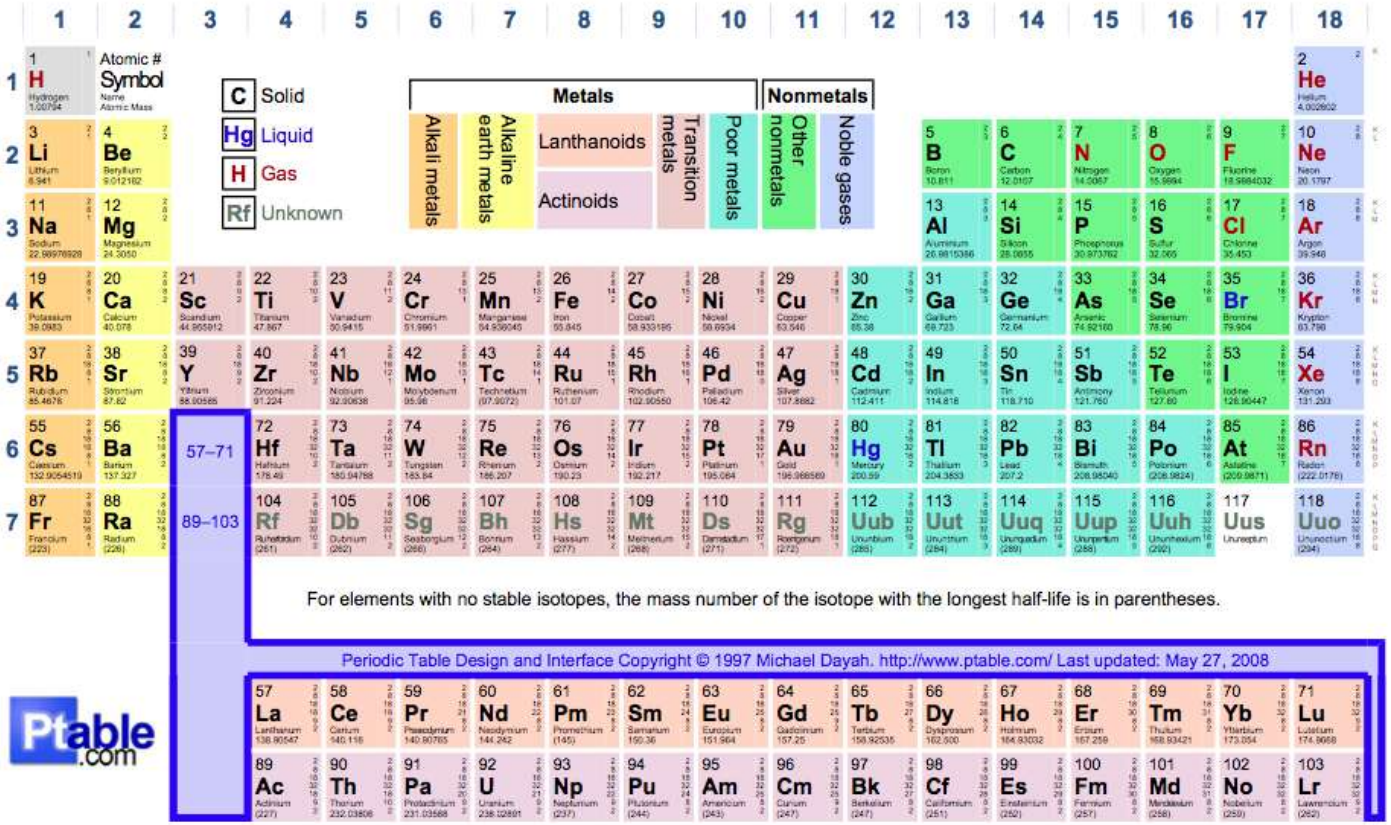
Review

- 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?



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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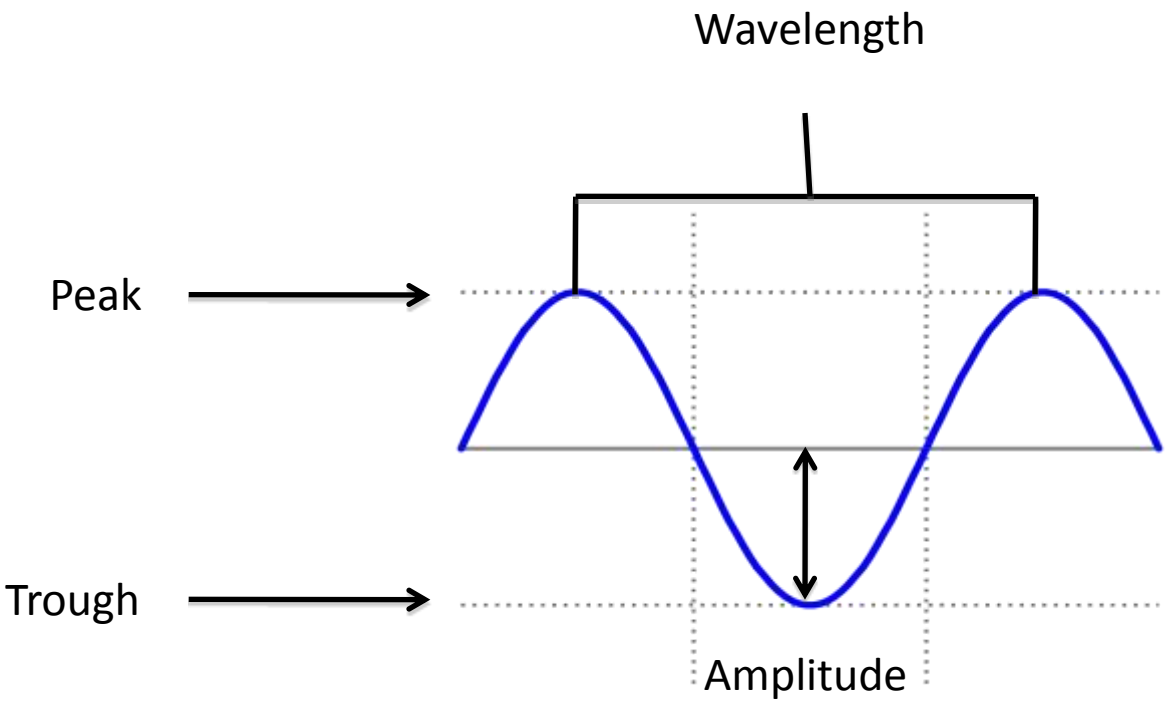
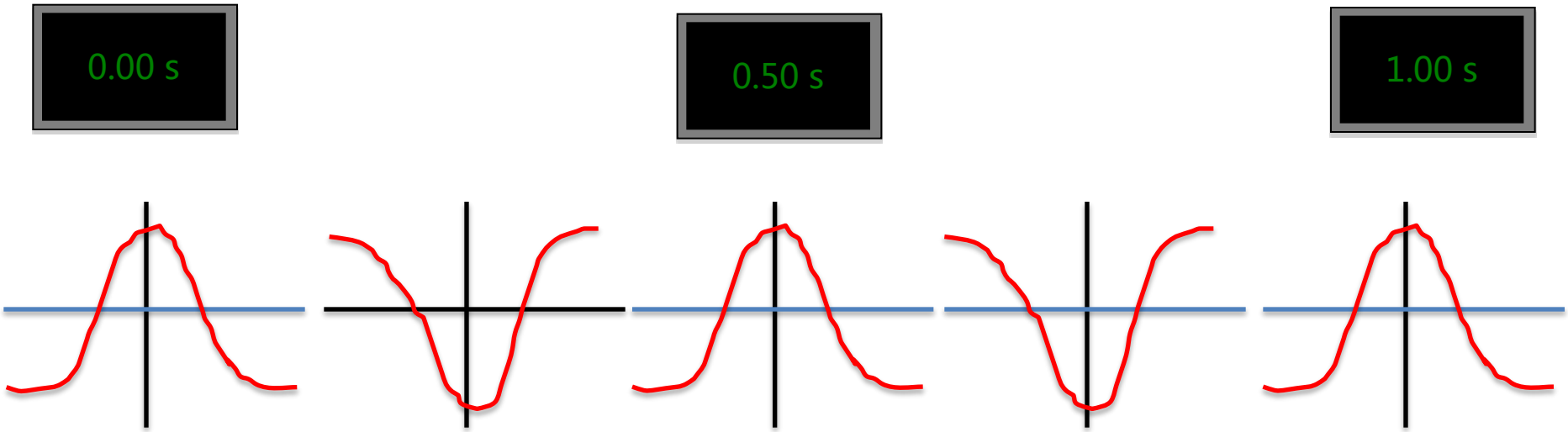
Waves

- 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



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

In vacuum

$$c = \lambda f$$

Speed of Light

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

In media

$$v = \lambda f$$

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	$\frac{1}{s}$

$$v = \lambda f$$

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

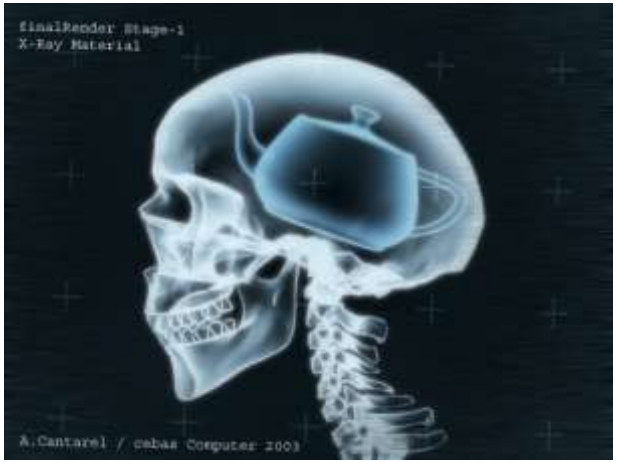
$$\left[\frac{m}{s}\right] = \left[\frac{m}{s}\right]$$

✓

In vacuum	Speed of Light	In media
$c = \lambda f$	$c \approx 3 \times 10^8 m/s$	$v = \lambda f$

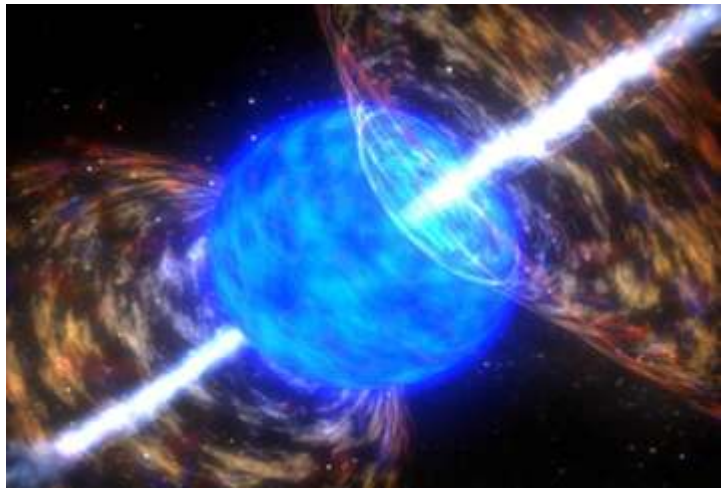
Mini Quiz

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



- X-rays have a frequency of 3E+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

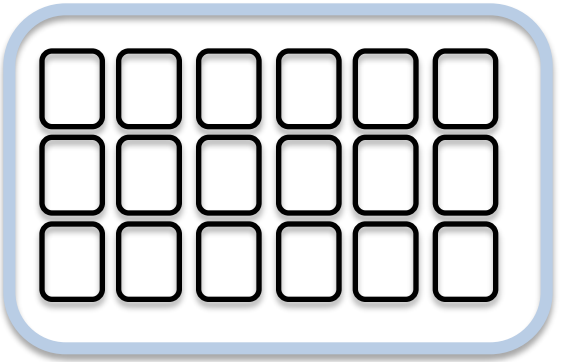
2450 MHz

$$c = \lambda f$$

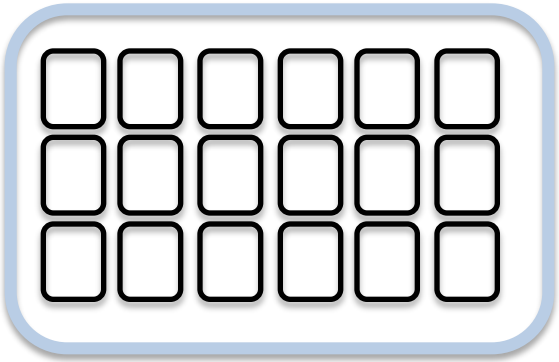
c = ?

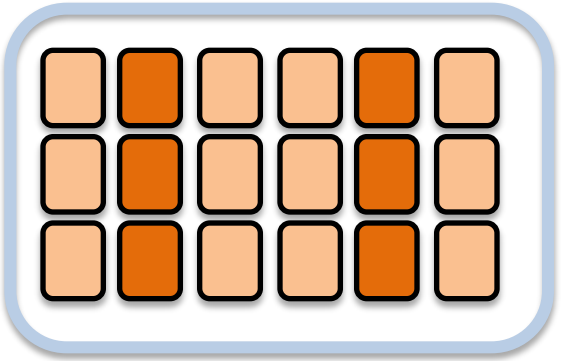
Mini Quiz

1. Arrange marshmallows in rows in glass pan.



2. Cook pan of marshmallows in the microwave.

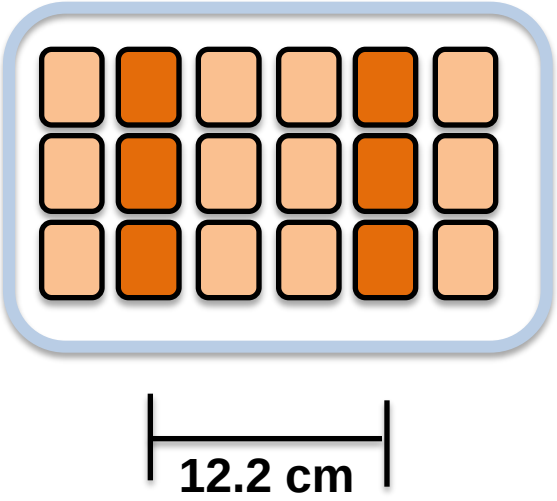


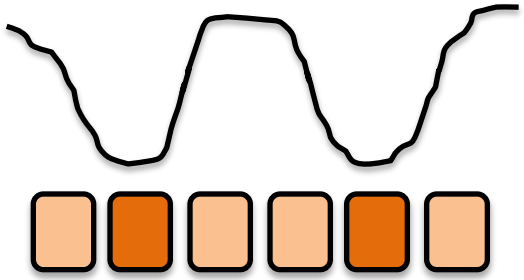


2450 MHz

Mini Quiz

3. Measure distance between darkest marshmallows.





4. Find speed of light.

Frequency of microwaves

$$c = \lambda f$$

$$c = 12.2cm \times 2450MHz$$

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

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

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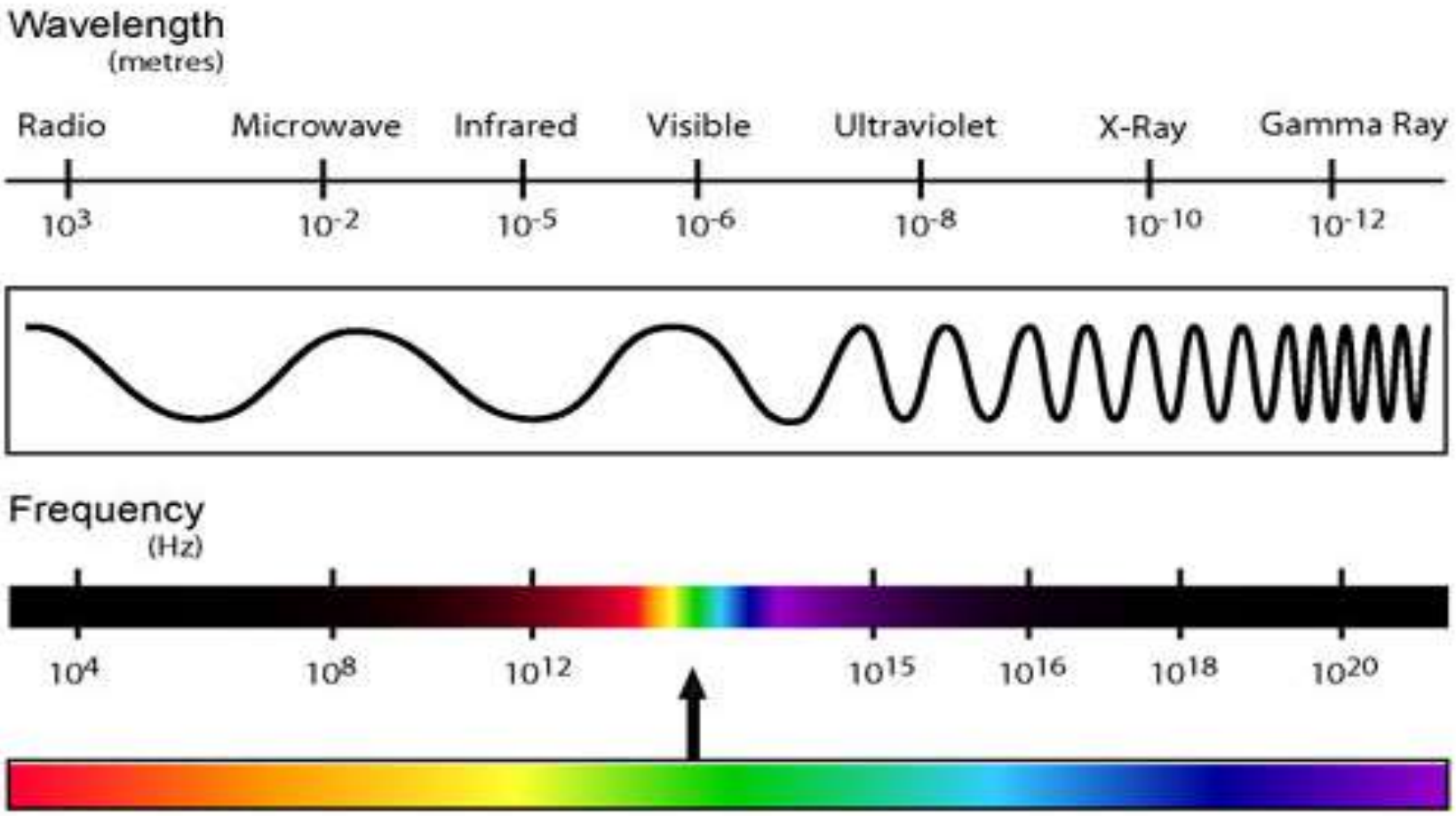
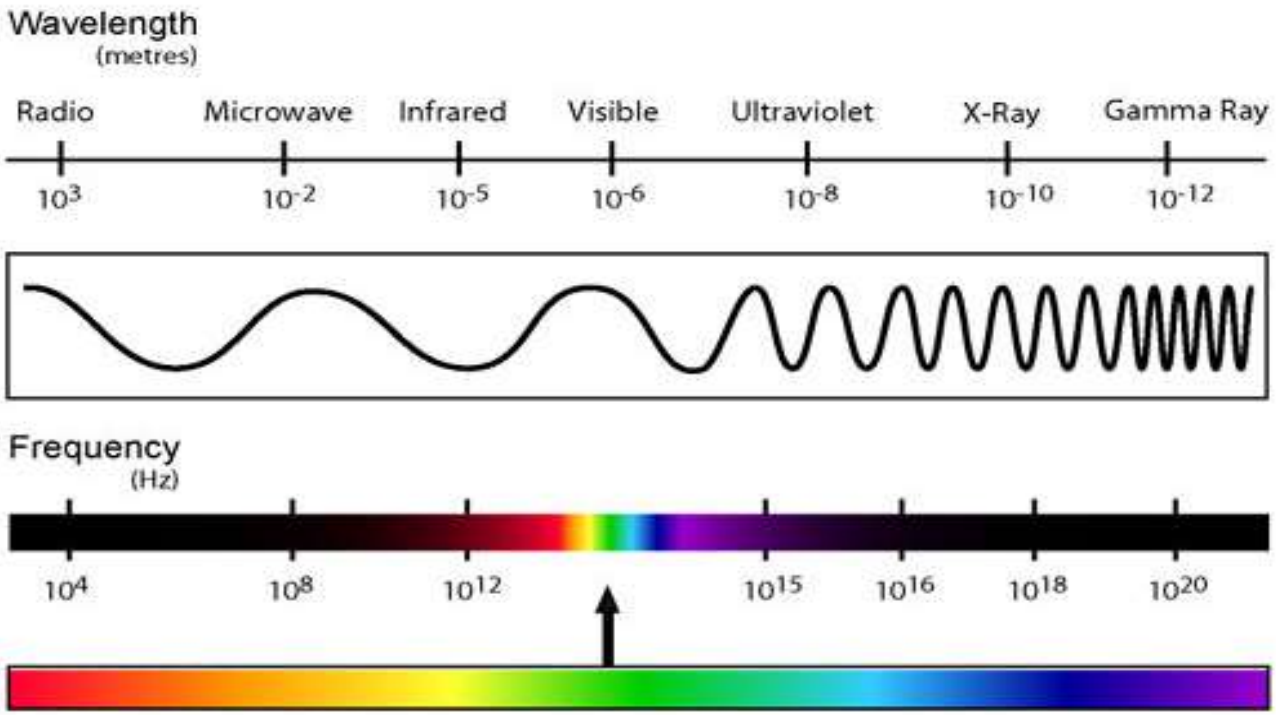
Electromagnetic Spectrum

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



Electromagnetic Spectrum

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



$$E = hf$$

$$c = \lambda f$$

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

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

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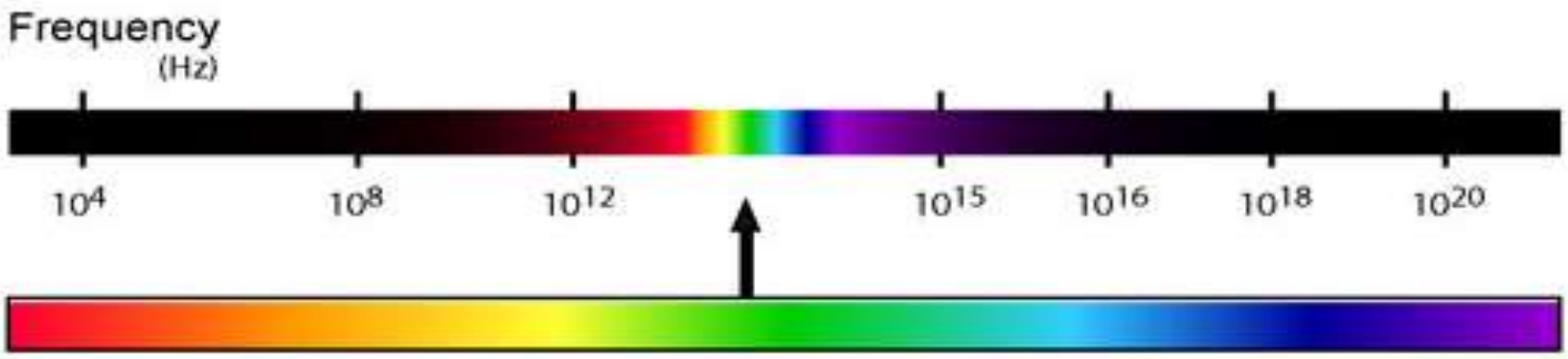
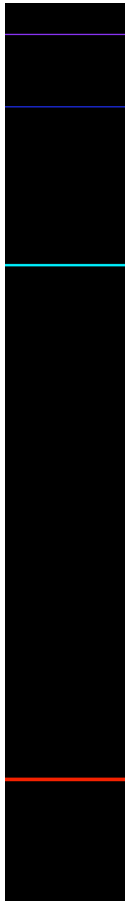
Blackbody Radiation

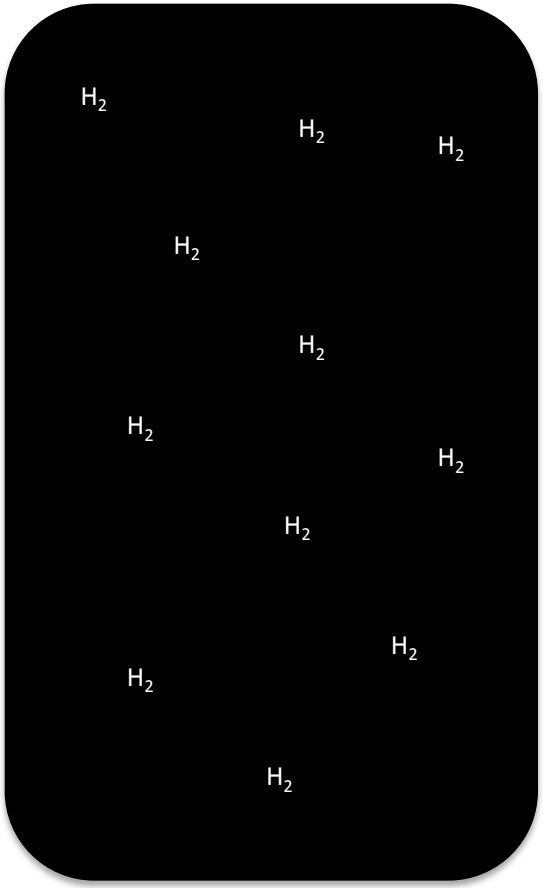
- Almost all frequencies of light are radiated from a heated body
- We observe their radiation as a **continuous** spectrum



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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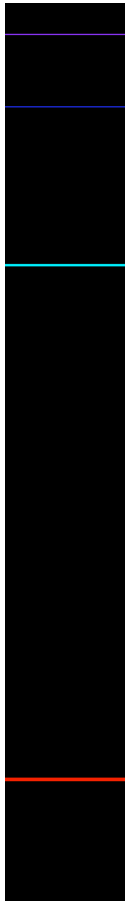

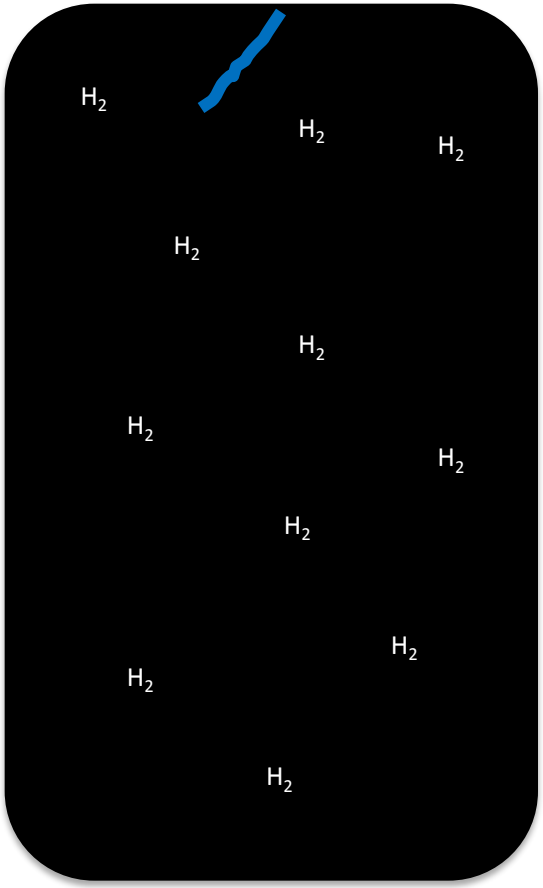

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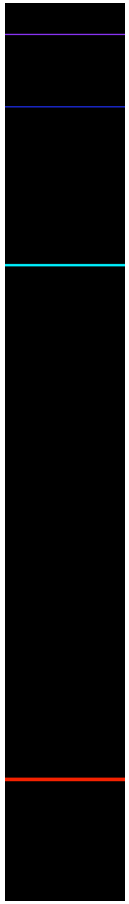

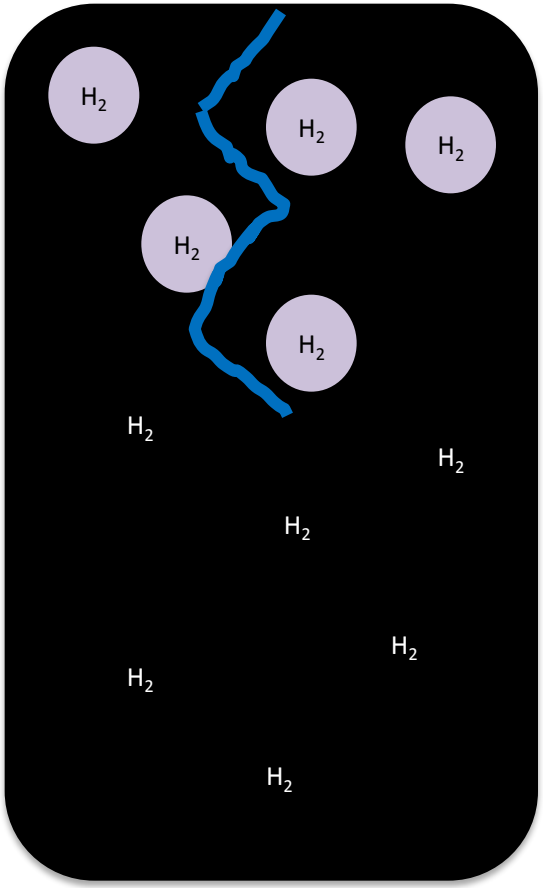

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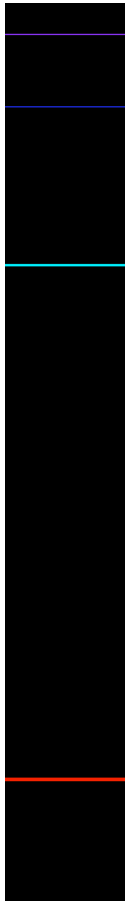

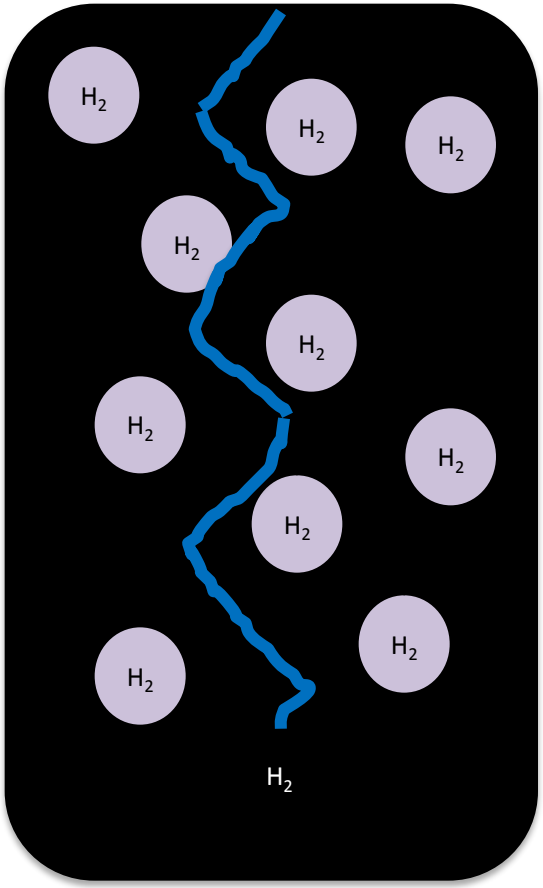

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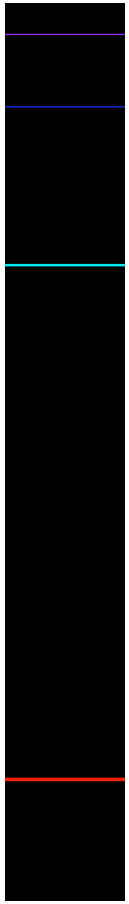

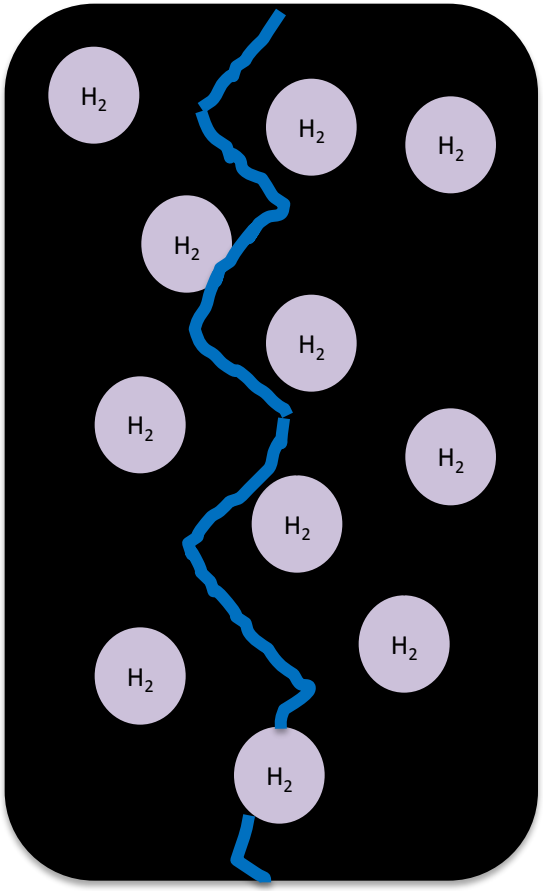

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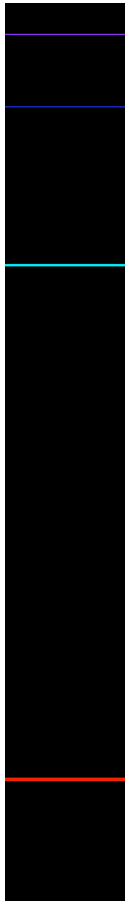
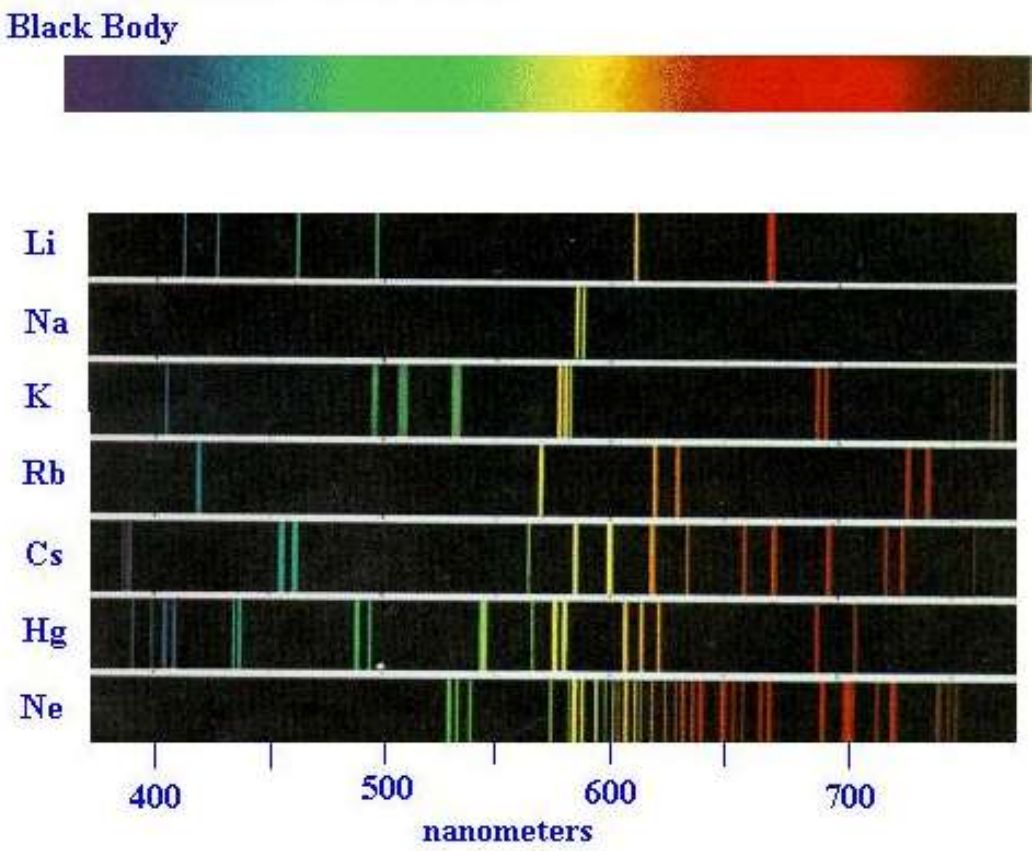
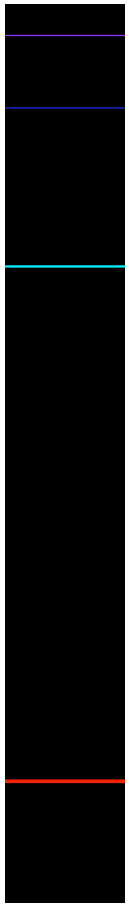




Rydberg Equation

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



Rydberg Equation

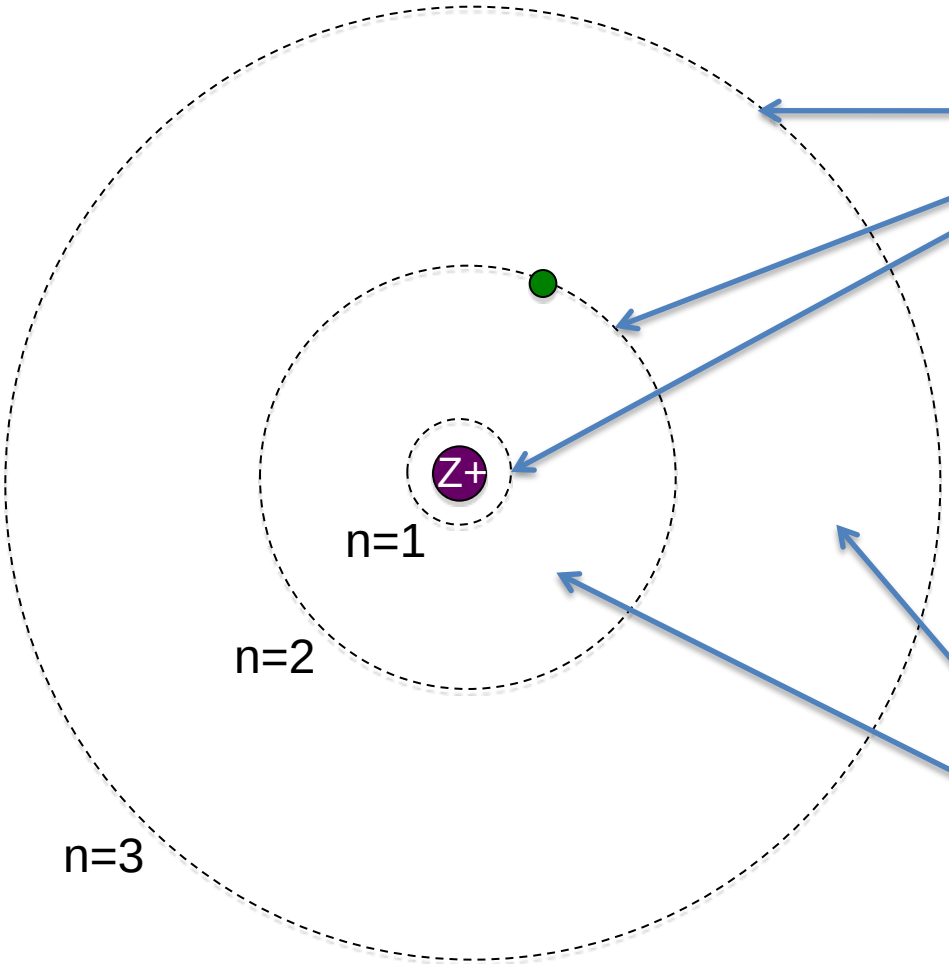
$$\lambda = \frac{n^2}{R_H} \qquad E = \frac{hcR_H}{n^2}$$

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

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**!



Electrons can be here.

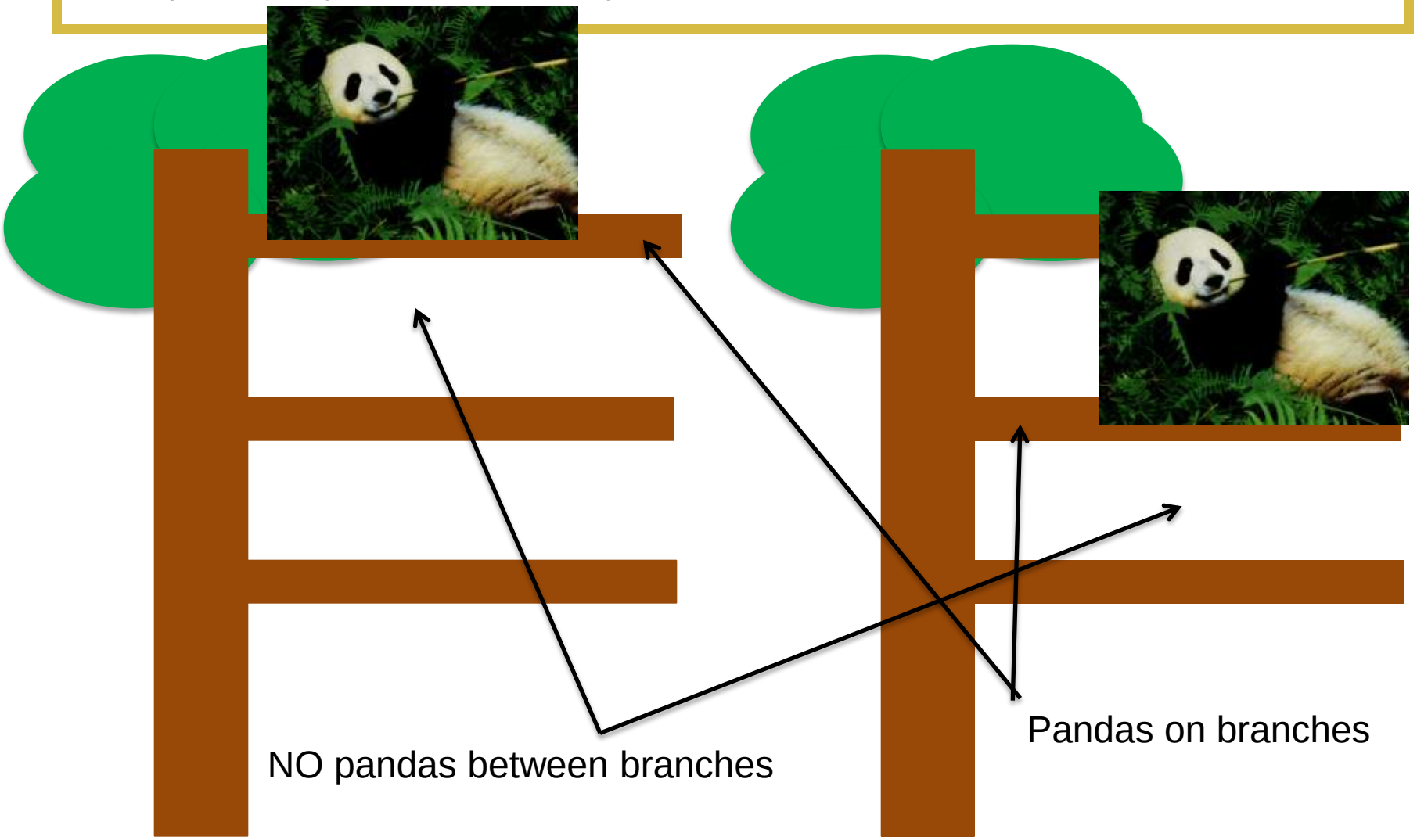
$$r_n = \frac{n^2}{Z} r_1$$

$$r_1 \approx 52.9\,pm$$

Electrons can NOT be here.

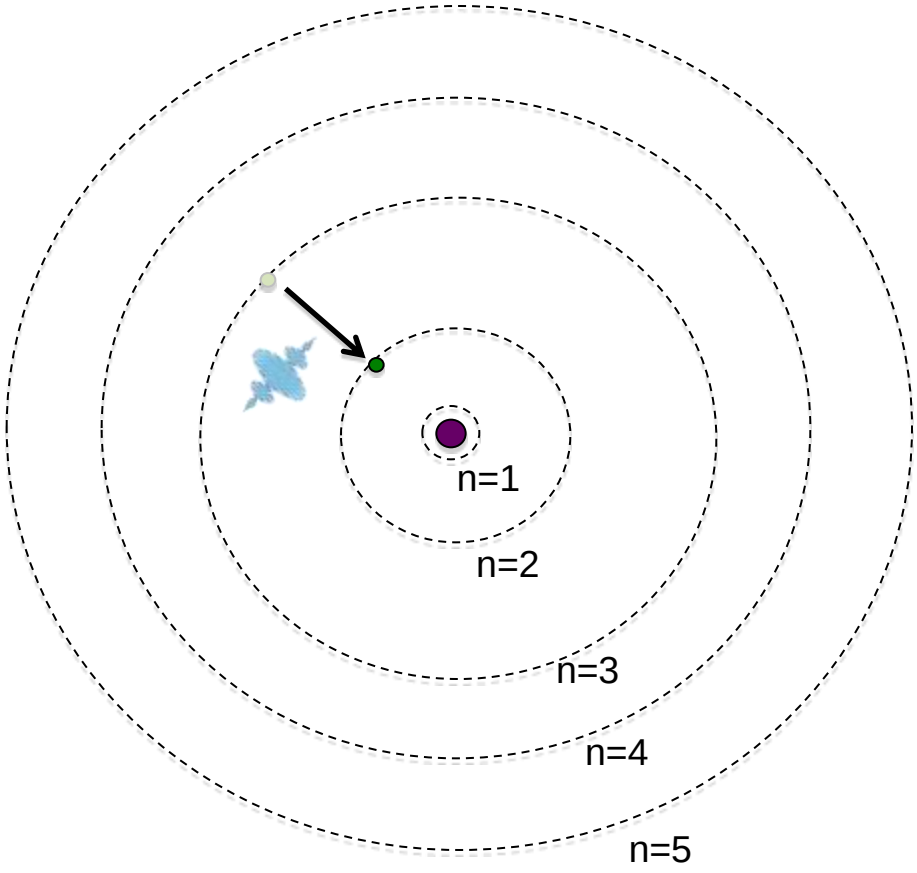
Quantization of Electron Energy Levels

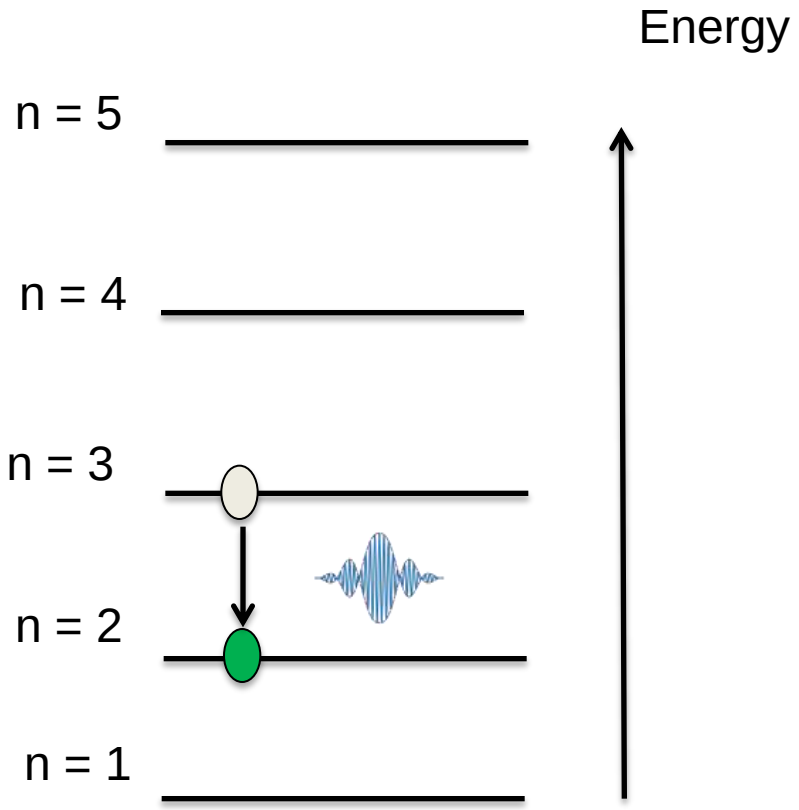
- Electrons can only ‘sit’ on specific orbits …
- … just like pandas can only sit on the branches of a tree.



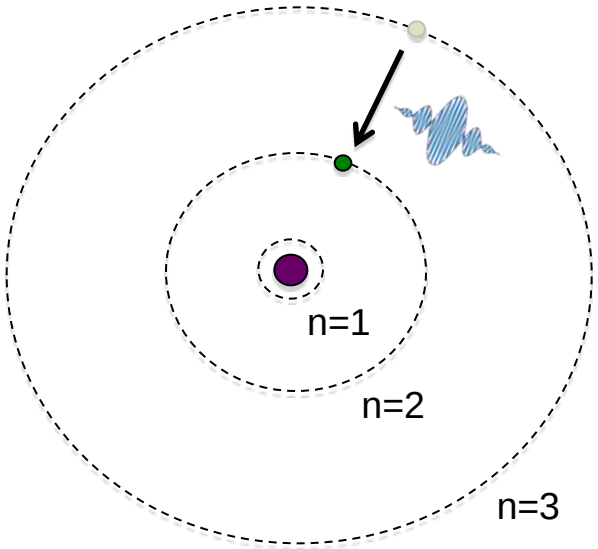
Quantization of Electron Energy Levels

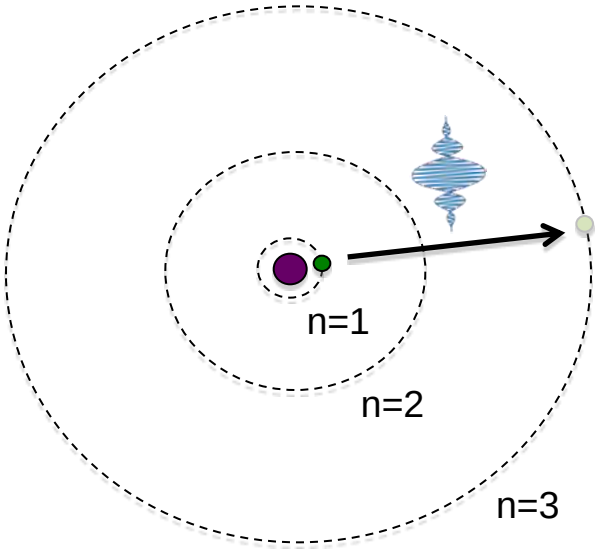
- When an electron moves between **specific (quantized) orbits**, it emits or absorbs light of a **specific (quantized) wavelength**





Emission and Absorption





We say radiation (energy) is …

emitted / **absorbed**

… when electrons …

relax / **are excited**

… to an orbital …

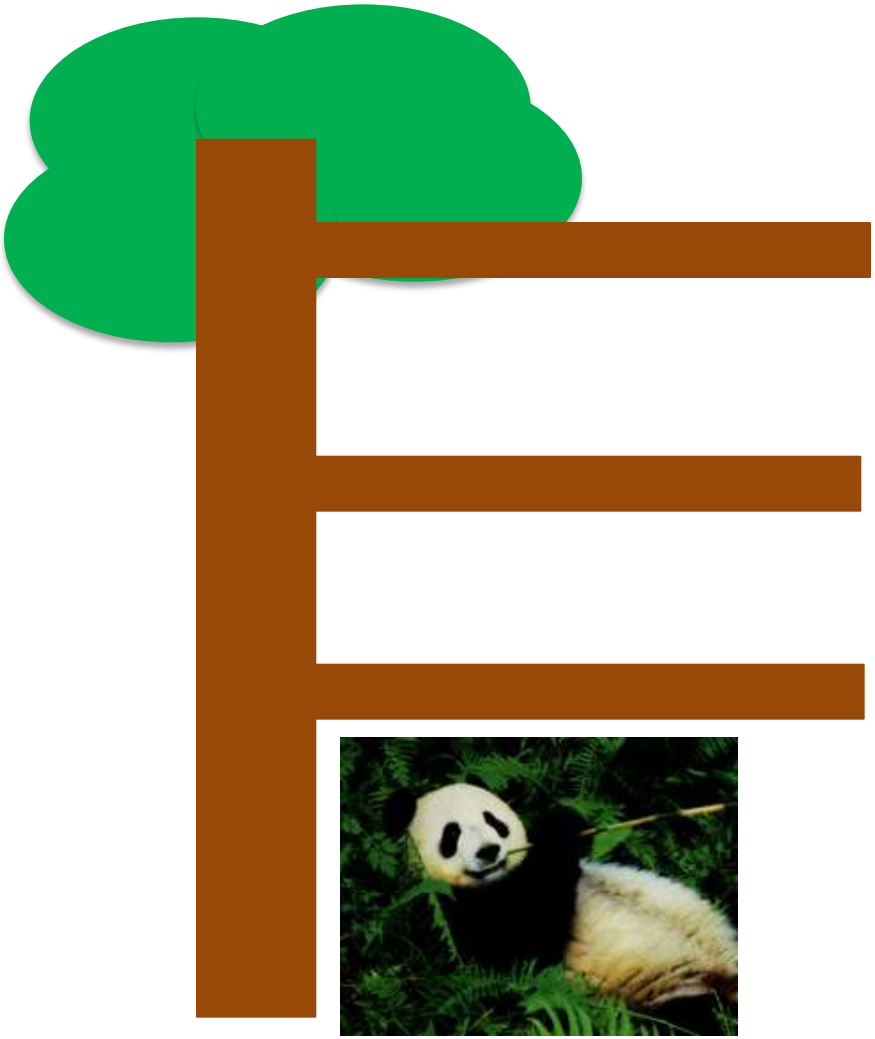
closer to the nucleus / **farther away from the nucleus**

… 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 …
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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**

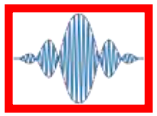
to a **higher**

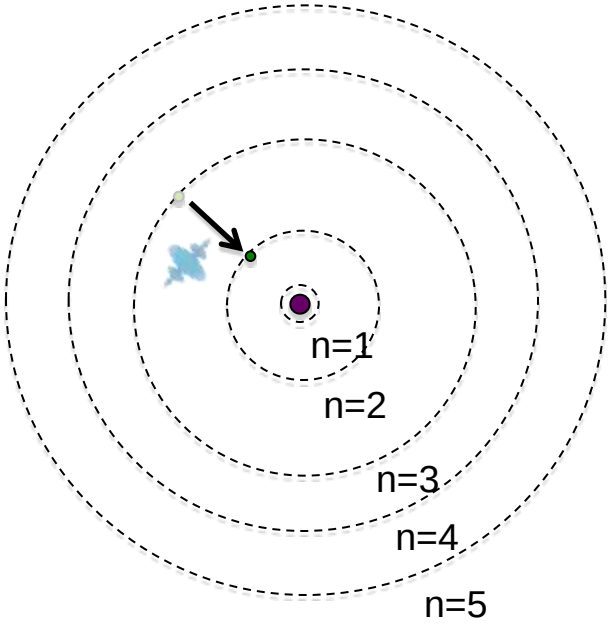
energy orbital that is **farther from**

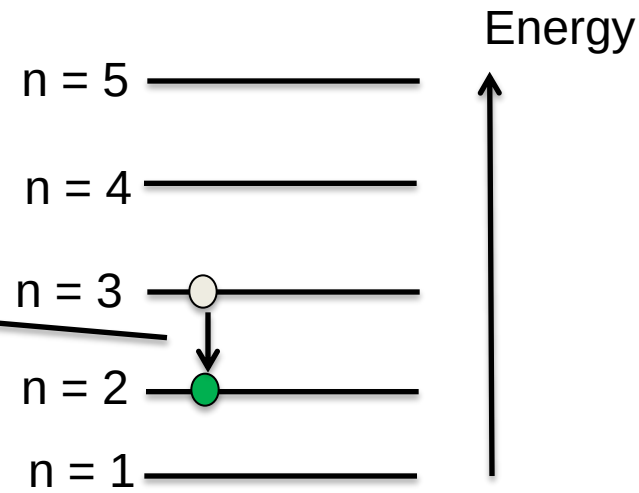
the nucleus by **absorbing**

radiation (light).

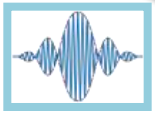
Quantization of Electron Energy Levels

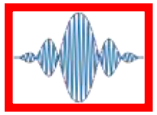


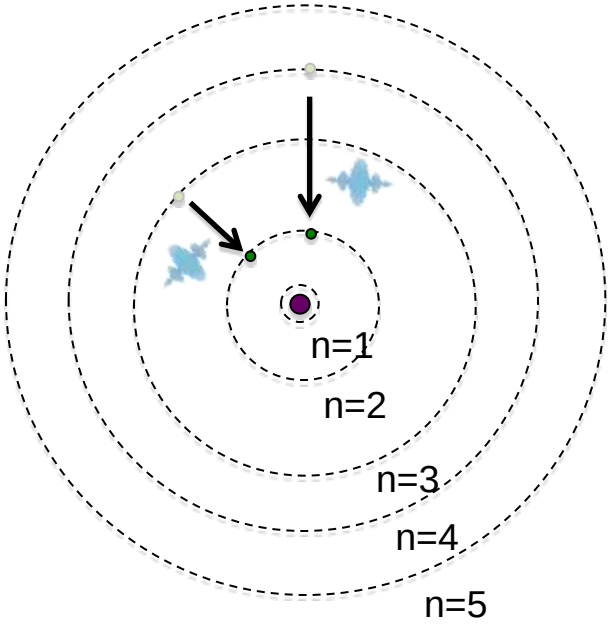


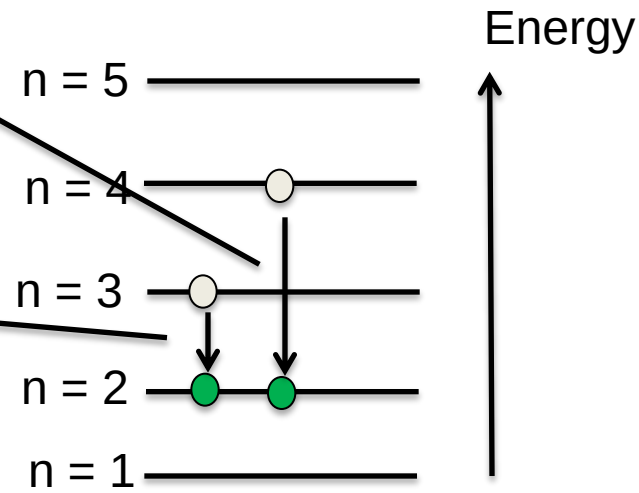


Quantization of Electron Energy Levels









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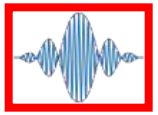
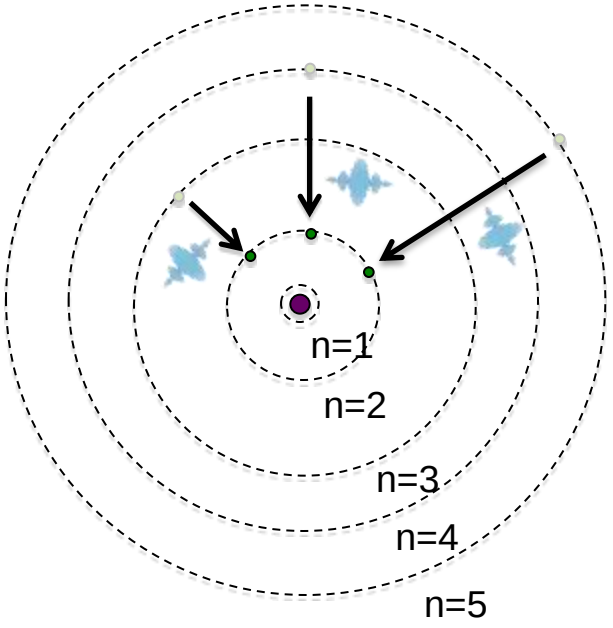
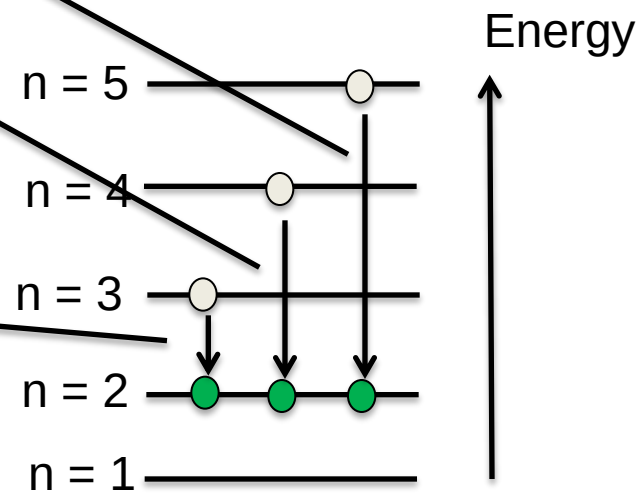
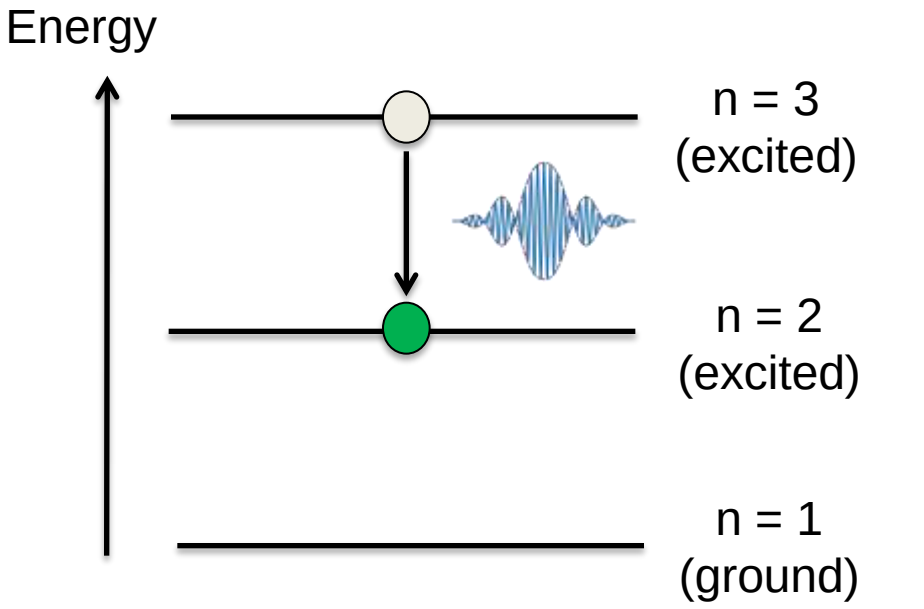




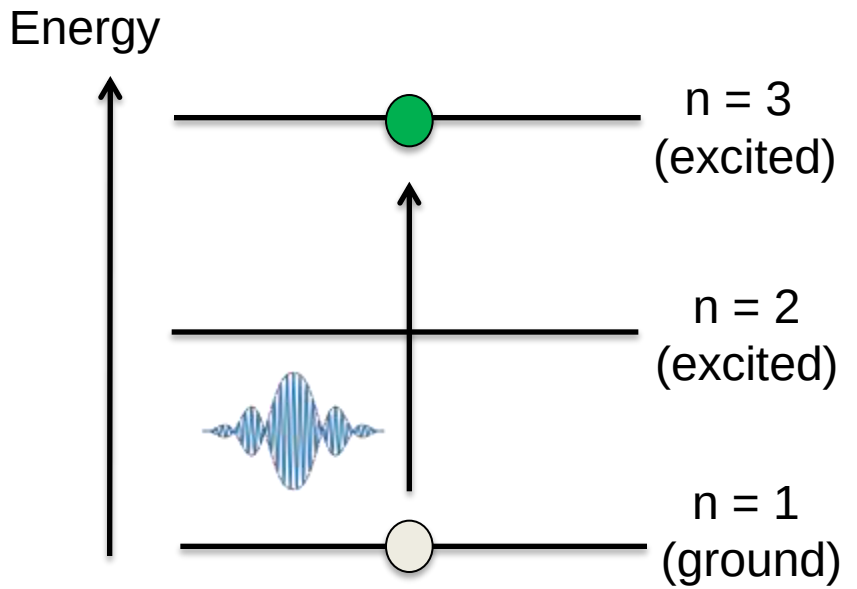


Emission and Absorption

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



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

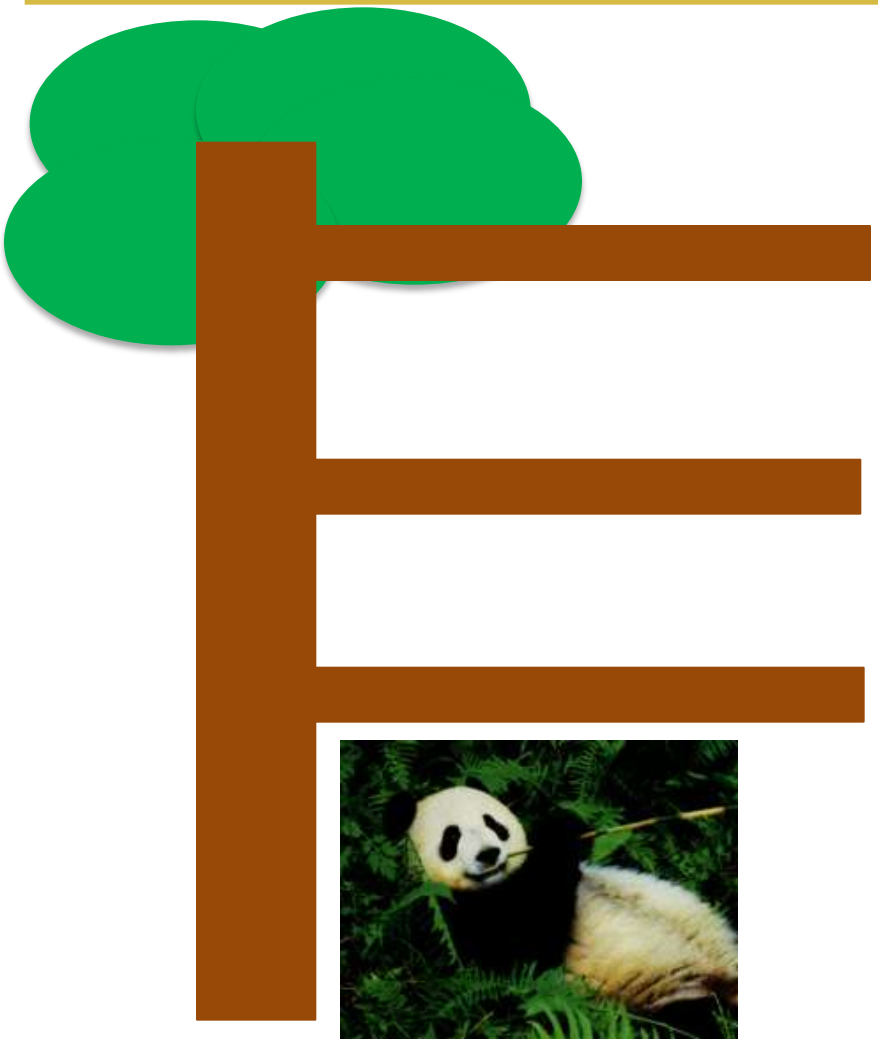


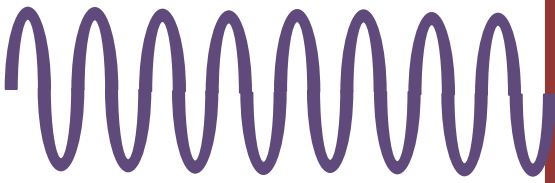
$$\Delta E_{light}^{absorbed} = E_{electron}(n=3) - E_{electron}(n=2)$$

- 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)





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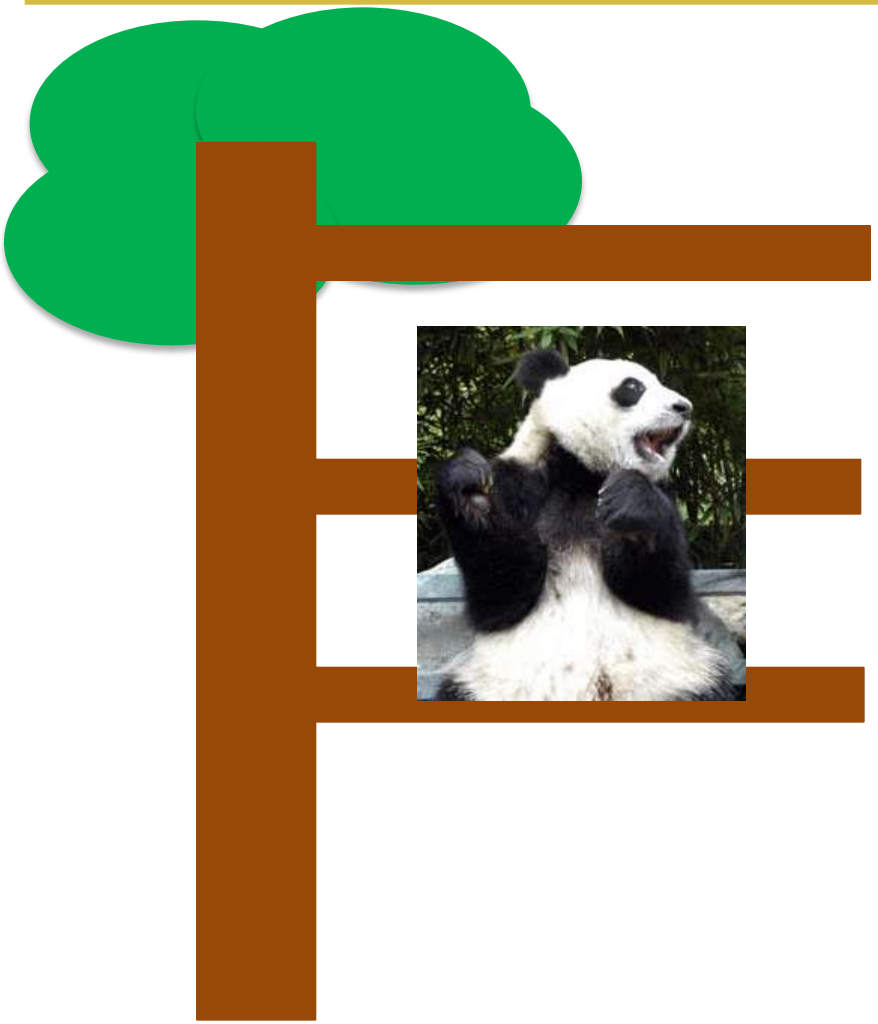

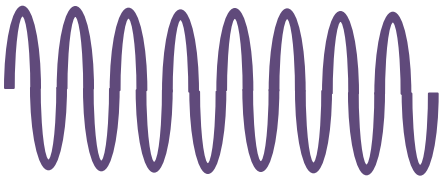

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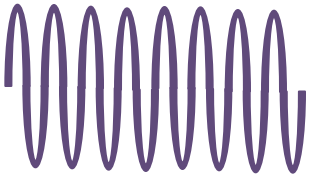

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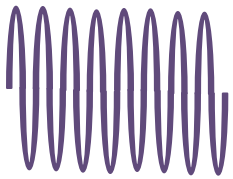

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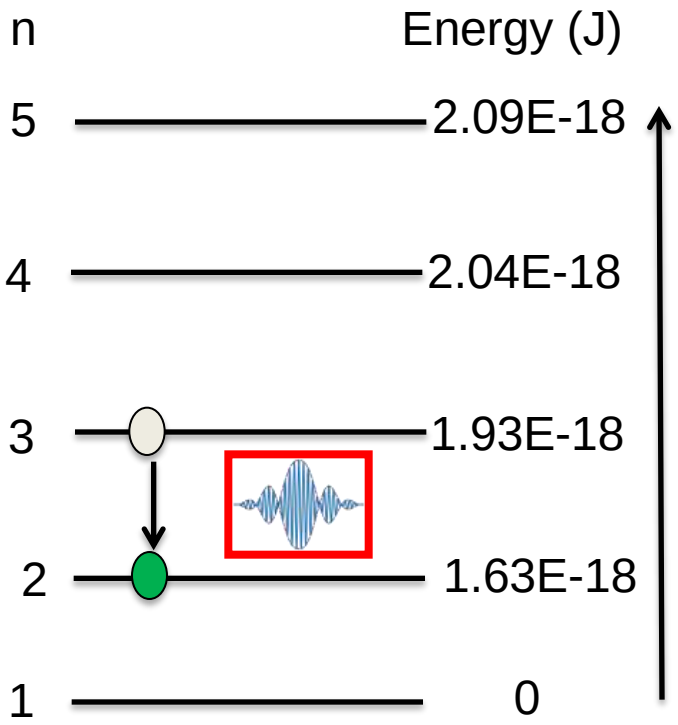

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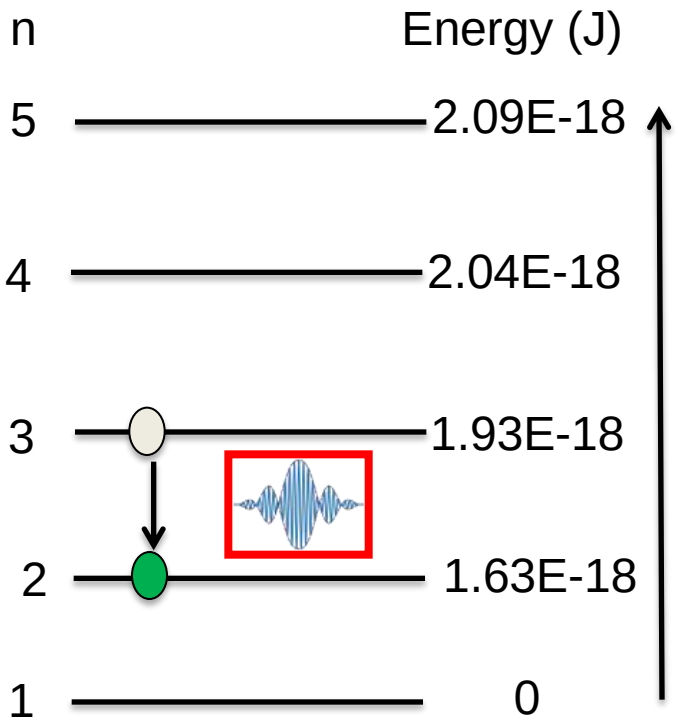

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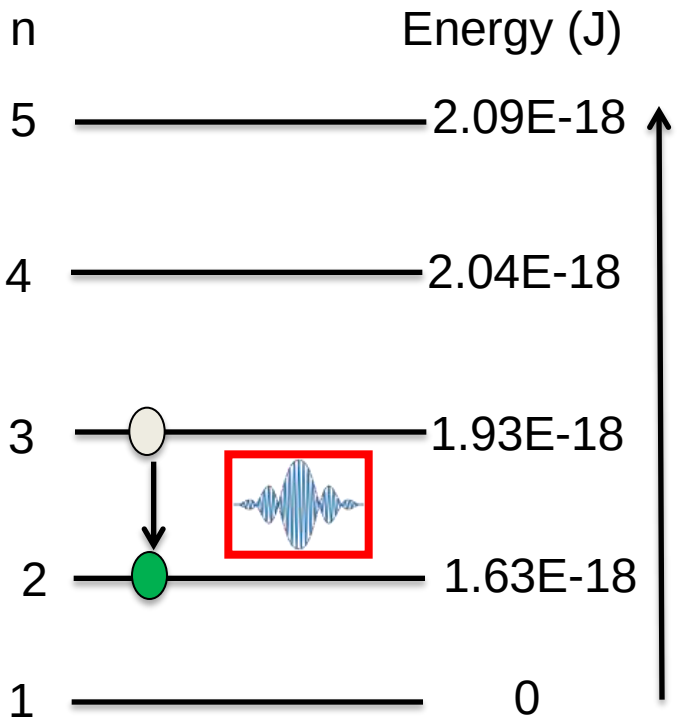

$$\Delta E_{light}^{emitted} = E_{electron}(n=3) - E_{electron}(n=2)$$

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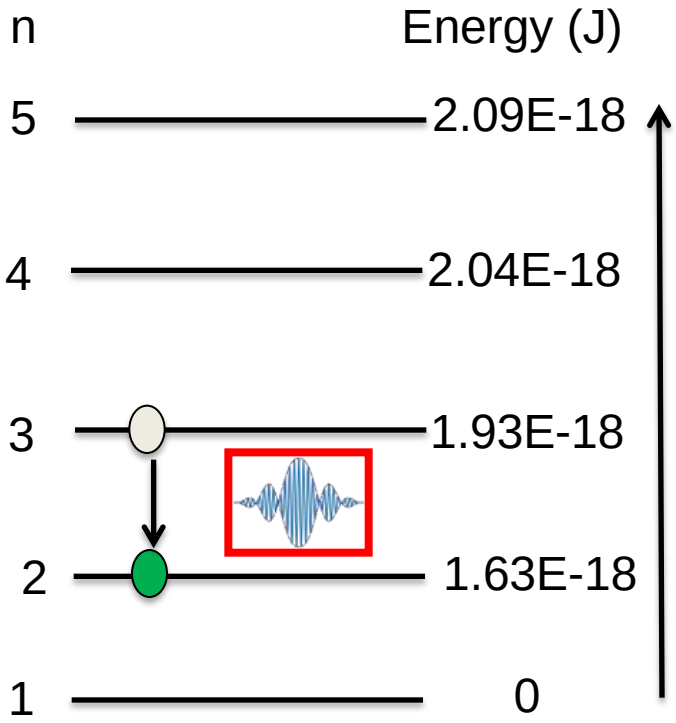

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$$\lambda_{emitted} \approx 656nm$$ (Red Light)

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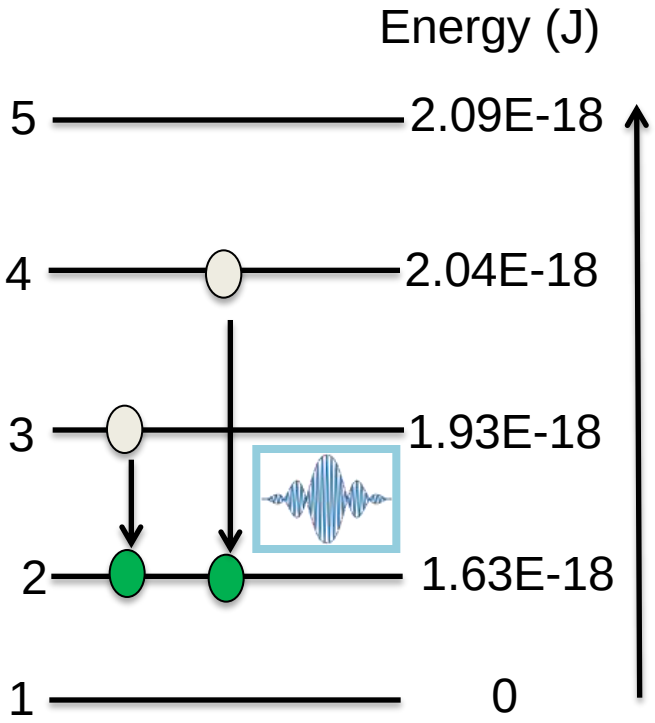


$$\Delta E_{light}^{emitted} = E_{electron}(n=4) - E_{electron}(n=2)$$

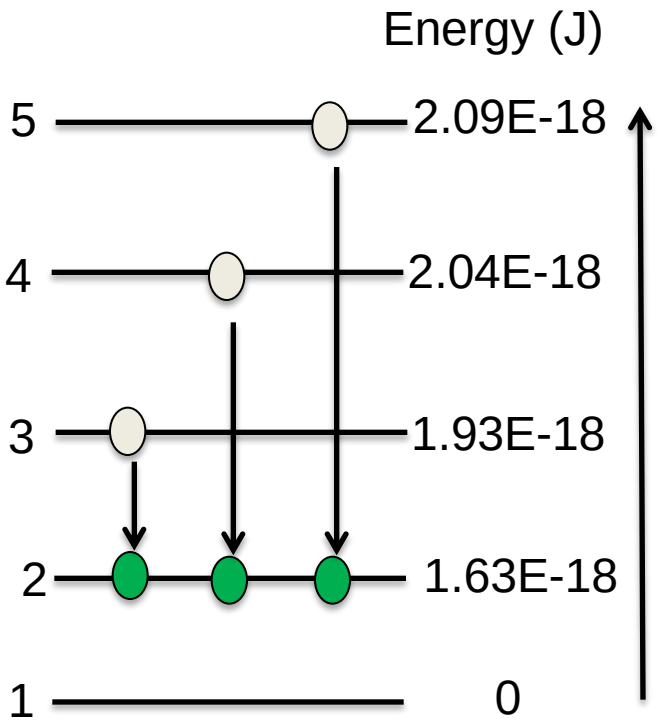
$$\Delta E_{light}^{emitted} = \frac{hc}{\lambda_{emitted}}$$

$$\frac{hc}{\lambda_{emitted}} = 2.04\times10^{-18}\,J - 1.63\times10^{-18}\,J$$

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

Mini Quiz

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



Mini Quiz

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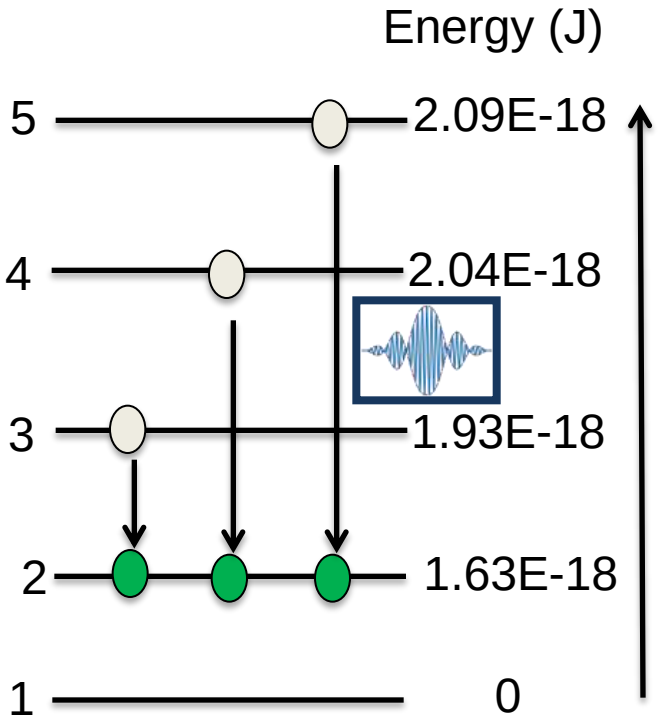


$$\Delta E_{light}^{emitted} = E_{electron}(n=5) - E_{electron}(n=2)$$

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

$$\frac{hc}{\lambda_{emitted}} = 2.09\times10^{-18}\,J - 1.63\times10^{-18}\,J$$

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

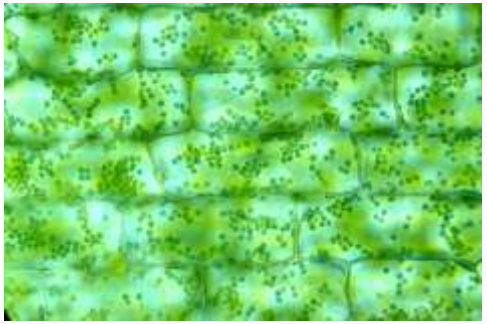
Outline

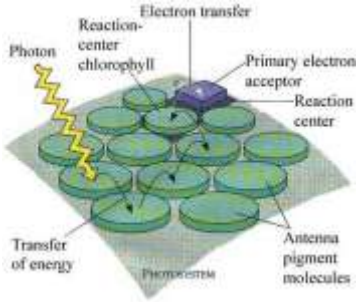
- Electromagnetic Radiation
- Introduction to Quantum Mechanics
- Chemistry?

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

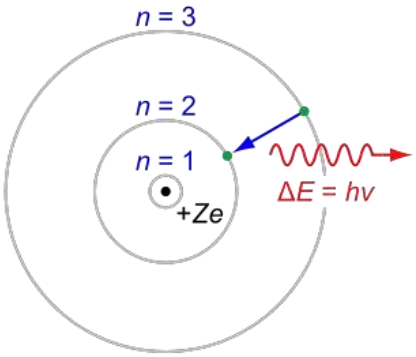
Where Is The Chemistry?

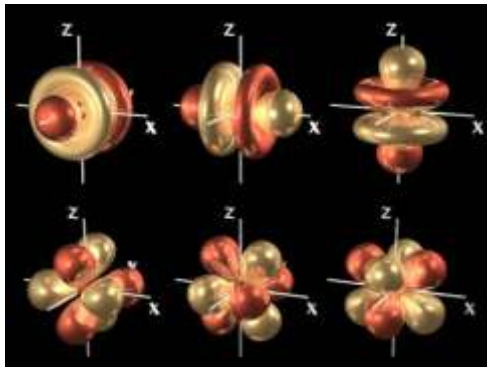
- The interaction of light with matter is responsible for all of life on Earth
- To appreciate life, we must understand both atoms and light





- 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)