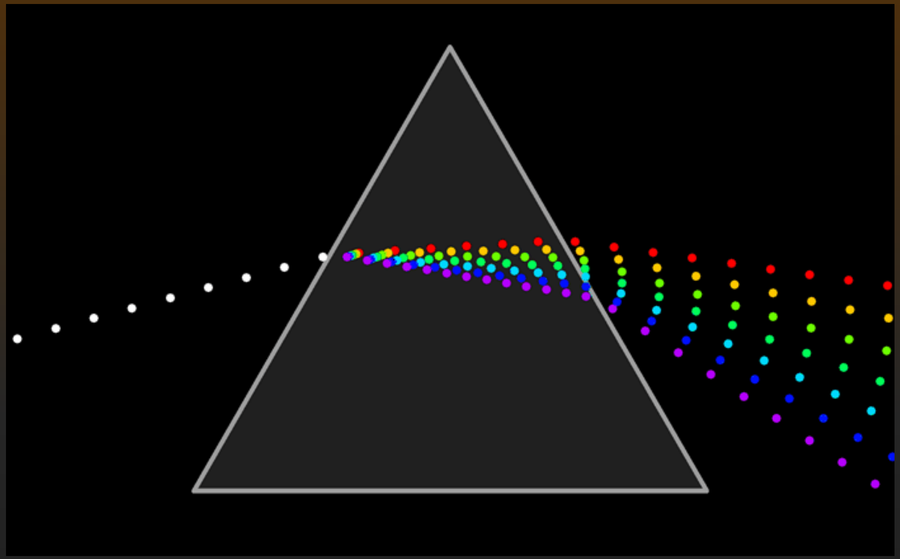
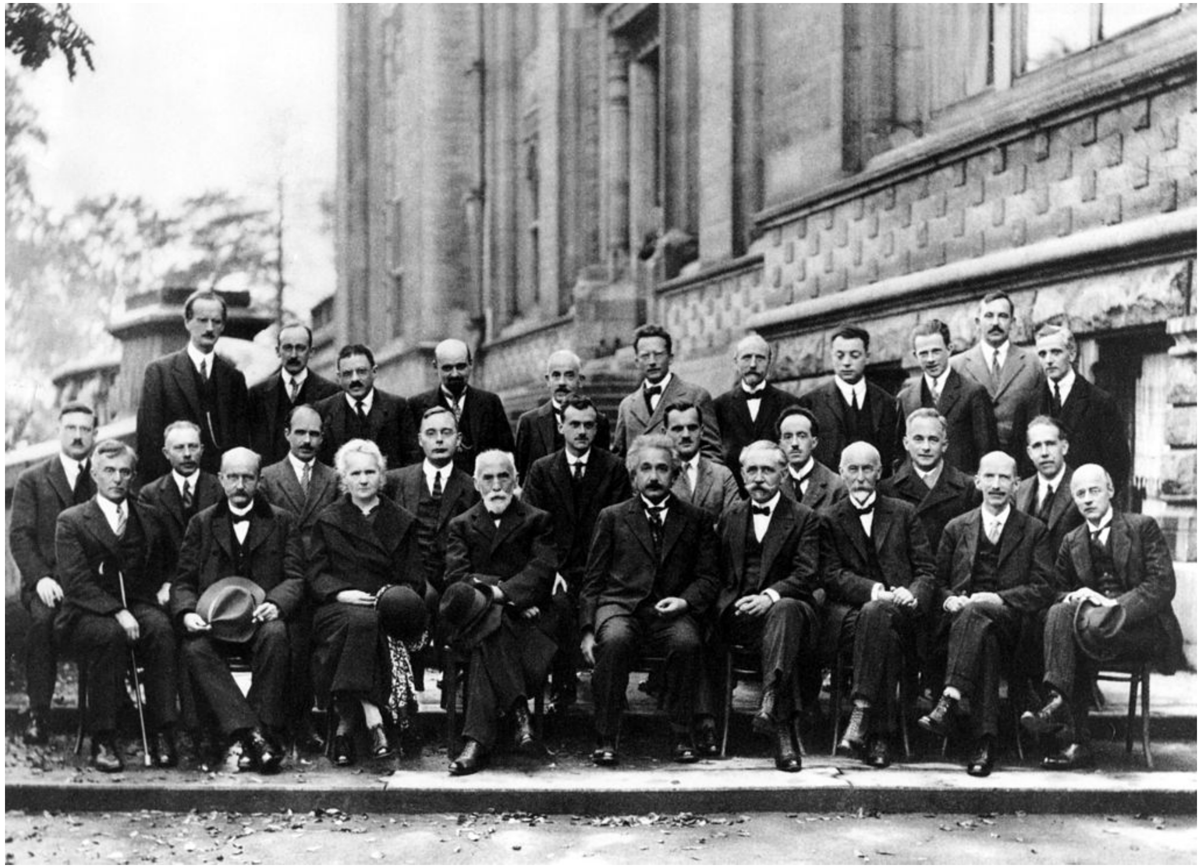


CH301 Unit 2

ELECTROMAGNETIC RADIATION AND INTRODUCTION TO QM

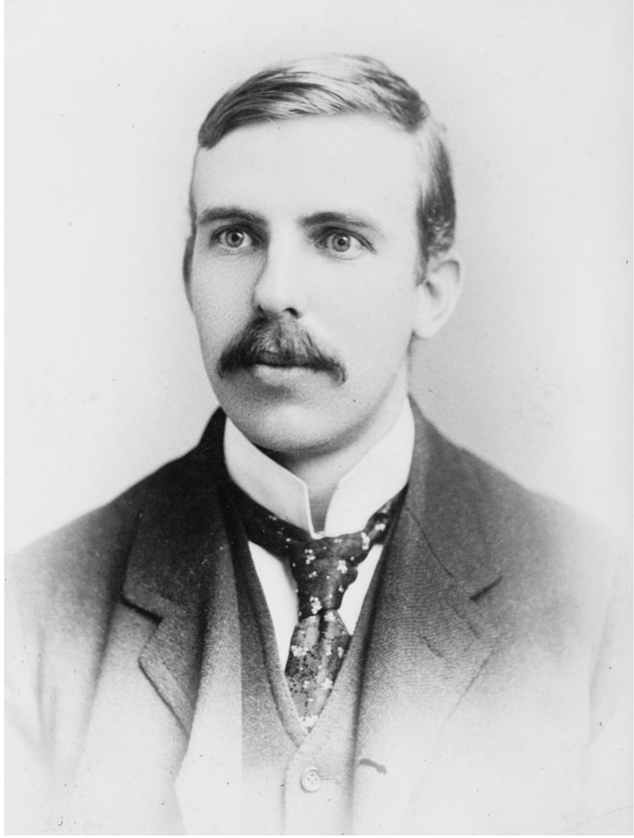
Goals for Today

- Discuss the properties of light in a vacuum
- Review the history of Quantum Mechanics
- Compare side-by-side the predictions of classical and quantum mechanics
- Make calculations with light, the photoelectric effect, and the work function
- Discuss Quantum Mechanics up to "n"



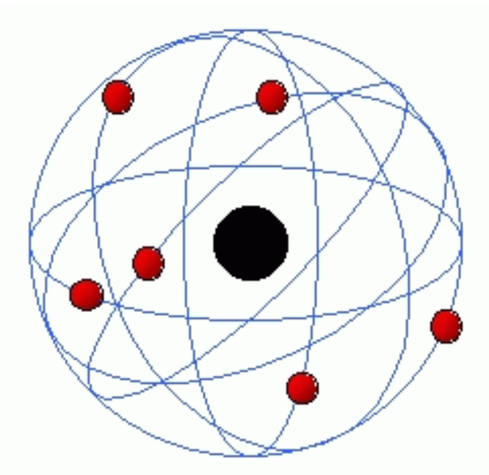
Classical Atomic Theory

- The classical theory of an atom is an important contribution to science that is still taught today even though it is extremely wrong.
- The following points are the main pillars of classical atomic theory
  1. The atom consists of three fundamental particles: protons, neutrons, and electrons
  2. Electrons whirl around the nucleus like planets around the sun, and (like all things in the universe) are governed by Newtonian laws of motion
  3. Light is a wave and exhibits only wave-like behavior



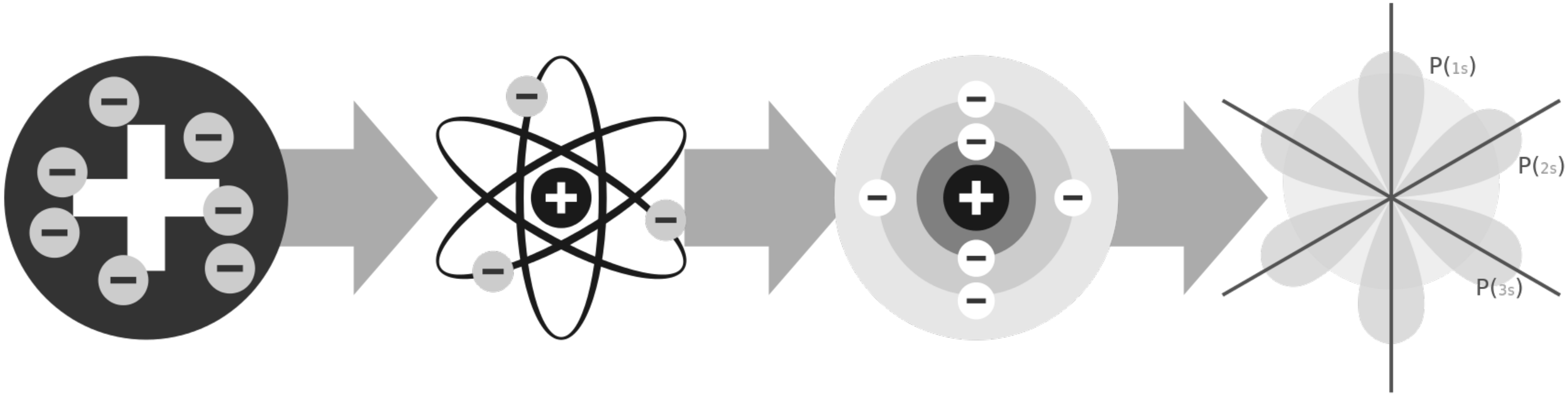
Classical Atomic Theory

- However, there were known failures in these models that, until technology caught up to theoretical physics, could not be explained:
  1. If electrons truly abided by the laws of classical motion, they would lose their energy and collapse in on the nucleus – this would happen on a human time-scale in the blink of an eye
  2. The UV catastrophe showed that blackbodies emit characteristic wavelengths at low wavelengths, whereas the current laws predicted that the absorption would approach infinity before the visible spectrum-range
  3. The spectrum of hydrogen absorption and emission showed indescribable patterns that conflicted with the idea that light and electrons could not interact



Not covered by MWF classes; likely to not be tested by TTH classes

The History of the Modern Atomic Model



Classical Theory

Quantum Theory

What is Quantum Mechanics?

- Quantum mechanics is the currently accepted model of the atom that describes the motion of subatomic particles and the interactions between them using the following empirically derived postulates:
  1. Electrons exist in **discrete, quantifiable energy states**.
  2. Electrons and light (photons) exhibit **wave-particle duality**.
  3. The motion of electrons can be described only with **probabilities**. That is, only the position or momentum can be known with certainty at any given time.
     - Furthermore, this demonstrates that electrons exist in "clouds" and not circular orbits

- Quantum mechanics is the mathematical model for subatomic motion. QM is therefore the model of a particle traveling from point A to point B, and the understanding that the path between these two points is not as simple as you might think.

Classical Vs. Quantum Mechanics

Classical Mechanics

- Three fundamental particles: protons, neutrons, and electrons
- Light is a wave
- Electrons and light do not interact
- Electrons orbit the nucleus
- Position and momentum are predictable

Quantum Mechanics

- Many subatomic particles and growing
- Light exists as tiny packets of energy called photons. Photons exhibit particle-like behavior.
- Electrons and light interact
- Electrons exist in a “cloud” outside the nucleus and are confined to energy levels (n) of various shapes (l)
- Position and momentum are not simultaneously predictable
- Everything with momentum has a quantifiable wavelength

Quantifying Light

- Modern physics defines light as photon particles exhibiting wave-like properties:

$$c = \lambda\nu$$

  - This equation states that the **speed of light** (c) is equal to the **frequency** (ν) times the **wavelength** (λ)
  - Or you could say that wavelength and frequency are inversely proportional

- You can also calculate the energy per photon:

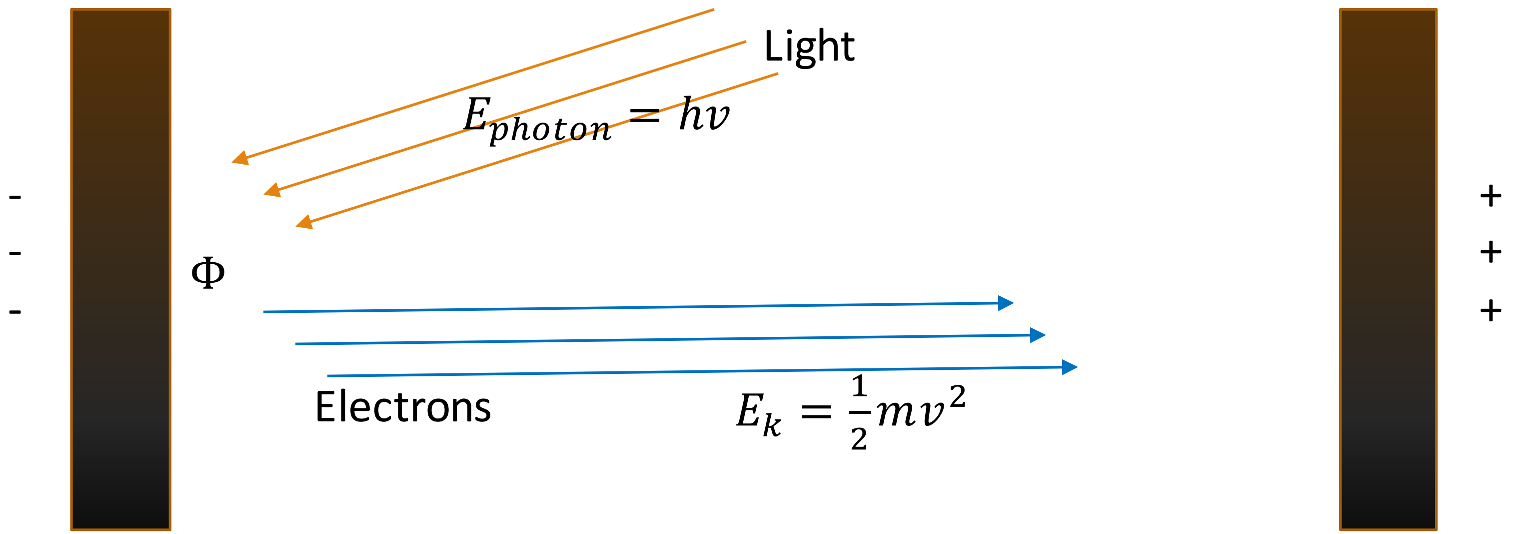
$$E_{photon} = \mathrm{h}\nu \quad \text{or} \quad E_{photon} = \mathrm{h}\frac{c}{\lambda}$$

  - This equation states that the **speed of light** (c) is equal to the **frequency** (ν) times the **wavelength** (λ)
  - Or you could say that wavelength and frequency are inversely proportional

Quantum Mechanics: Photoelectric Effect

- The postulates of quantum mechanics were demonstrated by a series of important experiments between 1885-1930's.
- **Photoelectric Effect**: a metal will eject electrons if a beam of light reaches a threshold energy
  - Proves that matter (the electrons of a metal) can interact with light

$$E_{photon} = \Phi + E_k$$

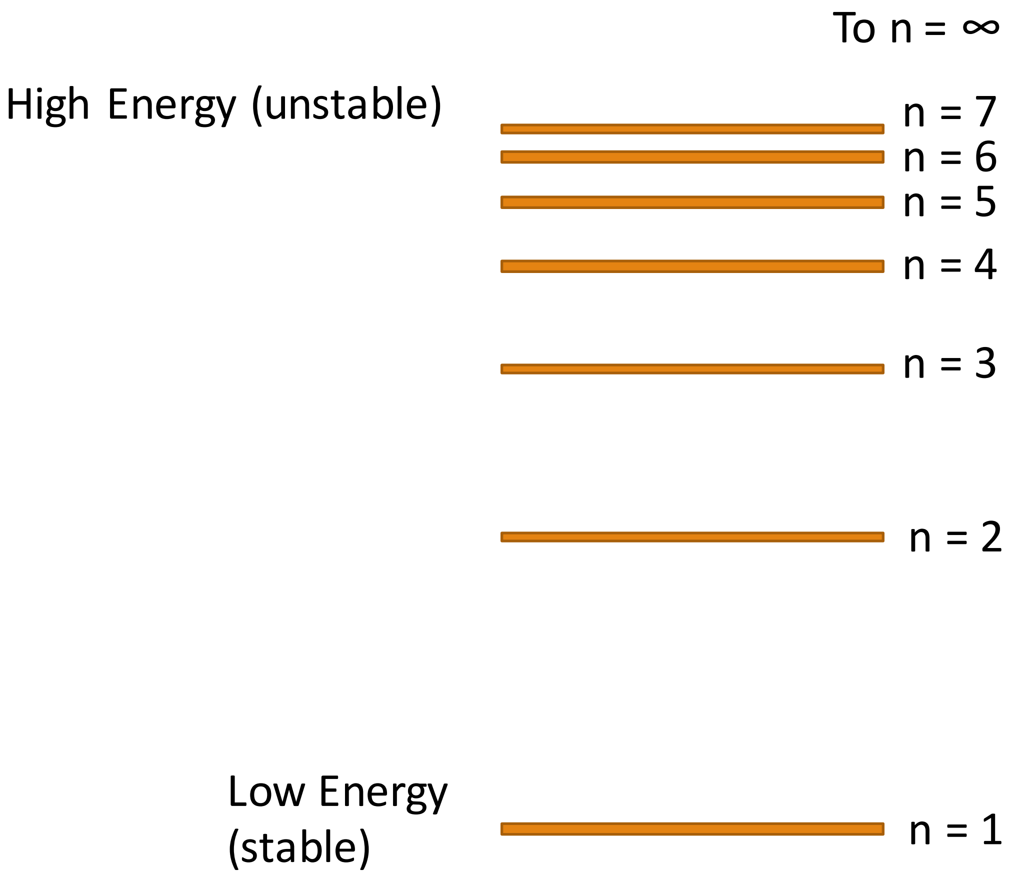


Key points:

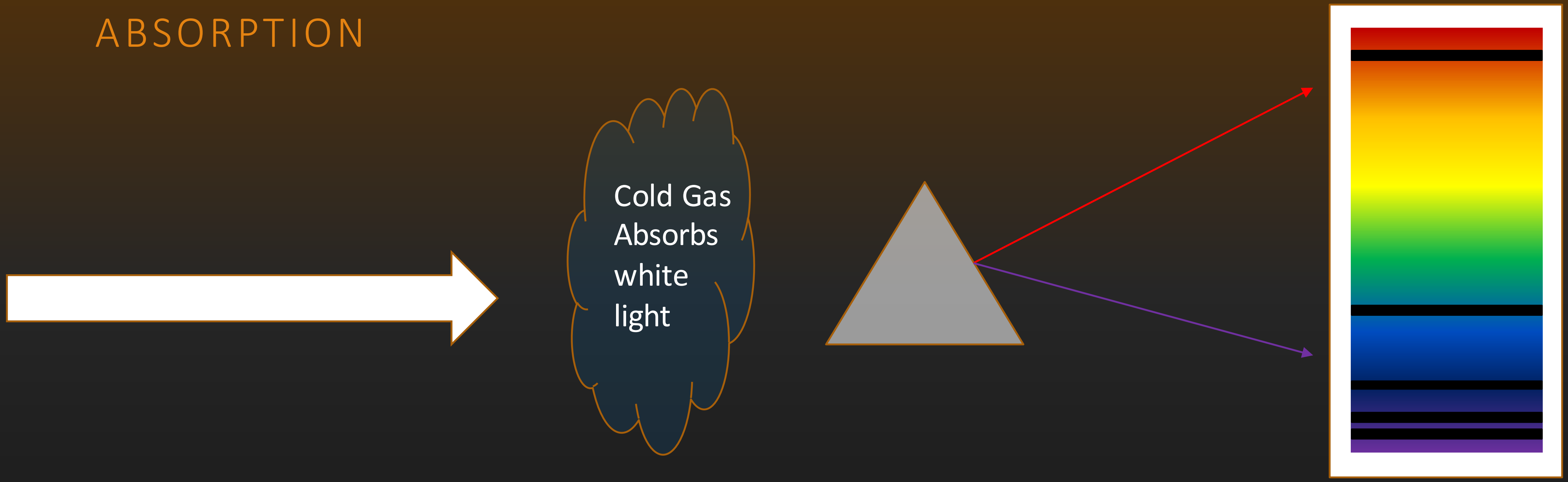
- If an electron is not ejected, your light does not have sufficient energy (you must decrease wavelength or increase frequency)
- Increasing the intensity will result in more electrons ejected if the threshold is reached. If the threshold is not reached, increasing the intensity will do nothing

Quantum Mechanics: Emission vs. Absorption

- A second hallmark experiment of Quantum Mechanics revealed that electrons of the hydrogen atom exist in “energy states,” which were later designated with the letter “n.”
- You can understand n-values by adhering to the following rules:
  1. N values begin at 1 (closest to the nucleus) and go to infinity (completely out of the influence of the nucleus/ free in space)
  2. The lower n value means
  3. The greatest energy difference between two consecutive numbers is 1 and 2.

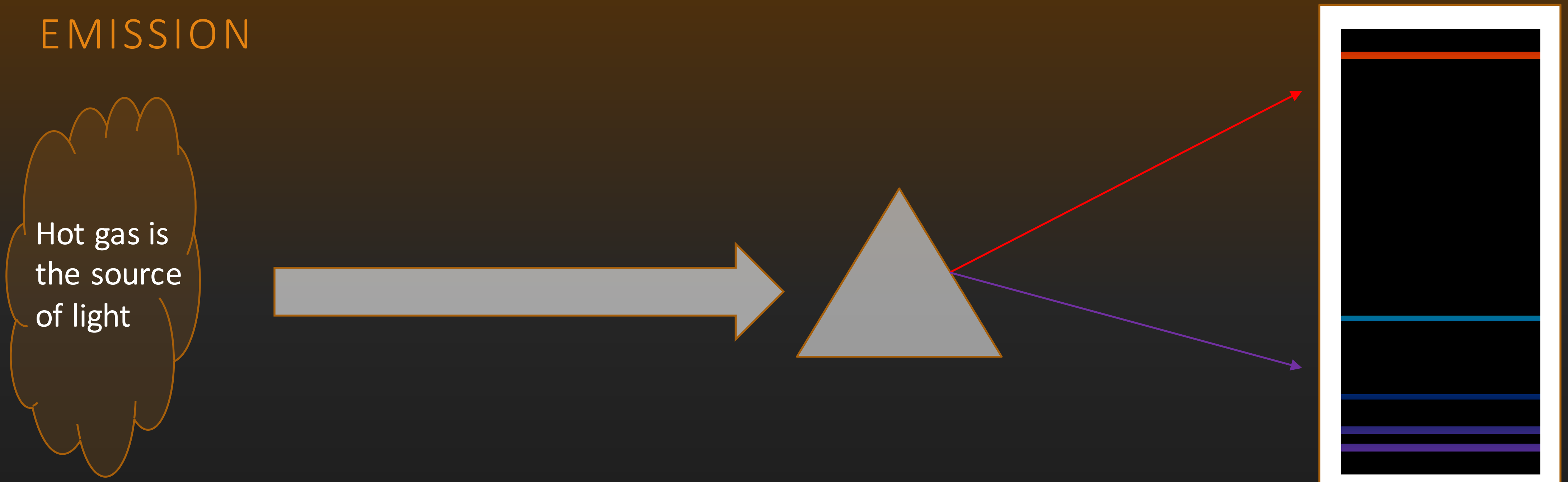


ABSORPTION



YOU WILL SEE THE CONTINUOUS (“WHITE LIGHT”) SPECTRUM MINUS THE CHARACTERISTIC FREQUENCIES OF HYDROGEN

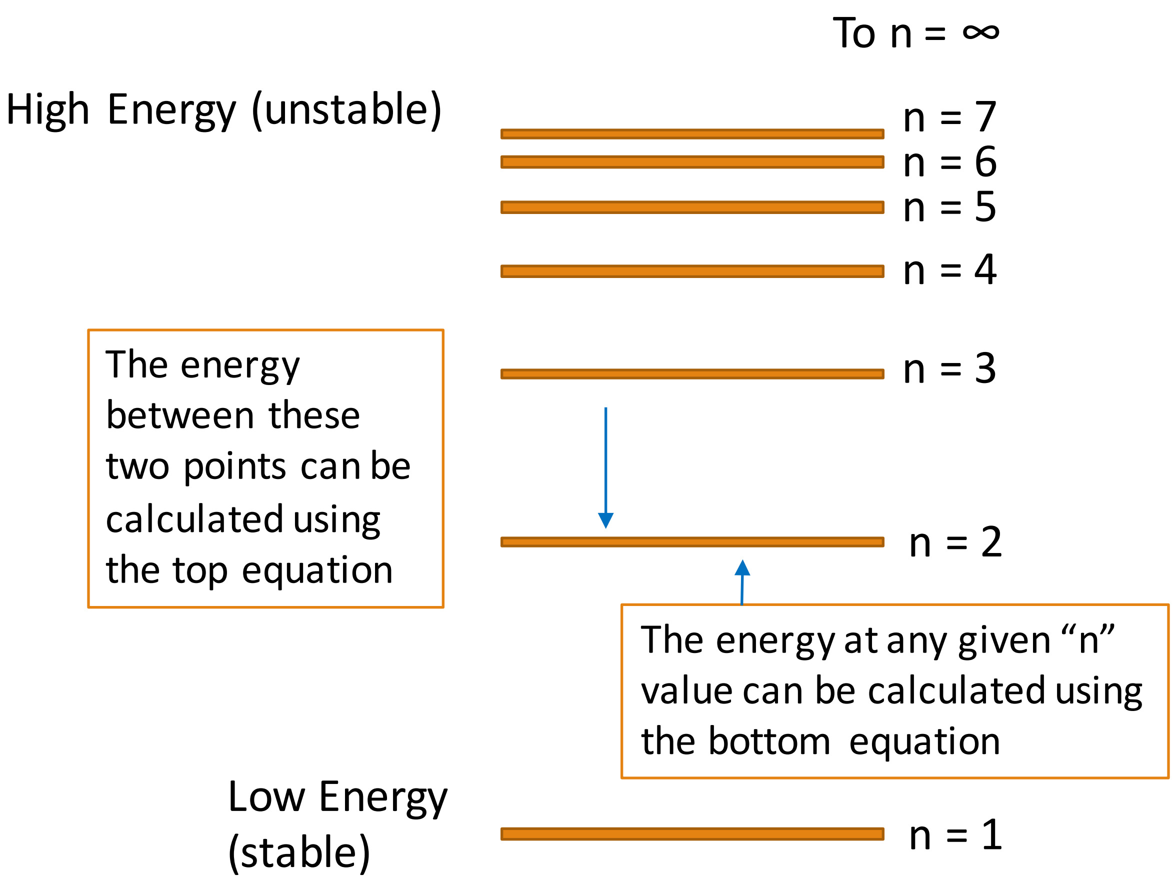
EMISSION



YOU SEE ONLY THE CHARACTERISTIC FREQUENCIES OF HYDROGEN EMISSION

Calculations with the Rydberg Equation

- Two equations you should know:
  - $\Delta E = R(\frac{1}{n_f^2} - \frac{1}{n_i^2})$
  - The change in energy is proportional to the difference of the inverse square of "n" values
  - $E_n = -R(\frac{1}{n^2})$
  - The potential energy of a given energy level is proportional to the inverse square of its "n" value



Remember, if you have the energy change, you can also solve for the wavelength of the light emitted using E = hv