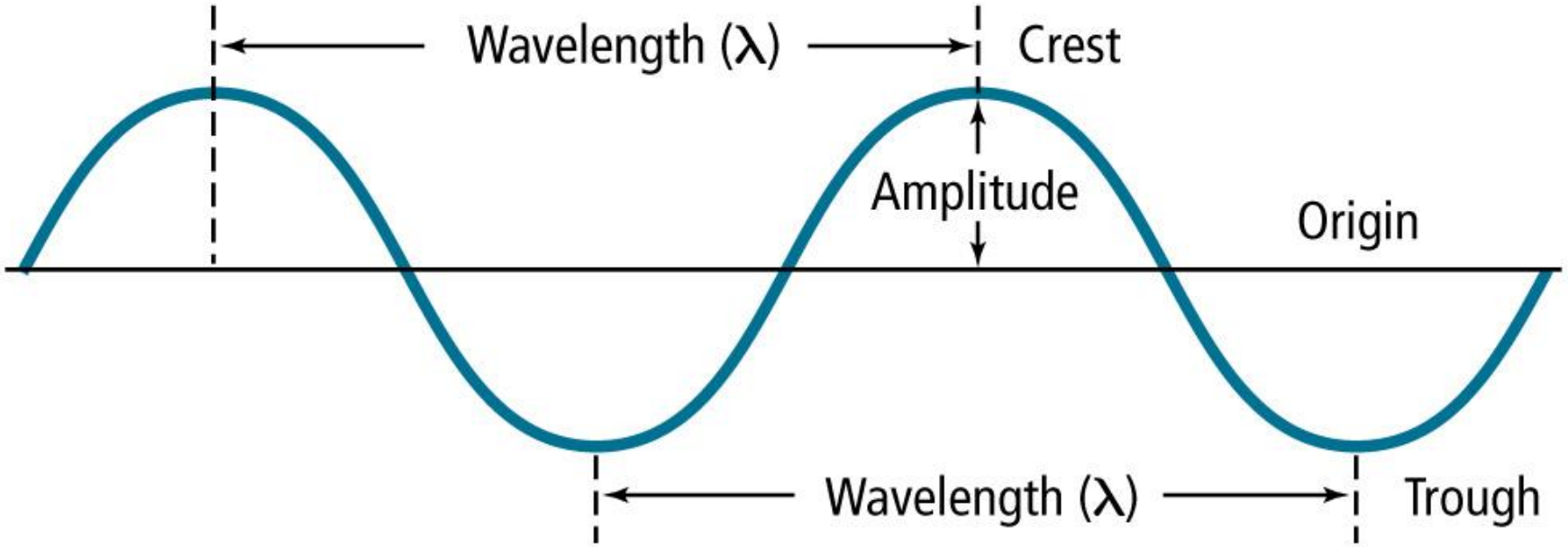
Quantum Mechanics

The hidden world of the electron

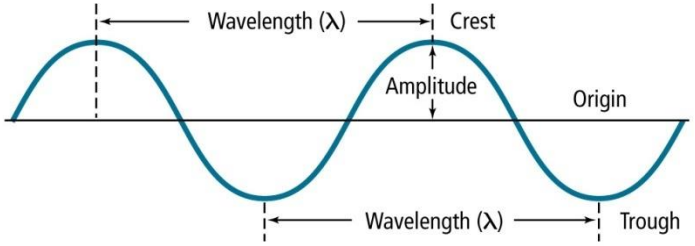
The Wave Nature of Light

- Visible light is a type of electromagnetic radiation, a form of energy that exhibits wave-like behavior as it travels through space.
- All waves can be described by several characteristics.

The Wave Nature of Light



The Wave Nature of Light

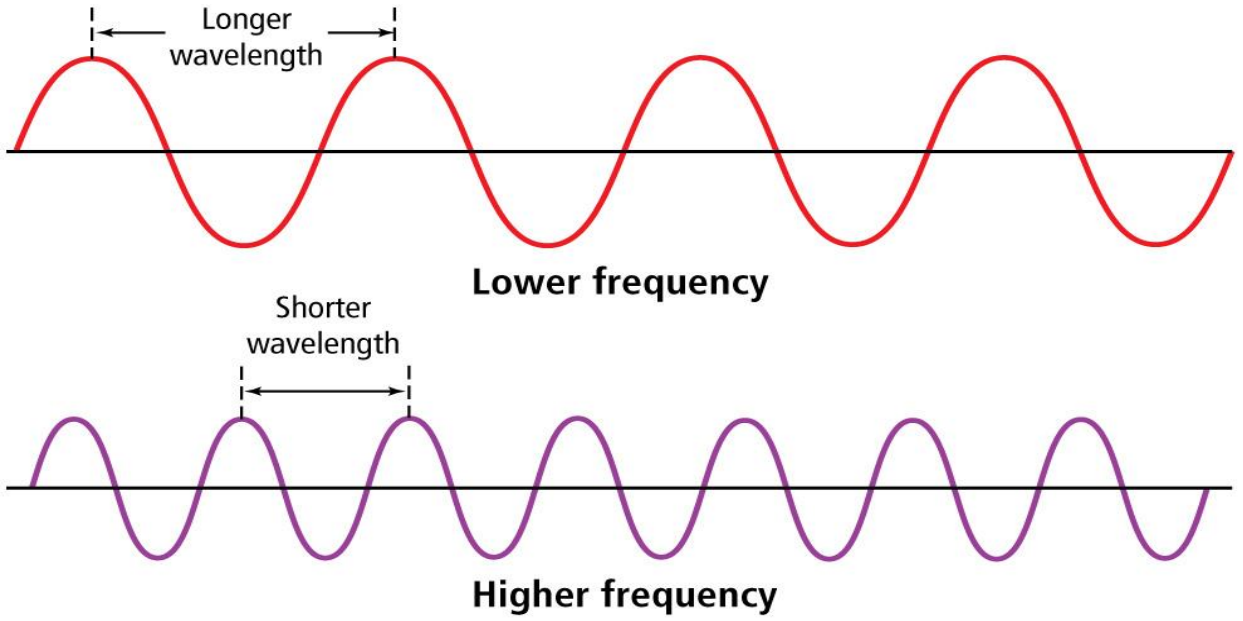


- The **wavelength** (λ) is the shortest distance between equivalent points on a continuous wave.
- The **frequency** (ν) is the number of waves that pass a given point per second.
- The **amplitude** is the wave's height from the origin to a crest.

The Wave Nature of Light

- The speed of light (3.00×10^8 m/s) is the product of it's wavelength and frequency

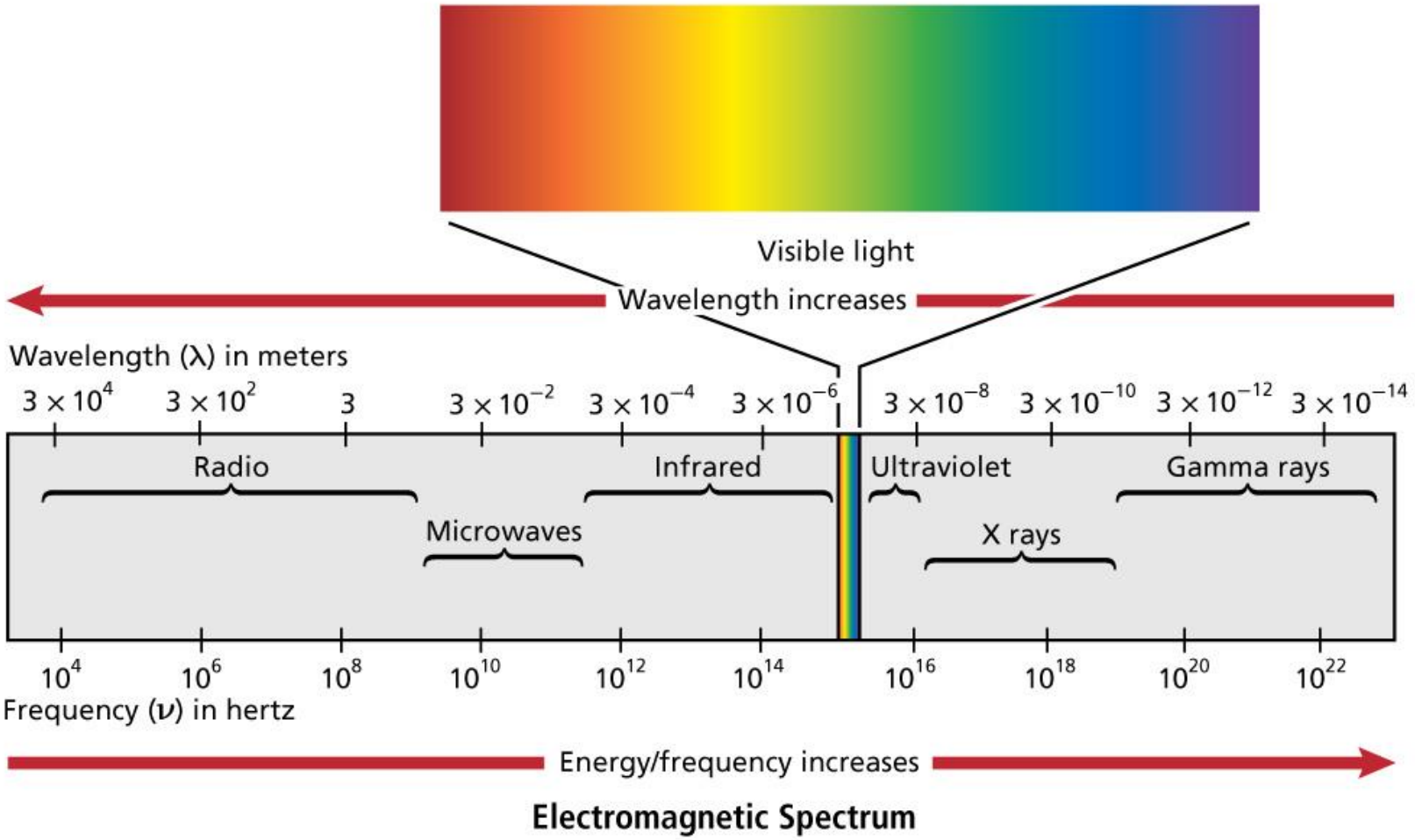
$$c = \lambda\nu.$$



The Wave Nature of Light

- Sunlight contains a continuous range of wavelengths and frequencies.
- A prism separates sunlight into a continuous spectrum of colors.
- The **electromagnetic spectrum** includes all forms of electromagnetic radiation.

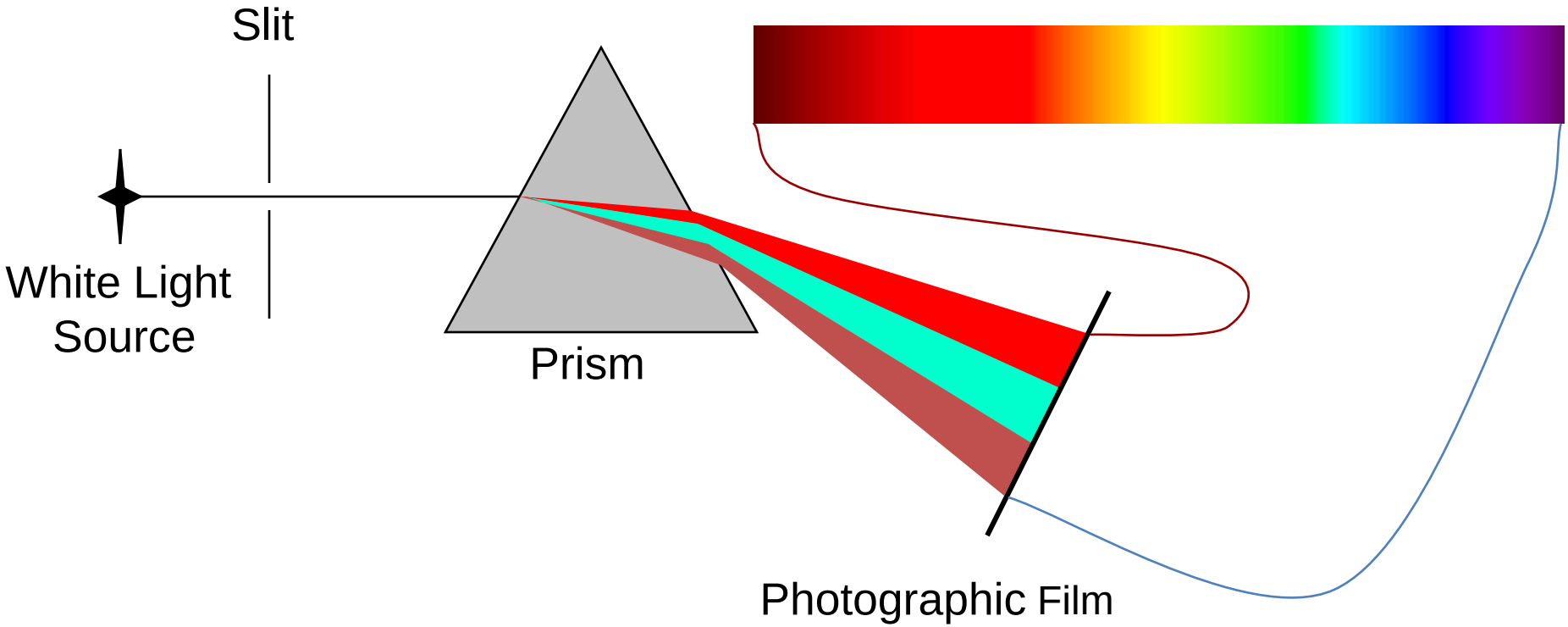
The Wave Nature of Light



Electromagnetic Spectrum

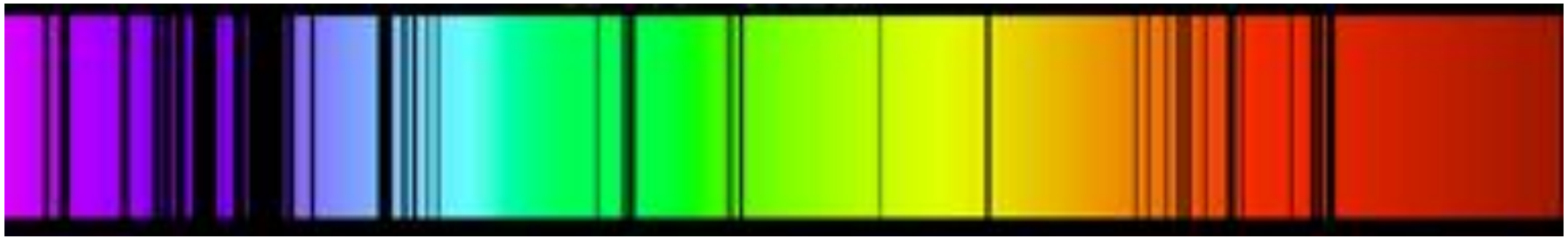
Shedding some light on it…

Continuous Emission Spectrum



Shedding some light on it…

- Astronomical analysis of light from stars showed dark lines in the spectra
  - Absorption spectra

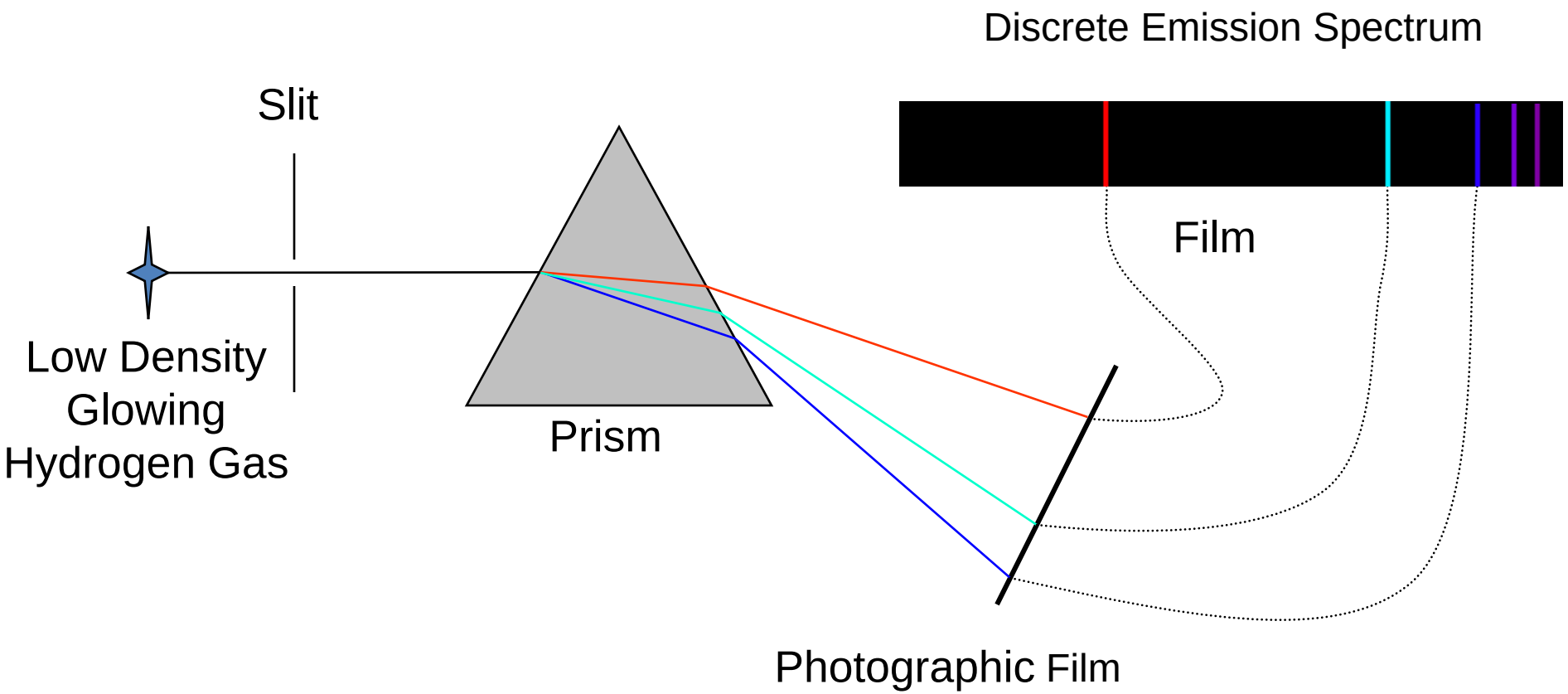


The Atom and Unanswered Questions

- In the early 1900s, scientists observed certain elements emitted visible light when heated in a flame.

- Analysis of the emitted light revealed that only specific frequencies of light were emitted, not a continuous spectrum

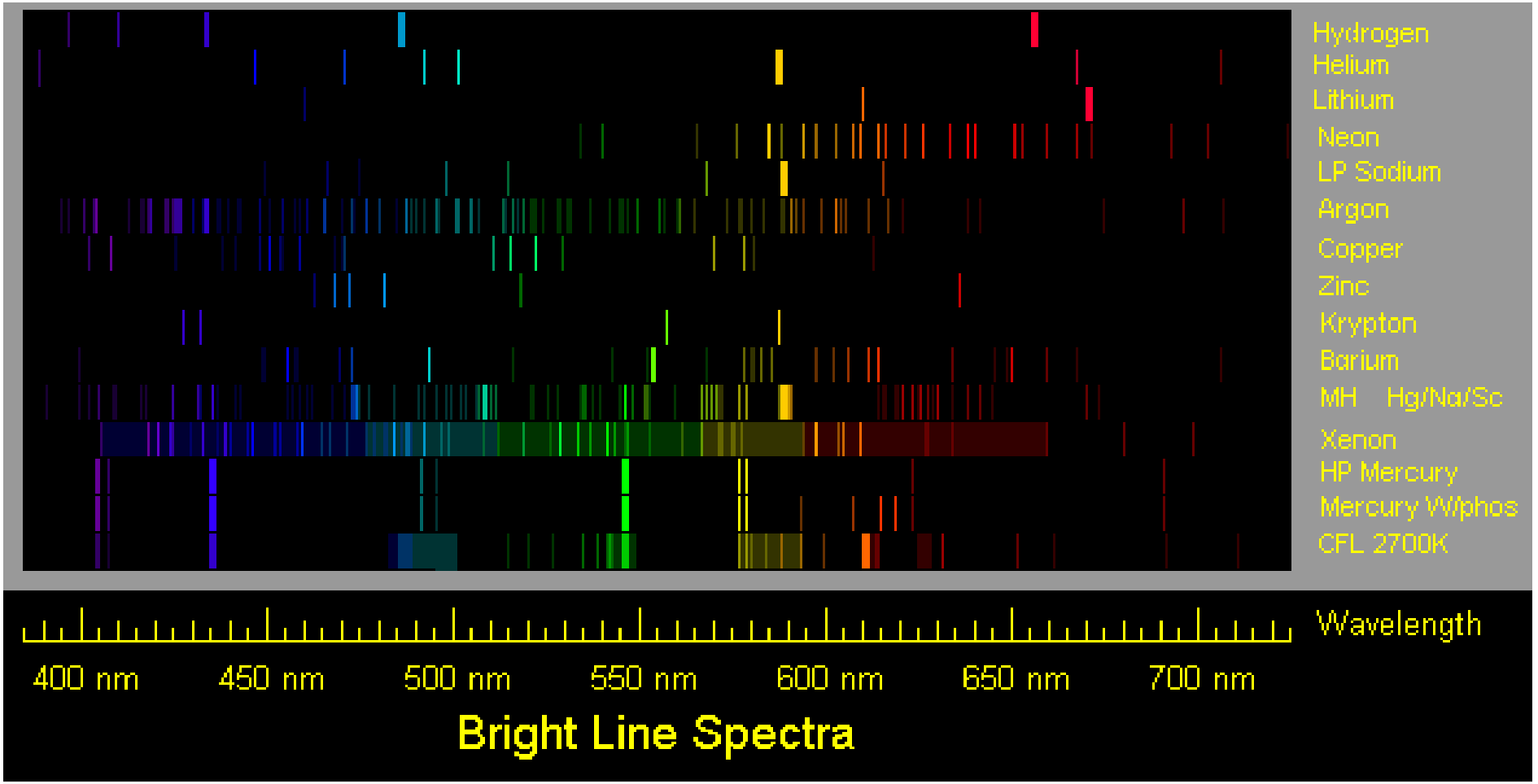
Shedding some light on it…



Shedding some light on it…

- Glowing gas of a single element produced only individual lines of color
  - Emission spectra
  - Like a “fingerprint” for the element
    - This is from hydrogen

Shedding some light on it…



http://members.misty.com/don/spectra.html

Energy is “quantized” in an atom

- *Each line in the emission spectrum was equivalent to a specific amount of energy the atom could absorb or release*

Planck

- Planck showed that matter can only release energy as light with specific energies dependent on the temperature of the matter, not just any energy
- The minimum energy that could be released as light was called a “quantum”
- Energy could be released in whole number multiples of the “quantum” of energy
  - “quanta”

Planck

- The frequency of the light that was released was proportional to the energy
  - Higher energy means higher frequency (ν)

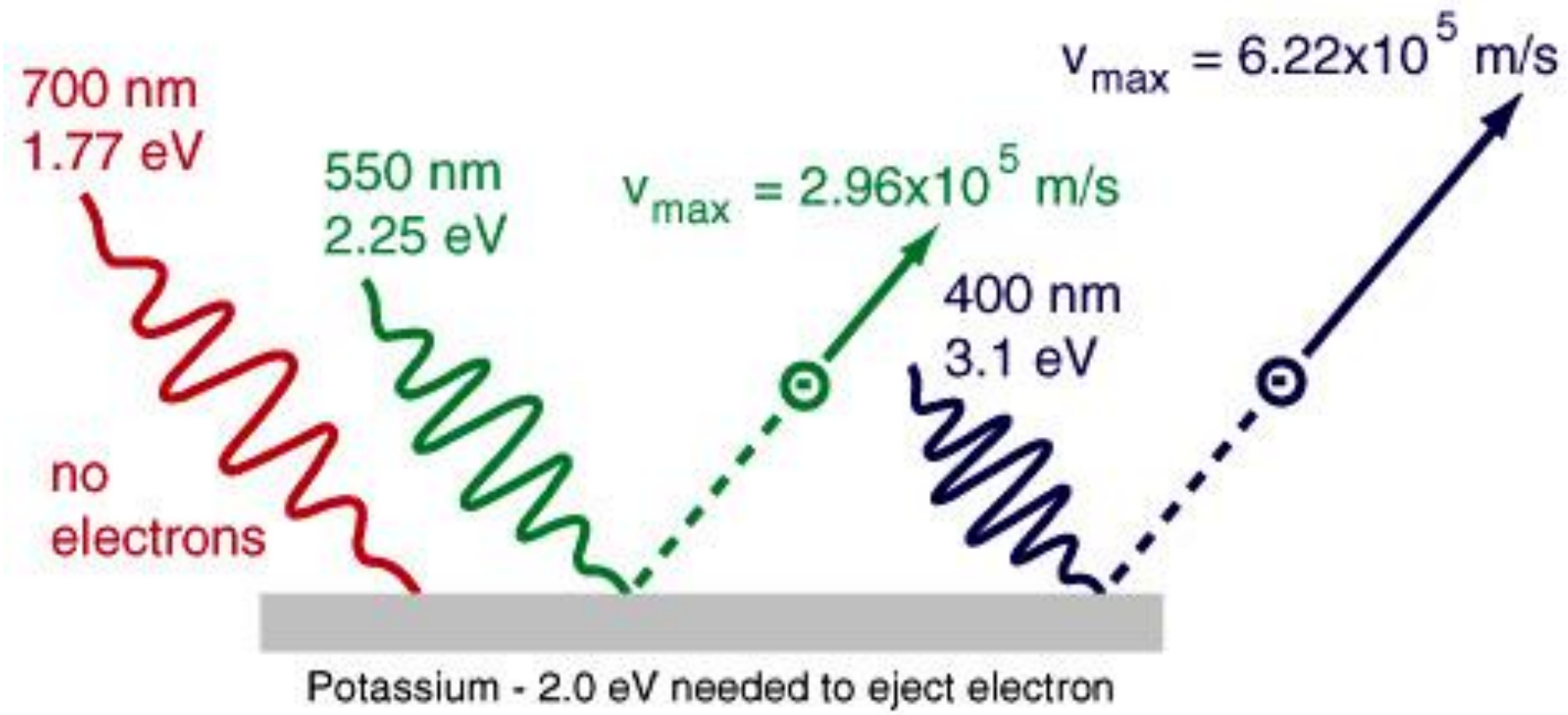
$$\mathbf{E = h\nu}$$

E = energy

h = Planck's constant

ν = frequency

Photoelectric effect



http://www4.nau.edu/meteorite/Meteorite/Images/Photoelectric_Effect.jpg

Einstein

- Einstein showed that light can behave as a "particle"
  - photoelectric effect
- A "particle" of light is called a "photon"
  - A mass-less particle of em energy
- The energy of the photon is proportional to its frequency

$$E=h\nu$$

Planck + Einstein

- The reason there was always a whole number multiple of the quantum of energy was that there was a whole number of photons released
- An atom can increase in energy when absorbing a photon of light or lower its energy when released by the atom as a photon of light