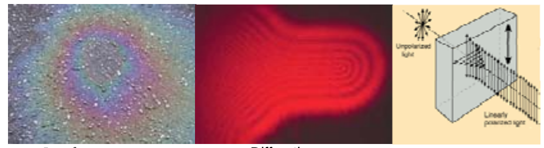
Wave-Particle Duality

Photoelectric Effect
Atomic Line Spectra

Wave-Particle Duality: Light

- Does light consist of particles or waves? When one focuses upon the different types of phenomena observed with light, a strong case can be built for a wave picture:

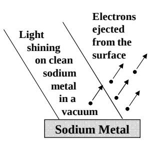


Interference   Diffraction   Polarization

- By the turn of the 20th century, most physicists were convinced by phenomena like the above that light could be fully described by a wave, with no necessity for invoking a particle nature. But the story was not over.

Photoelectric Effect

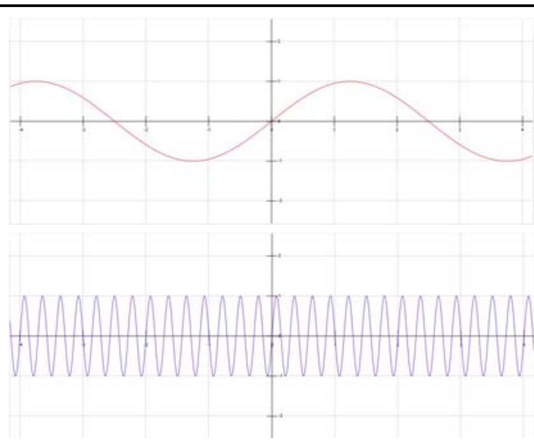
- Under the right circumstances light can be used to push electrons, freeing them from the surface of a solid.
- The photoelectric effect is the emission of electrons from a surface when illuminated with light of a certain frequency.



- The details of the photoelectric effect were in direct contradiction to the expectations of very well developed classical physics.
- The explanation marked one of the major steps toward quantum theory.

Light Energy

- Max Planck suggested that atoms can absorb and emit energy in only discrete chunks called quanta
- Einstein discovered that quantum behavior of light was not due to atoms, but was due to a property of energy itself.
  - Found a simple relationship between the energy of a light wave and its frequency.
  - Light energy is emitted and absorbed in discrete quanta of energy.
  - Postulated that light itself consists of individual quanta of energy, (now called photons)



PHOTON

- Massless "particle" of light which has a specific amount of energy associated with it.
- Under the photon theory of light, a *photon* is a discrete bundle (or *quantum*) of light energy.
- The amount of energy depends on the frequency (color) of the light.
- Photons can have particle-like interactions (i.e. collisions) with electrons and other particles.

Light Energy

$$E = hf$$

E = energy (J)
h = Planck's constant (6.63 E -34 Js)
f = frequency (Hz)

Photoelectric Effect

- Each photon has a specific energy related to its frequency (color)
- The higher the **frequency**, the higher the **energy of the emitted electron**
- One photon can make one electron move so the **brighter** the light the **greater the amount of current**.

Technology

- "Electric eye", light meter, movie film audio track
- Photoconductivity: an increase in the electrical conductivity of a nonmetallic solid when exposed the electromagnetic radiation
- Photovoltaics (PV): leading to the direct conversion of radiant energy to electrical energy (solar power)
- Photostatic copying

Atomic line spectra

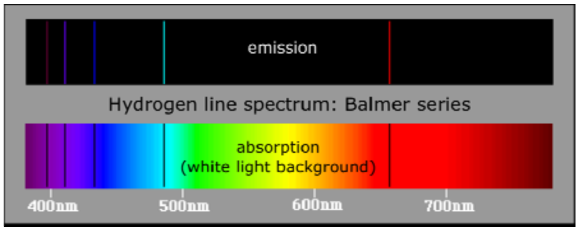
Atomic Line Spectra

- When a gas at low pressure is heated to incandescence it glows.
- If this light is observed through a prism or diffraction grating distinct bright lines of color are seen.
- Each line of color corresponds to a specific frequency (think color).
- This series of lines is called an emission spectrum.
- Each element has a specific emission spectrum.

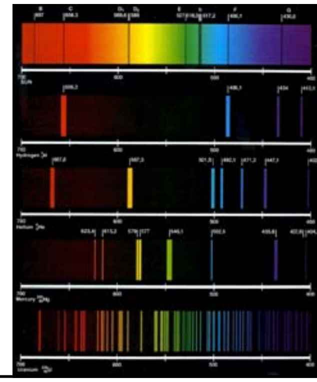
Atomic Line Spectra

- In addition to giving off light at specific frequencies each element will also absorb light at those same specific frequencies producing an absorption spectrum.
- These atomic line spectra can not be explained with light being a wave.

Atomic Line Spectra



Atomic Line Spectra



Atomic Line Spectra

- In 1913 Niels Bohr proposed a model of the hydrogen atom that explained atomic line spectra.
- In Bohr's model the electrons orbiting the nucleus could only be located in certain orbits and never between the orbits.
- Electrons move instantly from one orbit to another without ever being between the orbits.

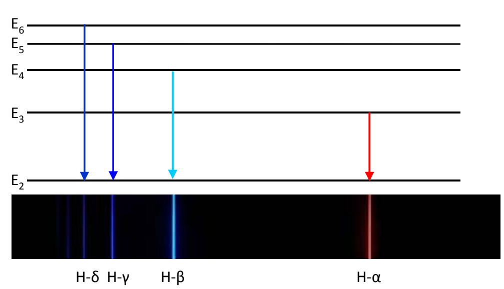
Atomic Line Spectra

- An electron must absorb or emit a specific amount of energy when it moves from one orbit to another.
- The energy emitted or absorbed is a photon of a certain frequency.
- These orbits are now called energy levels.

Atomic line spectra

- In order for an electron to move from a low energy level to a high energy level it must **absorb** a specific photon of energy.
- When the electron moves back to the lower energy level it must **emit** a specific photon of energy.
- We see these emitted photons as specific bands of colors.
- These energy level jumps are called **quantum leaps**. (really!)

Hydrogen Balmer Lines



Wave-Particle Duality: Light

Phenomenon	Can be explained in terms of waves	Can be explained in terms of particles
Reflection	✓	✓
Refraction	✓	✓
Interference	✓	⊗
Diffraction	✓	⊗
Polarization	✓	⊗
Photoelectric Effect	⊗	✓
Emission Spectra	⊗	✓

Wave-Particle Duality: Light

- Light behaves like a wave!
- Light behaves like a particle!
- ***Light must be both a wave and a particle!***