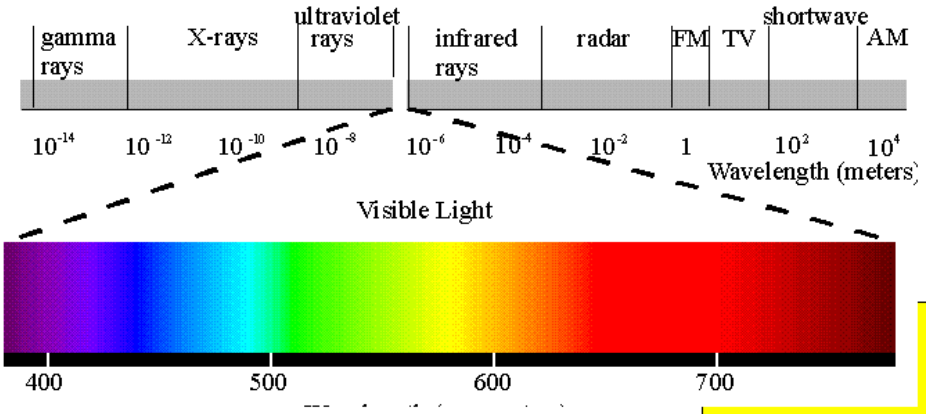
Quantum Mechanics

Thursday, October 16, 2008
1:07 PM

The Early History of Quantum Mechanics

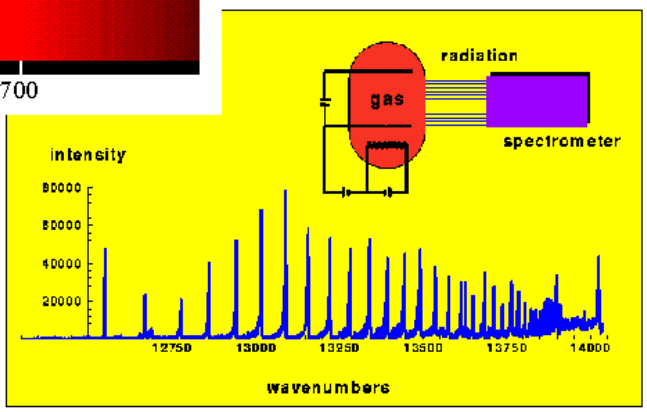
1859-1896 - Blackbody Radiation
1900 - Planck Explains Blackbody Radiation
1905 - Einstein Explains the Photoelectric Effect
- Introduces the photon
1913 - The Bohr Model for Hydrogen
1924 - deBroglie's Thesis - Particles behave like Waves
1925 - Matrix Mechanics - Heisenberg
1926 - Derivation of Planck's Law - Dirac
1927 - The Uncertainty Prinicple - Heisenberg
1927 - Davisson-Germer Verified deBroglie's idea
1928 - Relativistic Quantum Mechanics - Dirac
1930 - Einstein challenged the Uncertainty Principle

EM Spectra

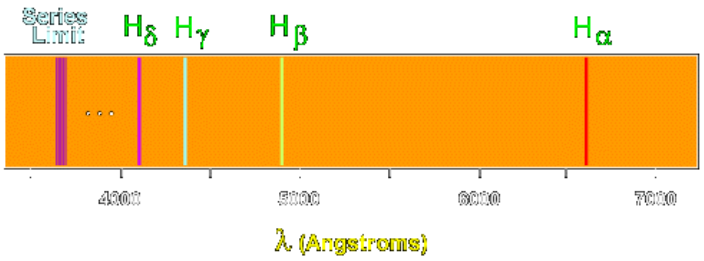


wavespeed = frequency x wavelength

$$c = f\lambda$$



Hydrogen Spectrum



Ionized gas gives off radiation - spectral lines
Balmer Series - Experimental Fit

wavelength = R (1/4 - $1/n^2$)
predicted 5th-7th lines

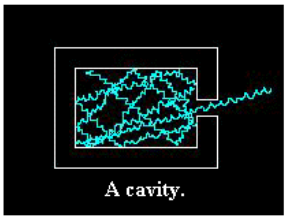
Other Series - Lyman and Paschen

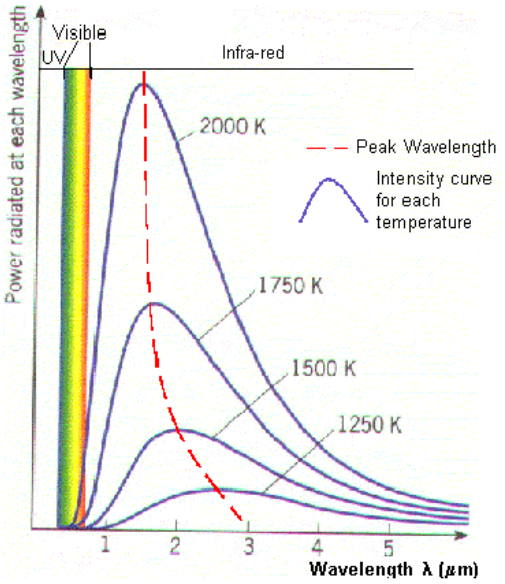
Blackbody Radiation

Heated bodies Radiate - Stefan-Boltzmann Law

Blackbody - A black body is a theoretical object that absorbs 100% of the radiation that hits it.

http://www.egglescliffe.org.uk/physics/astronomy/blackbody/bbody.html



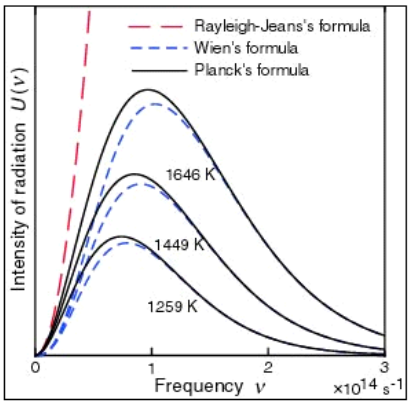


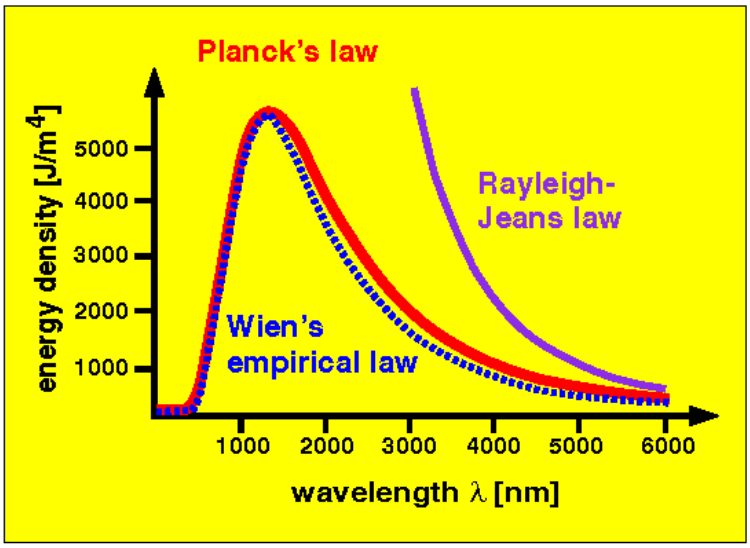
Explanation of Experiments

Wien's Law (1896) and Rayleigh-Jeans Law (1900)

The Formulae

Summary



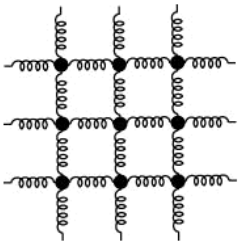


Ultraviolet Catastrophe "...when you turn on your toaster, you are instantly fried by a massive gamma ray burst, since your little blackbody toaster should emit infinite energy at the shortest wavelengths."

Max Planck - 1900

Max Planck proposed that oscillators can only vibrate at discrete frequencies:

$$E = nhf.$$



Thus, the energy difference = hf,

where Planck's constant is given by

$$h = 6.63 \times 10^{-34}\ Js$$

Photoelectric Effect

Ejection of electrons from a metal in response to incident light.

Heinrich Hertz 1887

physical materials absorb energy and emit charged particles

the minimum voltage required to draw sparks from a pair of metallic electrodes was reduced when they were bathed in UV (mercury lamp)

Philipp Lenard,1900 using a metal plate

the charged particles emitted were electrons

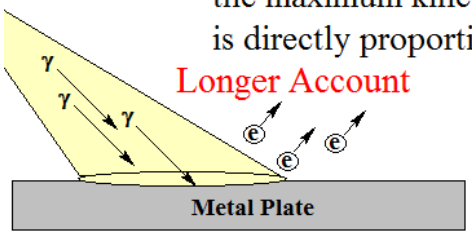
By 1902, the *photoelectric current*

is proportional to the intensity of the light for any given frequency

the maximum kinetic energy imparted is independent light intensity

is directly proportional to the frequency of the light.

Longer Account

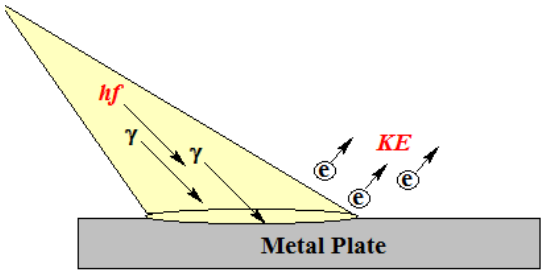


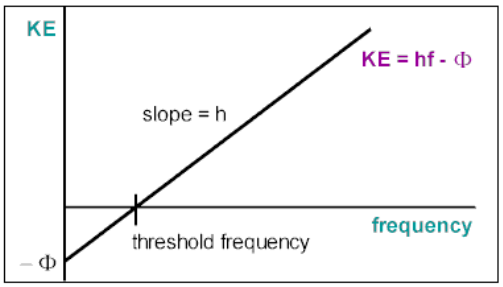
Photons ala' Einstein

Einstein proposed that light comes in packets of energy: photons

$$hf = KE_{max} + \Phi$$

$$(f = c/\lambda)$$





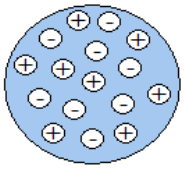
Photoelectric Effect

Light can cause currents

- **Electrons can be ejected from irradiated metal plates.**
- **Light can be act like either particles (quanta) or waves.**
- **Extended Planck's ideas of energy quantization.**
- **Lead to explanation of electromagnetic spectra,**
- **Lead to the development of lasers, transistors and other applications.**

Model of the Atom

Aristotle - Four Elements vs Democritus' atom
1808 John Dalton Foundation's of Atomic Theory



1897 J J Thomson - electrons, Plum pudding model

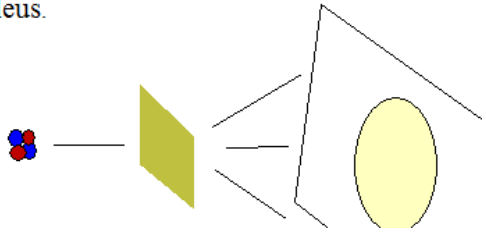
1909 Rutherford, Geiger, Marsden - Gold Foil Experiment

(1) The majority of any atom is empty space.

(2) The atoms positive charge is present in a small, dense nucleus.

Rutherford's Model

Negatively charge electrons orbit postively charged nucleus.

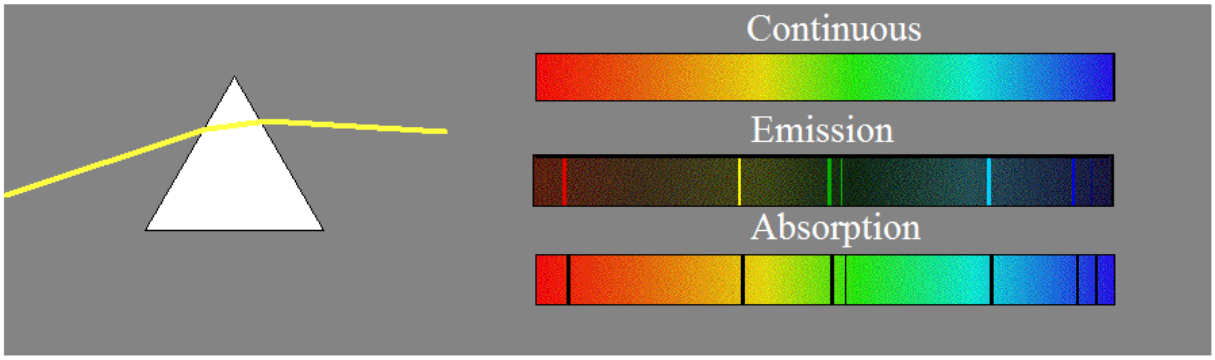


Spectra

Failure of Rutherford Model to explain ionization spectra:

A. Classic Theory - Electrons radiate at orbital frequency and slow down in the process - spiraling to demise!

B. Ionized atoms give off discrete spectra - not continuous!

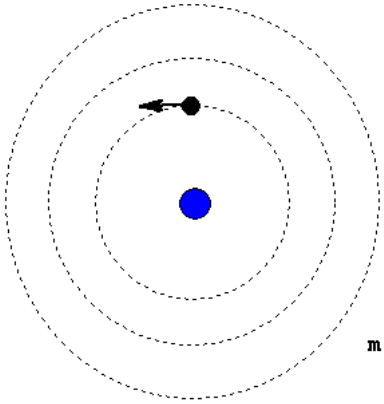


Bohr's Model of the Hydrogen Atom

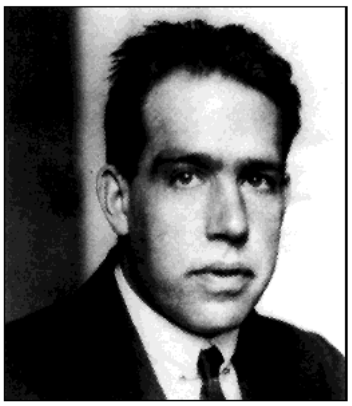
1913 Niels Bohr

Accelerating electrons do not radiate as long as they have specific energies.

$$E_n = -R_H/n^2$$



$$m v r = n \frac{h}{2\pi}$$



See Atomic Orbitals

Electromagnetic Spectra

Emission of energy $\Delta E = E_n - E_m$ => Balmer's Series

$$E_n = R_H(1/m^2 - 1/n^2)$$