Physics 102 - February 24, 2014

Last Time

Maxwell's equations
interference
diffraction
Refraction
dispersion
⋮

light is a wave!

Planck

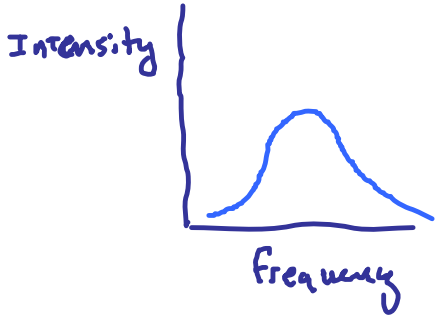
Blackbody Radiation

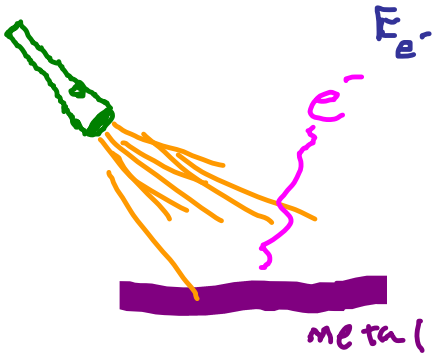
Einstein

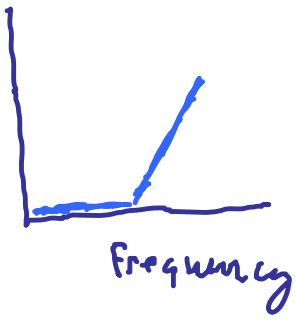
Photoelectric effect

light comes in little packets with energy $E = h\nu$

light is a particle!







Louis Victor Pierre Raymond, 7th duc de Broglie

French, Nobel Prize 1929

mid-1920's

de Broglie hypothesized matter can have wave characteristics with a wavelength given by

So-called de Broglie Wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

From special relativity ← form of "$E=mc^2$" when particle moving

$$E = \sqrt{p^2c^2 + m^2c^4}$$

For photon, $m=0$

$E=pc$ or $p = \frac{E}{c}$

From Blackbody + PhotoElectric

$E = h\nu \rightarrow E = \frac{hc}{\lambda}$ ($\nu = \lambda\nu$) $\rightarrow \frac{h}{\lambda} = \frac{E}{c}$

$\lambda = \frac{h}{p}$ for photon

deBroglie: Perhaps Also true for Particle with Mass

particles are particles

And

particles are waves!

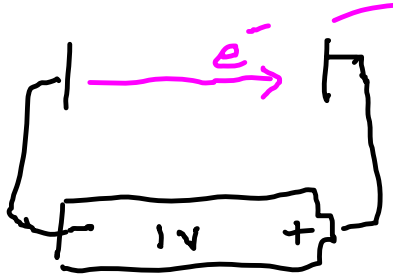
what is λ for baseball — 92 MpH

142 g

41 m/s

$$p_{baseball} = mv = 5.7 \text{ kg m/s}$$

$$\lambda = \frac{6.6 \times 10^{-34} \text{ J·s}}{5.7 \text{ kg m/s}} = 1 \times 10^{-34} \text{ m}$$



1 eV e^- beam

1.6×10^{-19} Joules

"

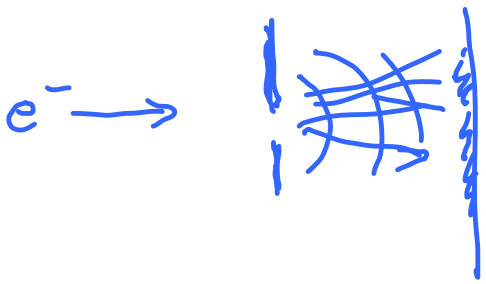
Kinetic Energy $= \frac{1}{2} m v^2$ $\longrightarrow$ $V = 596 \frac{m}{s}$

$m_e = 9 \times 10^{-31}$ kg

$p_{e^-} = mV = (9.1 \times 10^{-31})(596) = 5 \times 10^{-28}$ kg $\frac{m}{s}$

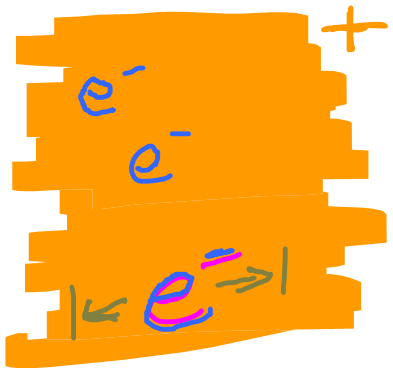
$$\lambda_{e^-} = \frac{6.6 \times 10^{-34}}{5 \times 10^{-28}} = 1.3 \times 10^{-6} m$$

$\sim 1 \mu m$



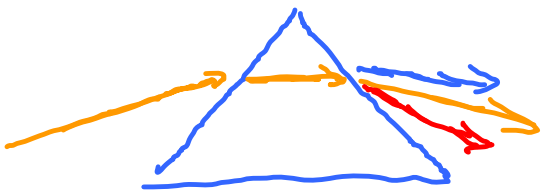
can be observed

Model of atom

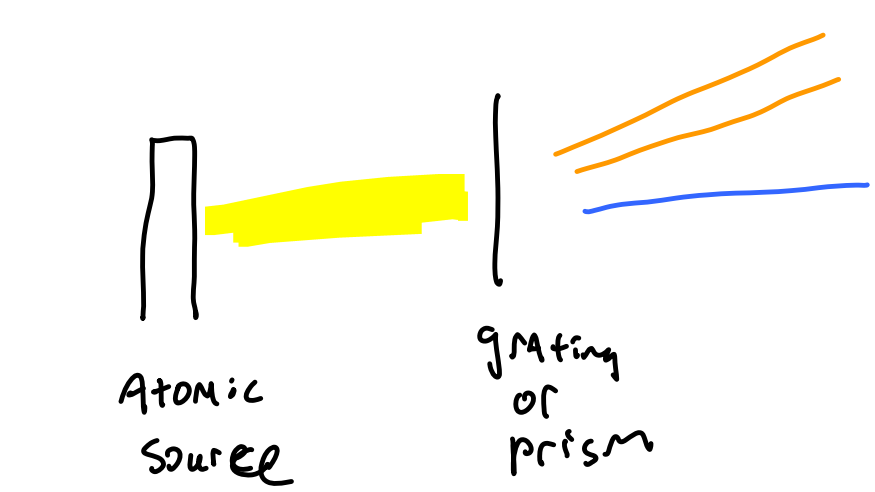


Dispersion

degree of Bending depends on ν




observer
See continuous rainbow
white light source
grating or prism



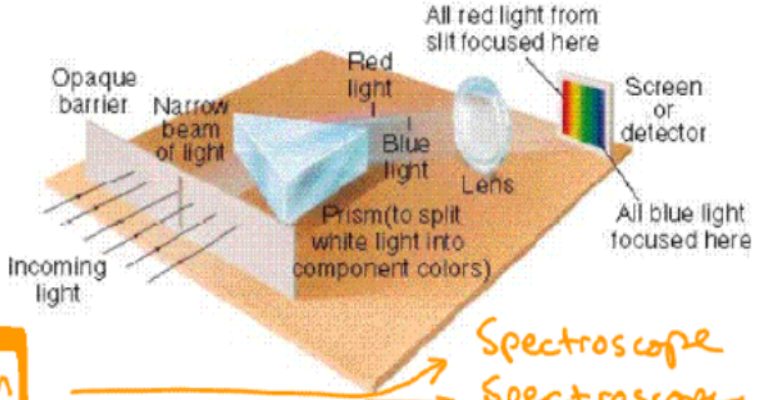
only a few discrete colors/frequencies (ν)
Energies ($E = h\nu$)

emitted

(Neon gas for example)

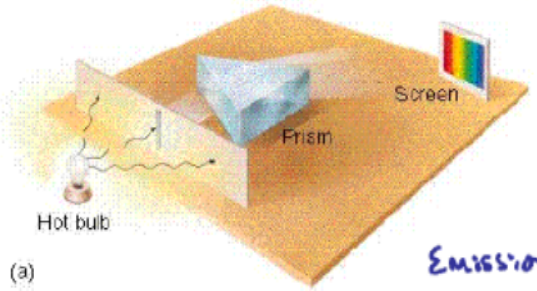
CAN split light to study as a function of frequency (ν) [or color]

Spectrum



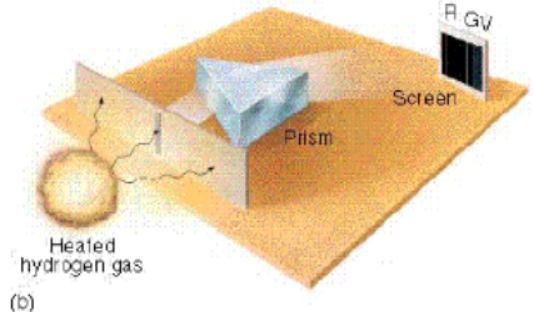
Spectroscope
Spectroscopy

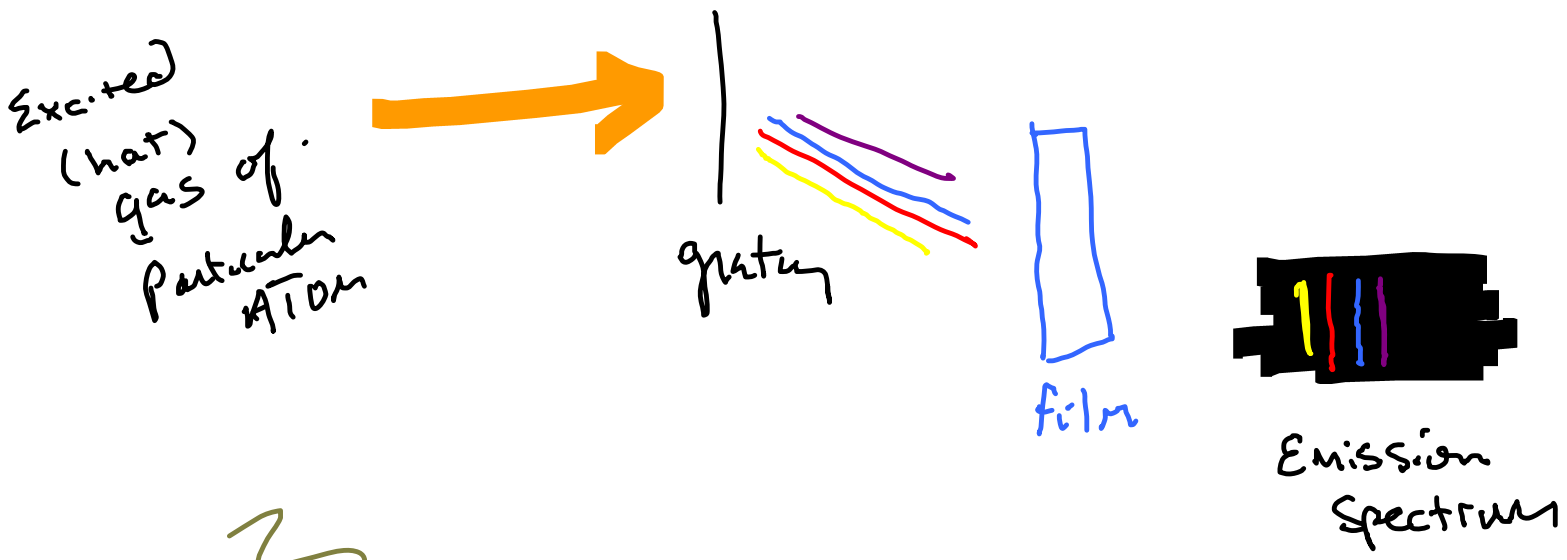
Light from Many Atoms
⇒ Continuous ν



Emission Spectrum

Light from specific atoms
⇒ discrete ν

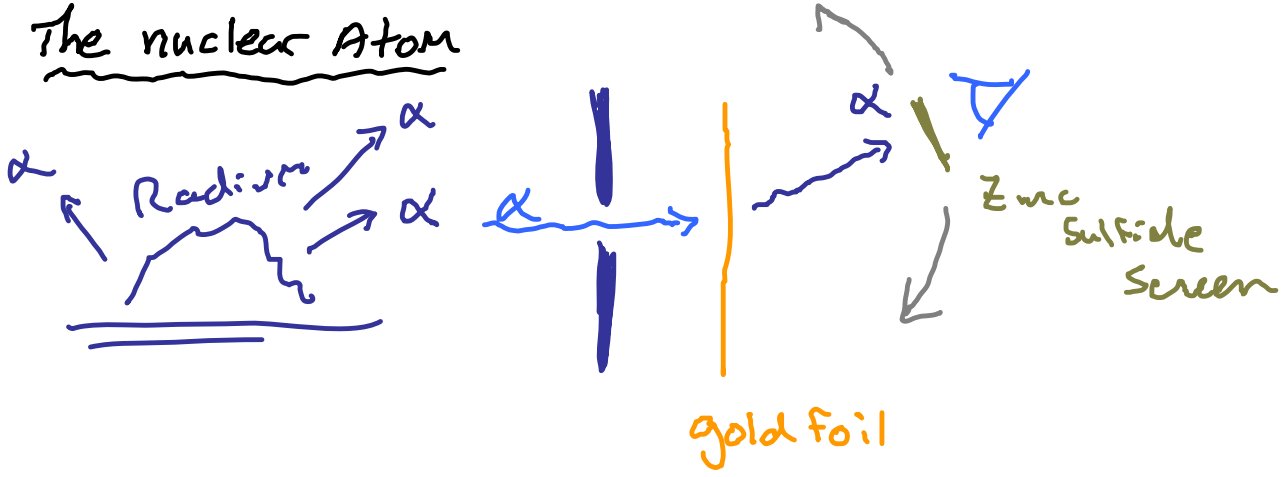


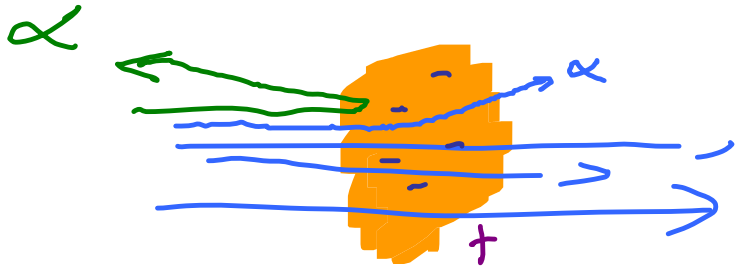

Excited (hot) gas of particular ATOM
grating
film
Emission Spectrum


STAR
cold gas of atom

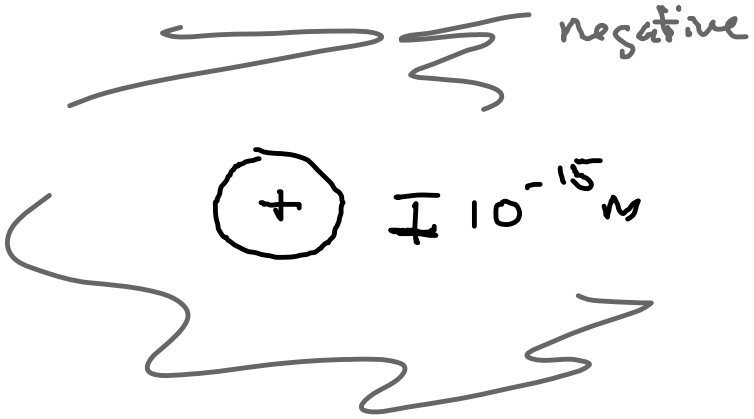
Ernest Rutherford
(1871 - 1937)
Nobel Prize in chemistry - 1908

The nuclear Atom





plum pudding model

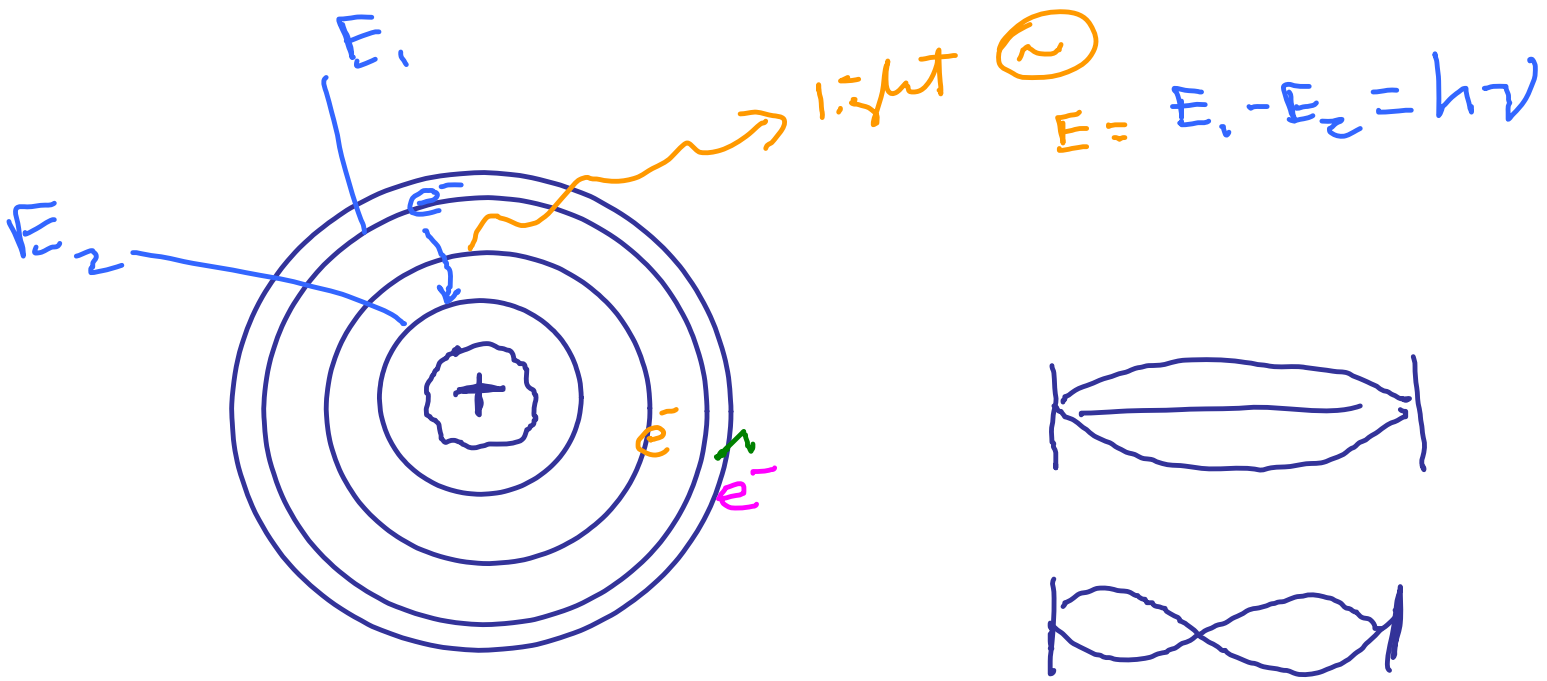

negative
+
10^{-15} m

Niels Bohr
(1885 - 1962) (Denmark)

1922 Nobel Prize in Physics

Atomic (planetary) model with fixed orbits

nicely motivated by de Broglie's matter waves in 1924


E1
E2
e⁻
light
E = E1 - E2 = hν
e⁻
e⁻