Photoelectric Effect

- Shining light on metal causes electrons to be Ejected

- Kinetic energy of ejected electrons does not increase when the intensity of light increases. [Contrary to classical physics]

- No electrons ejected unless light's frequency exceeds a certain value (that depends on the particular metal)

- Kinetic energy of ejected electrons increases with frequency of incident light [Contrary to classical physics]

Explanation requires Quantum Physics (Einstein)

- Assume that electrons cannot be ejected unless they receive an energy that exceeds some value ϕ (that depends on the metal) [ϕ is called the "Work Function"]

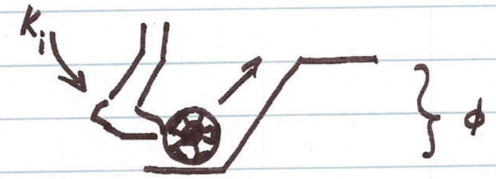
- Assume that light consists of particles with energy $E = hf$ (f = frequency, h = Planck's constant)

- Assume that electron can only absorb 100% of the energy of a particle of light (photon)

Then kinetic energy of emitted electron is

$$\frac{1}{2}mv^2 = hf - \phi$$

↳ What is observed experimentally. (Nobel → Einstein)

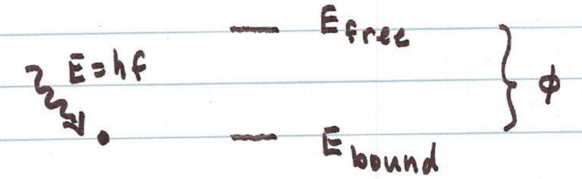


$K_f = K_i - \phi$

K_i = kinetic energy imparted to soccer ball

ϕ = potential energy needed to clear ramp

K_f = final kinetic energ of soccer ball (after it clears ramp)



$K_f = hf - \phi$

Electron receive "Kick" of energy hf from photon with frequency f.

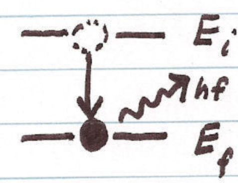
Line Spectra

- Send a current through a container filled with a gas (e.g. Hydrogen).
- Gas glows
- Pass light through a prism or diffraction grating
- Get "line spectrum" — a discrete spectrum (as opposed to the continuous "rainbow" spectrum of white light), i.e. only certain colors (frequencies) present in spectrum

Bohr Atom

- An attempt to explain line spectra
- Assumes that atoms have discrete energy levels
- Assumes that frequency of photon emitted by atom is given by

$$hf = E_i - E_f$$



- Assumes circular orbits

- Assumes quantized angular momentum

$$L = r \times p = rp = rmv = n\frac{h}{2\pi} \qquad n = 1, 2, \ldots$$

- From above assumes can conclude

1) Atom has discrete orbital radii for electrons

$$r_n = \frac{\epsilon_0 h^2}{\pi m_e e^2} n^2 \qquad n = 1, 2, \ldots$$

2) Atom has discrete energy levels

$$E_n = -\frac{1}{\epsilon_0^2} \frac{m_e e^4}{8h^2} \frac{1}{n^2} \qquad n = 1, 2, \ldots$$

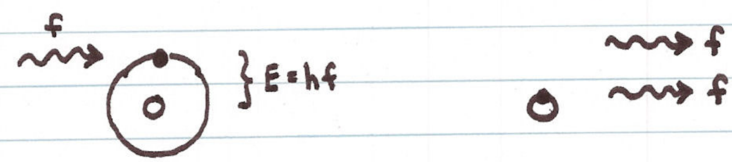
3) $E_n = hf_n$ or $f_n = \frac{E_n}{h}$ gives observed spectral lines for hydrogen

- Problems
  - only works for hydrogen atom
  - Cannot explain fine structure in hydrogen spectrum

LASER

- Light Amplification by Stimulated Emission of Radiation

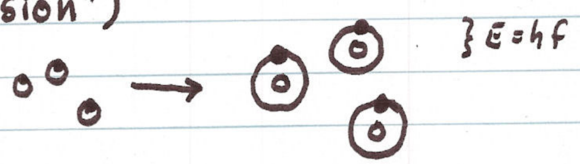
- Principle: when a photon of frequency f hits an electron ~~state~~ in an energy state $E = hf$ above its groundstate, electron emits a "clone" of incident photon



Cloned photon has same frequency, phase, direction of incident photon

To create beam:

1) Excite atoms (so that many more atoms are excited than in ground state – "population inversion")



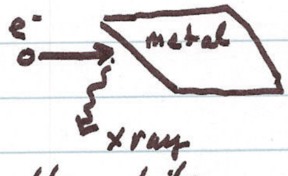
2) Send in light of frequency f (just a few photons)

3) Photons get cloned. Clones get cloned etc

4) Resulting radiation has same frequency, phase, direction

coherent – having same frequency, phase and direction

Lasers used in eye surgery, micro cauterization, tumor destruction.



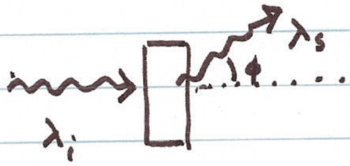
X-Ray Production

- Accelerate electrons and have them hit the surface of a metal
- When electrons loose kinetic energy, they emit x-rays
- Inverse of photoelectric effect: electro kinetic energy converted into e-m radiation.

Compton Scattering

- Wave length of scattered x-ray depends on angle at which it's scattered

$$\lambda_{Scatter} - \lambda_{initial} = \frac{h}{m_e c}(1 - \cos\phi)$$



- X-rays scattered by electrons in matter
- Can be derived from energy and momentum conservation with assumption $p = \frac{h}{\lambda}$

De Broglie Wavelength

- According to quantum mechanics (Schrödinger eq.) particles behave like waves with wavelength λ given by

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

where p is the momentum of the particle

- So particles can be diffracted (shown by Davisson & Germer) just like light (electron microscope)