Wave paticle duality 波粒二象性

- light is ...

Wave
- principals
  - Huygen's : diffraction
  - superposition } interference
    - grating
    - standing wave
- basic of motion
  - phase
  - propagation
    - reflection 反: PE detection
    - refraction 折 → 全反射
  - oscillation : polarization

$E = hf$ $\quad \lambda = \frac{h}{p}$

particle → discrete of energy
- photon
- free e in metal → photon electric effect
- atomic electron in gas

- Quantization (仅适用于光子)

The fundamental minimum step in energy which is very small.

$$E = hf$$

↑ 仅限于光子的能量

h (Planck's constant) $= 6.63 \times 10^{-34}\ J_m$

f : frequency of photon (光子)

- electrons are ...

  - waves
    - diffraction
      - 双缝实验 > 有确向的分布
  - particles: ionization (fixed mass and charge are removed)

- De Brogile equation (适用于所有)

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

λ: 电子波长

p(粒子的动量) $= mv$

- 补充

$$\text{potential difference} = \frac{\Delta E_{电子} / W_{电子}}{\text{charge}} \qquad 1V = \frac{1J}{1C}$$

- Radiation intensity

def. intensity: the amount of energy landing on unit area in a unit time.

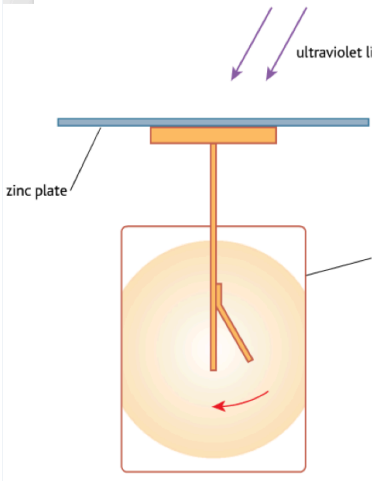
$$I = \frac{P}{A} = \frac{E}{At}$$

unit: Ws^{-1}

(若斜着入射, 求垂直分量)

Photoelectron effect 光电效应

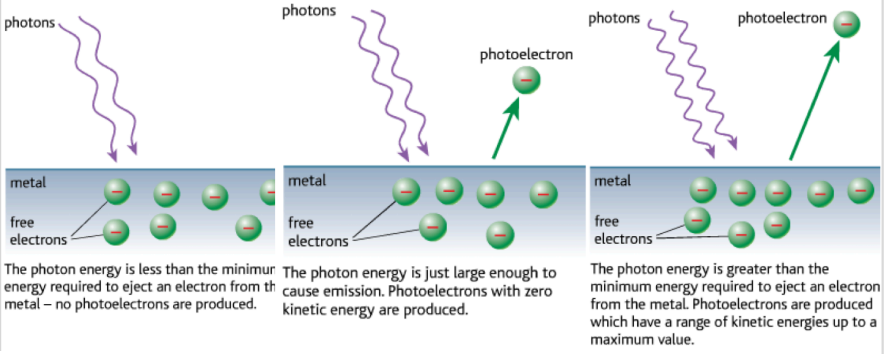
def.



Electrons which absorb the energy of atoms and emit out.

原理:

Explanation: When light strike the surface of the metal, a photon may strike a electron. The electron will absorb the photon (energy package), and it may now have sufficient energy to escape from the metal.



实验:

1. No light, leaf falls shower;
   ---- charge leaking through air.
2. The fall is stopped if glass is placed between zine plate and UV lamp;
   ----- glass absorb UV light.
3. The closer the lamp, the rapid the fall;
   ----- number of photoelectrons← intensity
4. Visible light, no effect;
   ----- threshold frequency
5. Positive charged, no effect;
   ----- UV can't transfer electrons to plate.

Einstein's photoelectric equation

- free electron
- $\Delta E(\phi)$: (work function) minimum energy require to emit electrons

f: threshold frequency $f_{光} \leq f_{金属}$ (threshold)

$\Delta E = hf$

h: plank constant

→ 光子数

波的粒子

波的能量是量子化的 (能量存在的最小单元)

- quantization : $E_0 = hf$

free electron

$E_0 < \phi$: electron doesn't absorb photon energy

$E_0 \geq \phi$: one electron absorb one photon (说明电子质点量子化)

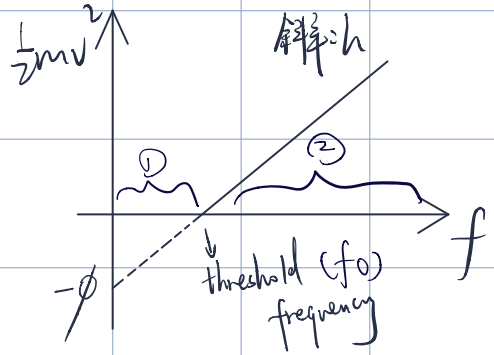
photoelectron emitted

$(hf = \phi + KE)$, $KE = \frac{1}{2}mv^2$

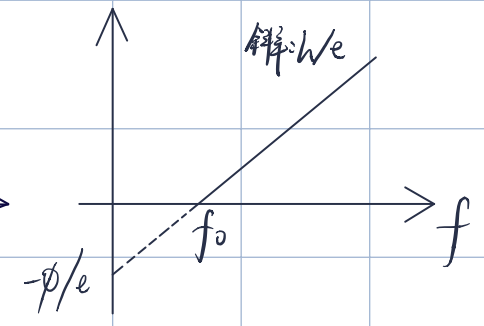
- $hf = \phi + \frac{1}{2}mv^2$ (photon energy ↑, work function ↑, 最大动能 ↑ 与光强无关)

① 光强再大也不会有光电效应 因为能量太小

② 没有电压也有光电流，光子会运动，形成电流



$hf = \phi + eV_{stop}$



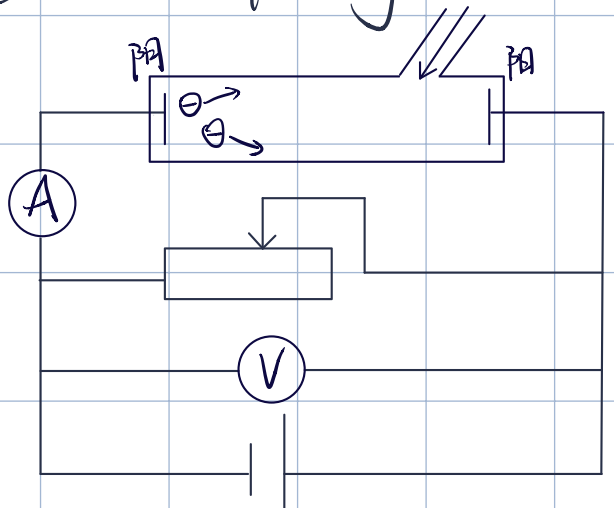
- 一定光强↑ → 光子数↑ → 照射金属产生的光子多 → 饱合电流大

↳ 仅影响光子总数. X单个光子能量

Electron volt (eV)

Def. the energy transferred when an electron travels through a potential difference of 1 volt

$1eV = 1.6 \times 10^{-19} J$



与e运动反向加电压，可使光子运动减速

反向电压=V_{stop}时，光子不再运动

(电流 →)

KE → 电势能

$(\Delta V = \frac{\Delta E}{q})$

$eV_{stopping} = \frac{1}{2} m v_{max}^2$

光子的能量 → $hf = \phi + eV_{stop}$

(ϕ 条件 > ϕ)

↑ 低于最小数字f，无法光电效应

↑ 光子最大初动能

f↑ $\xrightarrow{E_{光子}=hf}$ $E_{光子}$↑ → $KE_{光子}$↑ → V_{stop}↑

I↑(光强) → f↑(光电流) → I光电↑

粒子/波动说

particle 能量非连续

one to one 存在最大值KE

wave 能量连续

energy build up (积累) KE won't limited

EXERCISE

What are the observations of photoelectric effect? Use particle theory or/and wave theory to explain these observations?

Answer:

Observations:

1. Minimum frequency for electron emission/ threshold frequency
2. Number of electrons emitted depends on intensity, not the frequency
3. Maximum electron kinetic energy/stopping potential depends on frequency, not the intensity
4. Emission of electrons is instantaneous, no delay.

Particle nature:
Energy is quantized/ packets of energy/energy of photon = hf

Wave nature:
Energy supply is continuous/can be build up (accumulated).

Observation 1: Minimum frequency for electron emission
Particle theory:

- One electron absorbs one photon
- Energy of photons increases with frequency ($E = hf$)
- Electron release needs a minimum amount of energy --- work function

Wave theory:

- If given enough time/enough intensity, electrons eventually released (which doesn't happen)

Observation 2: Electron emission starts at once (even for low intensity)
Particle theory:

- If photon energy >= work function, electron emit; otherwise not.
- One photon releases one electron

Wave theory:

- Wave theory allows energy to build up, so low intensity needs long time to emit electrons (which doesn't happen)

Observation 3: Increasing the intensity increases the number of electrons emitted(per sec)
Particle theory:

- One photon releases one electron
- Intensity determines rate of photons

Wave theory:

- Higher intensity would provide more energy to release more electrons

Observation 4: Increasing intensity does not increase the KE of electrons
Particle theory:

- One photon releases one electron
- Energy of photons depends on frequency ($E = hf$), not intensity
- $\frac{1}{2} mv^2_{max} = hf - \varphi$, φ is smallest energy required for electron emitted which is a constant

Wave theory:

- Higher intensity provide more energy, so greater KE of electrons (which doesn't happen)

Observation 5: Increasing frequency increases KE/V_{stop}
Particle theory:

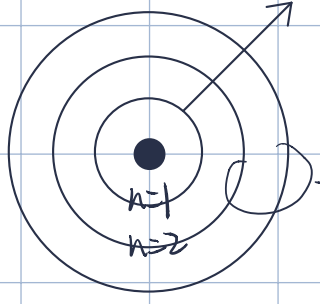
- One photon releases one electron
- Energy of photons increases with frequency ($E = hf$)
- $\frac{1}{2} mv^2_{max} = hf - \varphi$, φ is smallest energy required for electron emitted

Wave theory:

- Energy will not affected by frequency, so no effect (which doesn't)

Atomic electron energy

- Spectron
  - emission spectrum
    - line spectra 线性光谱
    - continuous spectra 频率连续
  - absorption spectrum (特定频率波吸收)



→ ground state 基态

→ 激发 excited state

- excited 诱发 诱因 absorb photon 电场做功
- de-excited 自发 emit photon

- atomic electron energy for free atoms 原子电子能量

electron only occupy certain discrete energy levels

① every orbit has its own energy levels

the closer to the nuclear, the lower the energy

② each element has its unique energy levels

③ energy level : specific . discrete