Compton & P.E.E

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★ 1905 Photoelectric Effect : Light particle = PHOTON

- Photoelectric effect depended on freq of incident light not intensity.
- for a fixed freq(ν), intensity of light changed the no. of photoelectrons emitted

Energy of photon := $\boxed{h\nu = \frac{hc}{\lambda} \quad (E)}$

Momentum of photon := $\boxed{\frac{h\nu}{c} = \frac{h}{\lambda} = \hbar k \quad (p)}$

{photons are particles of light $\Rightarrow$ they have a momentum.}

★ P.E.E. : $h\nu = KE + \phi$ ↳ work function of metal $\phi = h\nu_0$ ↑ Threshold freq

$\therefore \boxed{KE = h\nu - h\nu_0}$

↳ kinetic En of released electron

★ Special relativity :

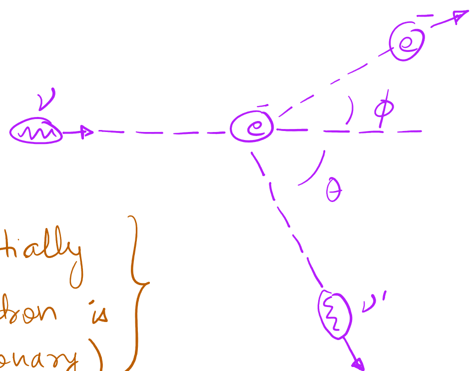
Energy of a particle of mass m : $\boxed{E^2 = p^2c^2 + m^2c^4}$ (p: linear momentum)

m ↓ so called "rest mass"

mc^2 = Mass Energy

COMPTON X-rays scattered by electrons :

Apply momentum & Energy Conservation :



$\boxed{\vec{P}_{e'} + \vec{P}_{\nu'} = \vec{P}_{\nu}}$ — ①

$\vec{P}_{e'}$: Momt of e^- → Momt of scattered e^-

$\vec{P}_{\nu}$: Momt of incident e^-

{ $\vec{P}_e = 0$ (initially the electron is stationary) }

$\boxed{E_{\nu'} + E_{e'} = E_{\nu} + E_e}$ — ②

$h\nu = \frac{hc}{\lambda}$ & $h\nu' = \frac{hc}{\lambda'}$

m_e = Mass of electron.

★ Expanding & Solving ① & ②

$\vec{P}_{e'}^{\,2} = (\vec{P}_{\nu} - \vec{P}_{\nu'})^2$ (squaring vec $\Rightarrow$ dot product)

$$\Rightarrow \quad (p_e c)^2 = c^2\left(p_\nu^2 + p_{\nu'}^2 - 2p_\nu p_{\nu'}\cos\theta\right) = h^2\left(\nu^2 + \nu'^2 - 2\nu\nu'\cos\theta\right) \quad \text{— (a)}$$

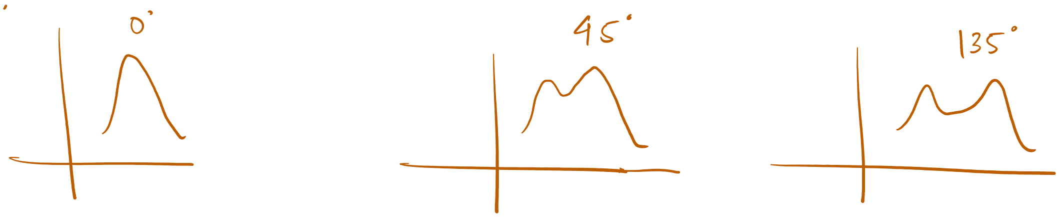
$$h(\nu - \nu') = \sqrt{m_e^2 c^4 + (p_{e'} c)^2} - m_e c^2 \qquad \{\text{substitute (a)}\}$$

$$\Rightarrow \quad \boxed{\lambda' - \lambda = \left(\frac{h}{m_e c}\right)(1 - \cos\theta)}$$

→ one of the 1st proofs of particle nature of Light. COLLISION OF LIGHT PARTICLES

$$\frac{h}{m_e c} = \lambda_c \equiv \text{Compton wavelength} \simeq 2.43\ \text{pm}$$

Graphs:



one peak at λ' due to Compton & one at λ due to tightly bound electrons.

X-rays are used because $\lambda \sim 10 - 1000$ pm $\Rightarrow \dfrac{\Delta\lambda}{\lambda_{xray}}$ is Measurable