COMPTON EFFECT

Lecture2

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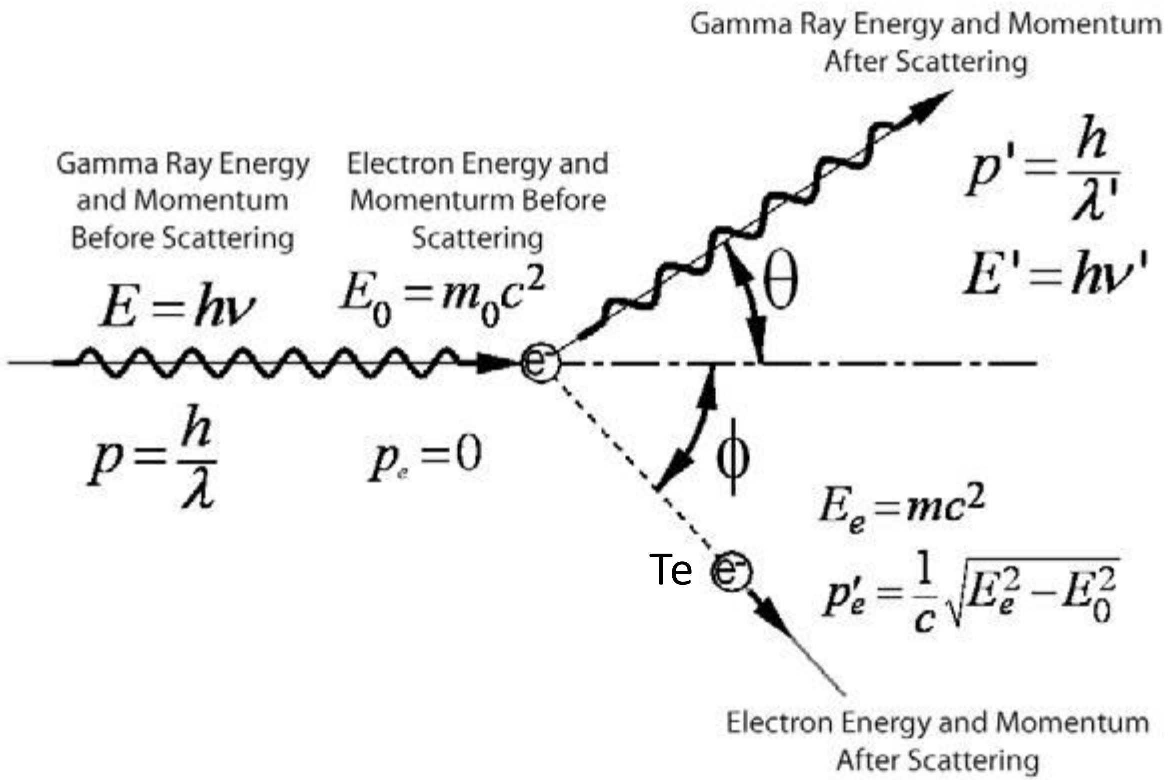
Compton effect:

When light falls on an electron ,then under the action of the electric field of the radiation the electron starts to oscillate. The oscillation frequency of the electron is same as to the frequency of the incident radiation. Then electron emits radiation of same frequency as that of the incident radiation.

But when high frequency radiation like X ray falls on an electron the scattered radiation consists of longer wavelength along with the original incident wavelength. This phenomenon cannot be explained with the help of classical theory. Later on, this was successfully explained by Compton on the basis of quantum concept and is known as Compton effect.



P= P'cosΘ + Pe'cosΦ

0= P'sinΘ + Pe' sinΦ

Let us consider an electron at rest with rest mass m_0. When a photon of energy E and momentum P incident on the electron at rest it gives some energy to the electron and scattered through an angle Ө with energy E‘ and momentum P‘. The electron recoils with energy Te and momentum P‘e, making an angle Φ with the incident radiation.

Now considering the collision to be elastic and applying the law of conservation of momentum and energy we can write

$$P= P' \cos\Theta + P_e' \cos\Phi \quad \text{......................1(a)}$$

$$0= P' \sin\Theta + P_e' \sin\Phi \quad \text{........................1(b)}$$

And $E= E' + T_e$ ....(2)

From equation (1)we get

$$Pe' \cos\Phi = P - P \cos\Theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3(a)$$

$$Pe' \sin\Phi = P' \sin\Theta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3(b)$$

Squaring and adding the above two equations we get

$$Pe'^2 = P^2 + P' - 2PP' \cos\Theta \quad \ldots\ldots\ldots\ldots\ldots (4)$$

From equation (2)we get

$$Te/c = E/c - E'/c = P - P' \quad \ldots\ldots\ldots (5)$$

here $E = m_o c^2$ & $E' = mc^2$

here $E/c = P$ and $E'/c = P'$

$P = m_o c$ & $P' = mc$

$$Te^2/c^2 = (P - P')^2$$

$$= P^2 + P'^2 - 2PP' \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Subtracting equation 6 from 4 we get

$$Pe^2 - Te^2/c^2 = 2PP'(1 - \cos\Theta) \ldots\ldots\ldots\ldots\ldots (7)$$

We know that the relativistic energy momentum relation for an electron is

$$Ee^2=C^2Pe^2 + m_o^2c^4 \quad m_o\text{--rest mass of the electron}$$

$$(Te + m_oc^2)^2= C^2Pe^2 + m_o^2c^4$$

$$Te^2/c^2 + 2Tem_o= Pe^2$$

$$Pe^2- Te^2/c^2= 2Tem_o$$

$$= 2m_o(P-P')c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Equating (6)& (7) we get

$$2m_o(P-P')c = 2PP'(1-\cos\Theta) \quad \text{here } P= hf/c =h/\lambda$$

$$1/P' -1/p = 1/m_oc\,(1- \cos\Theta) \quad \text{and } P'= hf'/c =h/\lambda'$$

$$\lambda' - \lambda= h/m_oc\,(1- \cos\Theta)$$

$$\Delta\lambda=2h/ m_oc\,(1- \cos\Theta)$$

$$=(2h/ m_oc).\sin^2\Theta/2 \quad \ldots\ldots(8)$$

Equation (8) shows that change in wavelength $\Delta\lambda$ is independent of the incident wavelength but depends on the value of scattering angle Θ. As Θ varies from 0 to л , $\Delta\lambda$ varies from 0 to $2h/m_o c$. When the photon scattered with л/2 then $\Delta\lambda = h/m_o c$. This shift in wavelength is called as Compton wavelength and is denoted by λc.

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