COMPTON EFFECT

Aim: 1) To measure shift in wavelength due to Compton effect

2) To verify the dual nature of light particles (photons)

Appratus: Use virtual lab.

Theory: In his 1923 experiment, Compton provided the most conclusive confirmation of the particle aspect of radiation. By scattering X-rays off free electrons, he found that the wavelength of the scattered radiation is larger than the wavelength of the incident radiation. This can be explained only by assuming that the X-ray photons behave like particles.

At issue here is to study how X-rays scatter off free electrons. According to classical physics, the incident and scattered radiation should have the same wavelength. This can be viewed as follows. Classically, since the energy of the X-ray radiation is too high to be absorbed by a free electron, the incident X-ray would then provide an oscillatory electric field which sets the electron into oscillatory motion, hence making it radiate light with the same wavelength but with an intensity I that depends on the intensity of the incident radiation I_0 (i.e., $I \propto I_0$). Neither of these two predictions of classical physics is compatible with experiment. The experimental findings of Compton reveal that the wavelength of the scattered X-radiation *increases* by an amount $\Delta\lambda$, called the wavelength shift, and that $\Delta\lambda$ depends not on the intensity of the incident radiation, but only on the scattering angle.

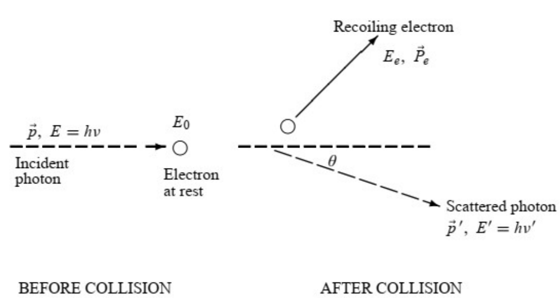

Fig.1 The Compton effect.

Compton succeeded in explaining his experimental results only after treating the incident radiation as a stream of particles—photons—colliding *elastically* with individual electrons. In this scattering process, which can be illustrated by the elastic scattering of a photon from a free electron (Fig. 1), the laws of elastic collisions can be invoked, notably the *conservation* of energy and momentum.

Consider that the incident photon, of energy $E = h\nu$ and momentum $p = E/c$, collides with an electron that is initially at rest. If the photon scatters with a momentum p' at an angle θ with energy $E' = h\nu'$, while the electron recoils with a momentum P_e and Energy E_e, the conservation of linear momentum and energy yields

$$\vec{p} = \vec{P}_e + \vec{p}\,'$$

$$\vec{P}_e^2 = (\vec{p} - \vec{p}\,')^2 = p^2 + p'^2 - 2pp'\cos\theta = \frac{h^2}{c^2}\left(\nu^2 + \nu'^2 - 2\nu\nu'\cos\theta\right)$$

The energies of the electron before and after the collision are given, respectively, by

$$E + E_0 = E' + E_e$$

$$h\nu + m_e c^2 = h\nu' + h\sqrt{\nu^2 + \nu'^2 - 2\nu\nu'\cos\theta + \frac{m_e^2 c^4}{h^2}} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_(A)}$$

Where, Rest mass energy and recoil energy of an electron are

$E_0 = m_e c^2$ and $E_e = \sqrt{\vec{P}_e^2 c^2 + m_e^2 c^4} = h\sqrt{\nu^2 + \nu'^2 - 2\nu\nu'\cos\theta + \frac{m_e^2 c^4}{h^2}}$

Conservation of energy From equation (A),

$$h\nu + m_e c^2 = h\nu' + h\sqrt{\nu^2 + \nu'^2 - 2\nu\nu'\cos\theta + \frac{m_e^2 c^4}{h^2}},$$

which in turn leads to

$$\nu - \nu' + \frac{m_e c^2}{h} = \sqrt{\nu^2 + \nu'^2 - 2\nu\nu'\cos\theta + \frac{m_e^2 c^4}{h^2}}.$$

Squaring both sides of (1.34) and simplifying, we end up with

$$\frac{1}{\nu'} - \frac{1}{\nu} = \frac{h}{m_e c^2}(1 - \cos\theta) = \frac{2h}{m_e c^2}\sin^2\left(\frac{\theta}{2}\right).$$

Hence the wavelength shift is given by

$$\boxed{\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta) = 2\lambda_C \sin^2\left(\frac{\theta}{2}\right),}$$

where λ_C $h = m_e c =$ 2.426 x10^{-12} m is called the Compton wavelength of the electron.

This relation, which connects the initial and final wavelengths to the scattering angle, confirms Compton's experimental observation: the wavelength shift of the X-rays depends only on the angle at which they are scattered and not on the frequency (or wavelength) of the incident photons.

In summary, the Compton effect confirms that photons behave like particles: they collide with electrons like material particles.

1. Observation Table:

	E1= 2 MeV **$\lambda 1$ =** **P1=**		E2= 4 MeV **$\lambda 2$ =** **P2=**		E3 = 6 MeV **$\lambda 3$ =** **P3=**	
θ **(degrees)**	λ'	Δλ	λ'	Δλ	λ'	Δλ
30						
60						
90						
120						
150						
180						

Conclusion: The particle nature of light particles (photons) is verified.

1.

2.

Link: https://www.geogebra.org/m/dgx8uSXJ