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Compton Effect

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Abstract:
This article is about the mechanisms of Compton scattering.

What is Compton effect?

When X-rays or gamma rays are scattered from materials, the scattered rays end up with larger wavelength than the wavelength of the incident rays.

Characteristics:

It was found that the wavelength-shift between the two rays depends purely on the angle of scattering but is totally independent of the wavelength of the initial radiation and also the nature of the scatterer.

Description of the scattering:

The process when X-rays of a certain wavelength interacts with atoms and is scattered by an angle θ, and emerge at a different wavelength which is related to θ is known as Compton effect. Although according to classical electrodynamics the wave length of scattered rays should be same as
the initial rays but experiments has found that the wavelength of scattered rays was longer.

The change in wavelength has an upper limit, i.e, X-rays of wavelength λ will scatter with a wavelength in the range λ+Δλ where Δλ has some specific upper limit.

In Compton scattering the energy of the incident light should be much higher than the energy by which the electron is bound to the atom, i.e, W(work function), (hυ>> W) in order that the electron recoils and the scattered photon of lower frequency appears.

In 1923, Compton explained the wavelength shift by attributing particle properties like momentum to light quanta(the energy of a light quanta depends only on the wavelength of light). It is assumed that each photon interacted with one electron.

Kinematics of Compton effect:

Relativistic equations are to be used for linear momentum and energy conversations.
Linear momentum of the photon before collision is h/λ and after the collision it is h/λ'. The linear momentum of the electron before the collision is zero, and after the collision is p_e.

The photon is scattered through an angle Φ and the electron is deflected through an angle θ from the line of impact. The equations corresponding to conservation of momentum and energy are:

Solving these equations we get,

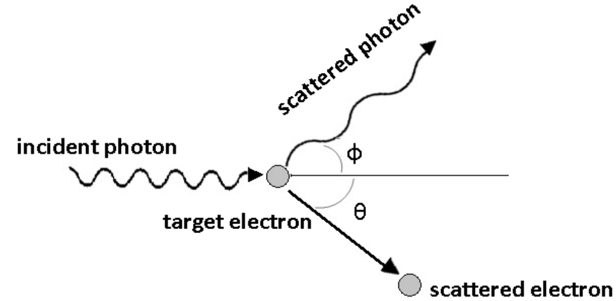
$$\frac{h}{\lambda} = \frac{h}{\lambda'}\cos\phi + p_e\cos\theta$$

$$0 = \frac{h}{\lambda'}\sin\phi - p_e\sin\theta$$

and

$$\frac{hc}{\lambda} + m_0c^2 = \frac{hc}{\lambda'} + \sqrt{m_0^2c^4 + p^2c^2}\ .$$

Δλ=λ'-λ=(h/mc)(1-cosΦ)
where,
λ is the initial wavelength,



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λ' is the wavelength after scattering,
h is plank's constant,
c is speed of light,
m is mass of electron,
Φ is the scattering angle.

The maximum value of Δλ is 2h/mc when the X-ray is observed at Φ=π , i.e, when it is scattered in the direction opposite to the incident direction. The quantity h/mc is known as the Compton wavelength of electron.

References:

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Modern atomic and nuclear physics- AB Gupta
Image: ResearchGate

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