The Compton Effect

The Compton Effect is the term used for an unusual result observed when X-rays are scattered on some materials. By classical theory, when an electromagnetic wave is scattered off atoms, the wavelength of the scattered radiation is expected to be the same as the wavelength of the incident radiation. Contrary to this prediction of classical physics, observations show that when X-rays are scattered off some materials, such as graphite, the scattered X-rays have different wavelengths from the wavelength of the incident X-rays. This classically unexplainable phenomenon was studied experimentally by Arthur H. Compton and his collaborators, and Compton gave its explanation in 1923.

The energy of photons is directly proportional to their frequency and inversely proportional to their wavelength, so lower-energy photons have lower frequencies and longer wavelengths. In the Compton effect, individual photons collide with single electrons that are free or quite loosely bound in the atoms of matter. Colliding photons transfer some of their energy and momentum to the electrons, which in turn recoil. In the instant of the collision, new photons of less energy and momentum are produced that scatter at angles the size of which depends on the amount of energy lost to the recoiling electrons.

Because of the relation between energy and wavelength, the scattered photons have a longer wavelength that also depends on the size of the angle through which the X-rays were diverted. The increase in wavelength, or Compton shift, does not depend on the wavelength of the incident photon.

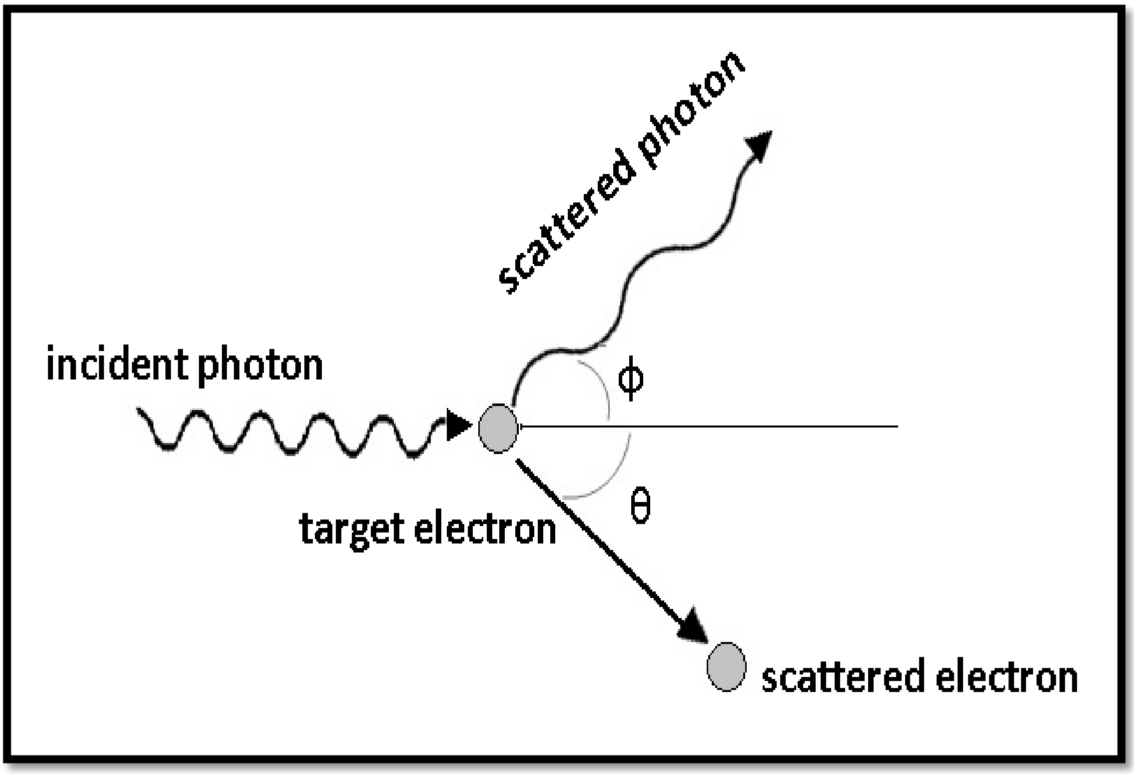

Figure 2 show the Compton effect

A photon of wavelength λ comes in from the left, collides with a target at rest, and a new photon of wavelength λ′ emerges at an angle θ.

Compton derived the relationship between the shift in wavelength and the scattering angle:

$$\lambda - \lambda' = \frac{h}{m_e c}(1 - \cos\theta)$$

where

- λ is the initial wavelength,
- λ' is the wavelength after scattering,
- h is the Planck constant,
- m_e is the electron rest mass,
- c is the speed of light, and
- θ is the scattering angle.

The quantity($\boldsymbol{h/m_e c}$) is known as the Compton wavelength of the electron; it is equal to 2.43×10^{-12} m.

The wavelength shift $\lambda' - \lambda$ is at least zero (for $\theta = 0°$) and at most twice the Compton wavelength of the electron (for $\theta = 180°$).

$\lambda_c = h/m_e c$

$= 0.00243$ nm

$= 2.43$ pm

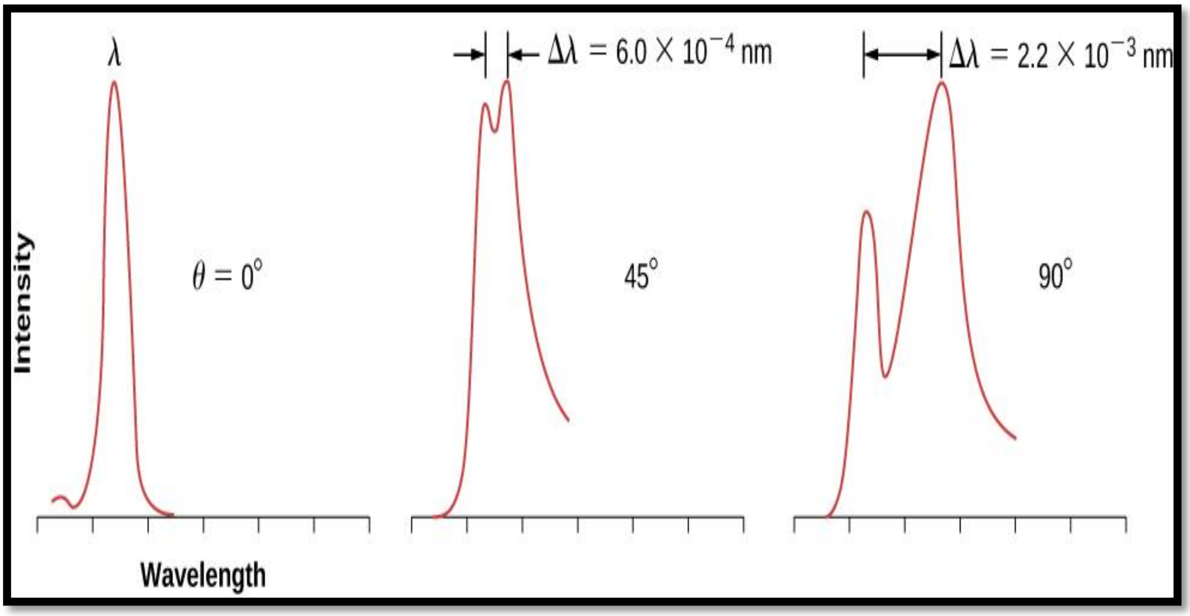

Figure 2 Experimental data show the Compton effect for X-rays scattering off graphite at various angles: The intensity of the scattered beam has two peaks. One peak appears at the wavelength λλ of the incident radiation and the second peak appears at wavelength λ'.λ′. The separation ΔλΔλ between the peaks depends on the scattering angle θ

Q/ Calculate the Compton wavelength for

a- An electron
b- A proton

What is the photon energy for an electromagnetic wave with a wavelength equal to Compton wavelength of

c- the electron

d- the proton