The Compton Effect

Arthur H. Compton discovered that when a beam of X-rays is scattered from a target, the wavelengths of the scattered X-rays are slightly greater than the wavelength of incident beam. Figure 1 shows the experimental arrangement Compton used to observe this Compton effect. A beam of X-rays of wavelength λ_0 falls on a carbon (graphite) target. Compton observed the X-rays that were scattered at various angles θ to the incident beam and measured the intensity and the wavelength of the scattered rays at several of these angles.

Figure 2 shows his experimental results for four different values of θ. From the figure, we see that although the incident beam consists essentially of a single wavelength λ_0, the scattered X-rays have intensity peaks at two wavelengths. One of them (λ_0) is the same as the incident wavelength, but the other (λ) is larger by an amount $\Delta\lambda$. This Compton shift $\Delta\lambda$ varies with the angle θ at which the scattered X-rays are observed.

Compton shift $\Delta\lambda = \lambda - \lambda_0 = \dfrac{h}{m_e c}(1-\cos\theta)$

where m_e is the mass of the electron. This expression is known as the **Compton shift equation.**

The unshifted peak at λ_0 in Figure 2 is caused by X-rays scattered from electrons tightly bound to the target atoms. This unshifted peak also is predicted from the above Compton shift equation, as if the bound electron mass is replaced with the mass of a carbon atom, which is approximately 23 000 times the mass of the electron. Therefore, there is a wavelength shift for scattering from an electron bound to an atom, but it is so small that it was undetectable in Compton's experiment.

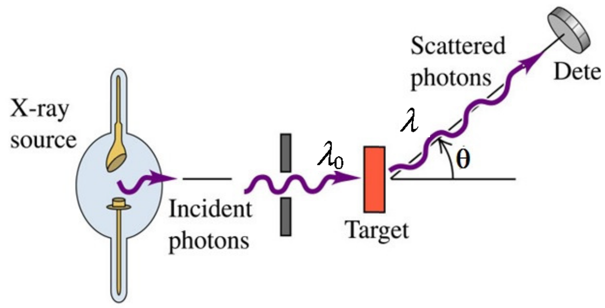

Figure 1. The experimental setup used for observing the Compton effect. The detector, which can be set to any desired angle θ, measure the intensity and the wavelength of the scattered X-rays.

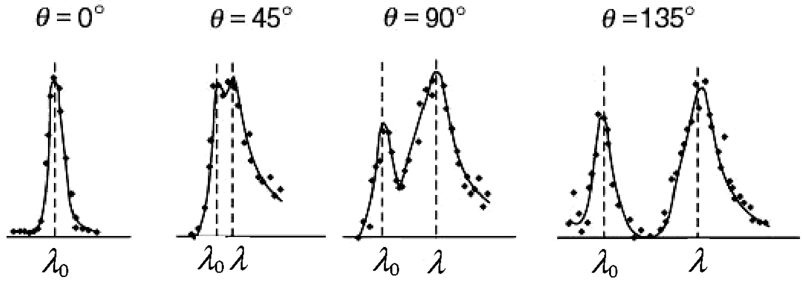

Figure 2. Compton experimental results for four different values of the scattering angle θ. The peak at λ_0 is due to the scattering of the incident radiation from the tightly bound inner electrons of the atom. The second peak represents the radiation scattered from the loosely bound, nearly free outer electrons.