# Teacher notes
# Topic E

## The Compton effect

A photon of wavelength $\lambda$ scatters at angle $\theta$ off an electron at rest and bounces off with a longer wavelength $\lambda'$. The electron recoils with kinetic energy. The Compton formula

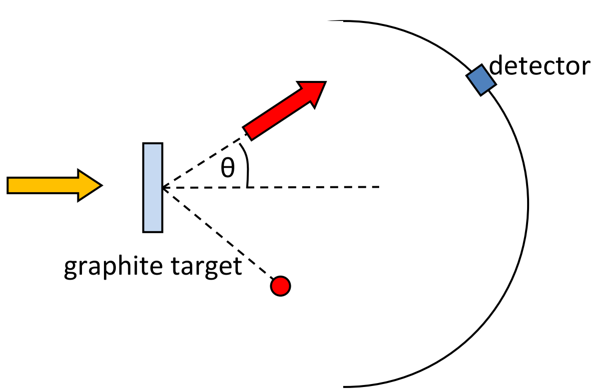
$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

is derived by treating the scattering as a 2-dimensional collision of two particles and applying the laws of energy and momentum conservation. This is a very strong piece of evidence for the particle nature of light, stronger than that provided by the photoelectric effect alone. Treating light as waves scattering off electrons (called Thomson scattering) does not result in a wavelength shift for the photon (at low light intensity). Hence the observed shift at low light intensities is very clear evidence for light as particles.

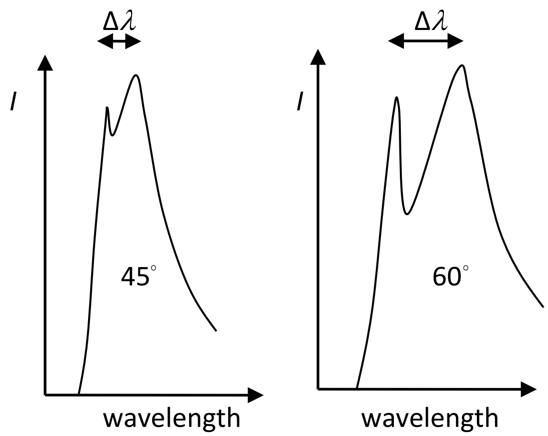
The Compton formula is interesting in that it involves the speed of light *c*, so the effect is relativistic. It also involves the Planck constant *h* so it is a quantum effect.

Notice that wavelength shift $\lambda' - \lambda$ is independent of $\lambda$.

The largest shift is obtained when $\theta = \pi$ in which case $\lambda' - \lambda = \frac{2h}{mc}$. However, only a very small fraction (less than 5%) of the incident photon beam will back scatter at $\theta = \pi$, most photons will go straight through the target material. Electrons inside the target material (graphite for example) are loosely bound to the atoms so they are essentially free.



The detector measures the intensity *I* (i.e. number of photons observed at each wavelength). The two peaks correspond to photons in the original beam that did not scatter off electrons or scattered off the entire atom which is heavy so did not lead to a shift in wavelength and the shifted peak is due to scattered photons. The diagram shows that the shift increases as the scattering angle increased from $45^\circ$ to $60^\circ$.




The kinetic energy transferred to the electron is $\frac{hc}{\lambda}-\frac{hc}{\lambda'}$. This is a fraction of the original photon energy of

$$\frac{\frac{hc}{\lambda}-\frac{hc}{\lambda'}}{\frac{hc}{\lambda}}=\frac{\lambda'-\lambda}{\lambda'}.$$

Quick check yourself question:

In Compton scattering the scattered photon has a wavelength that is

**A** smaller than the incident wavelength.

**B** larger than the incident wavelength.

**C** equal to the incident wavelength.

**D** larger, smaller or equal to incident wavelength depending on the scattering angle.