AL-MUSTAQBAL UNIVERSITY

COLLEGE OF SCIENCE

MEDICAL PHYSICS DEPARTMENT

FOURTH STAGE

Detection of Ionizing Radiation

Lecture Four: Interaction of Gamma-rays with matter

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Interaction of Gamma-rays with matter

The processes by which gamma rays lose their energy when they interact with matter are different from the interaction of heavy and light charged particles. The interaction of gamma rays with matter in several ways, but the most important of these methods are the photoelectric effect, Compton scattering and pair production.

- **Photoelectric effect:** The effect of the photoelectric effect is evident for photons with energy ranging from 0.5 to 0.1 MeV. In this process, the incoming photon is absorbed by one of the electrons attached to the nucleus of the atom and gives its energy, and thus the electron is released from the atom with kinetic energy, as in the equation below:

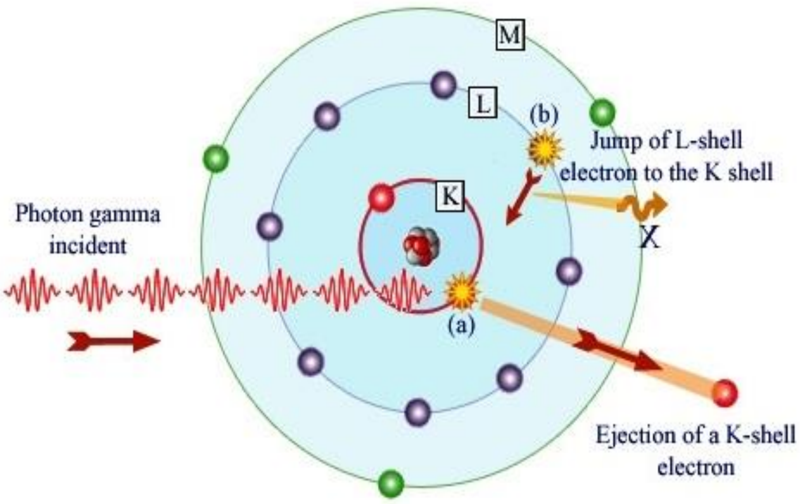
$$hv = E_B + E_K$$

Where: hv = Energy of incident photon.

E_B = Binding energy of electron.

E_K = Kinetic energy of electron.

After an electron is emitted from the atomic orbit, it leaves a hole which is filled by an electron from the outer orbits. After that, the process is accompanied by the emission of continuous x-rays, and this phenomenon is called (Auger effect).



- **Compton scattering:** The Compton scattering phenomenon is evident for photons with energy ranging from (0.1 to 10 MeV). In this process, the incident gamma rays (photons) interact with one of the outer orbital electrons of the atom, which is considered a free metaphor, and transfer part of the energy of the photon to the free electron, so it is liberated from the atom and a photon is emitted with energy less than the energy of the incident photon, and by applying the energy conservation law, we get:

$$h\nu = h\nu^{-} + E_K$$

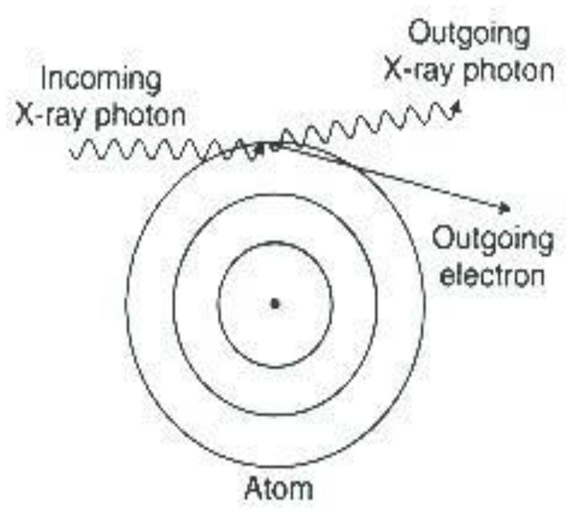
Where: $h\nu$ = Energy of incident photon.

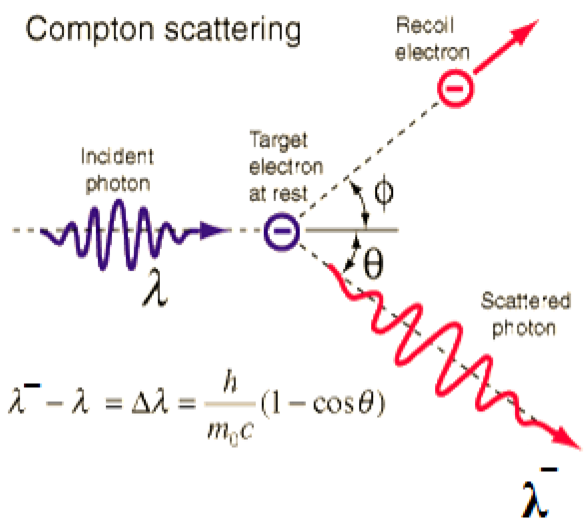
$h\nu^{-}$ = Energy of scattered photon.

E_K = Kinetic energy of electron.

The relation between the incident and scattered photon can be expressed by the equation:

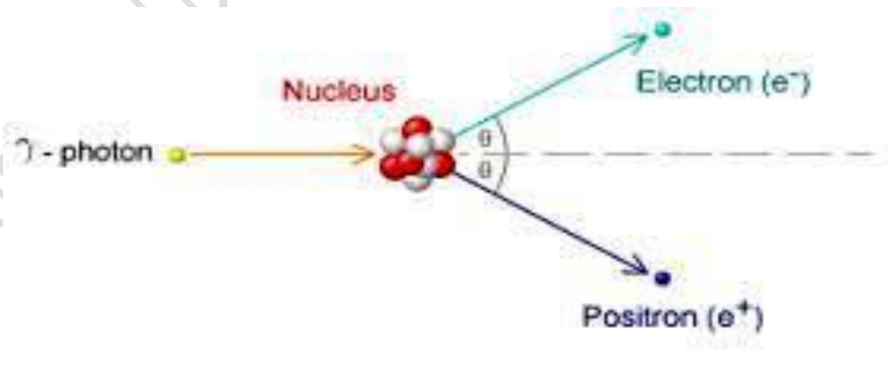
$$h\upsilon^{-} = \frac{h\upsilon}{1 + \frac{h\upsilon}{m_0 c^2}(1 - \cos\Phi)}$$





- **Pair production:** In this type of interaction, gamma rays are absorbed by matter in the production of an electron-positron pair. According to the classical concept, there is no explanation for this interaction, but according to the quantum concept, the scientist Dirac was able to provide a solution to this matter, as he assumed the existence of an electron in two energy levels, the first level with positive energy and the second with negative energy. Therefore, the values of the free electron energy were determined, so that they are either greater than or equal to $E \geq +m_0c^2$ or less than $E \leq -m_0c^2$; there is no energy for the electron between these two limits, so this region was called (Forbidden Region). If any electron present in the negative energy levels is given energy equal to or greater than 2 m_oc^2 which equals to 1.02 MeV. The electron will rise from the negative energy level to the positive energy level. The transition of the electron from the negative level to the positive level leaves a hole. This represents the positron. As for the appearance of the electron in the positive energy level, it will mean the appearance of the ordinary electron, and thus it will be a pair of particles (electron - positron). A positron is a particle that has the same properties as an electron, except that its charge is positive. The process of pair production usually takes place in the electric field of the nucleus of the atom. In this field, energy transfer to the electron and positron takes place, and thus the nucleus conserves energy as follows:

$$hv = m_{o_{e-}}C^2 + m_{o_e}C^2 + E_{K_{e-}} + E_{K_e}$$



$E_o > 2m_0c^2$, where m_0 is the electron rest mass

Examples 1: Gamma photon emitted from the cesium source ^{137}Cs, has energy 0.662 μeV, and was absorbed with the electron in the ground level of the hydrogen atom by the photoelectric interaction. Hydrogen binding energy 13.6 eV, calculate the kinetic energy of the electron?

Examples 2: Calculate the energy, frequency and wavelength of the scattered photons at an angle $\Phi = 90^{\circ}$ when the energy of the incident photons is 1.173 μeV; Calculate the kinetic energy of the outgoing electron?

Example 3: Calculate the kinetic energy of the positron resulting from the pair production interaction when the energy of the incident photon is 2.022 μeV?

Example 4: Calculate the thickness of the water layer that reduces the number of gamma photons to 80% of its original number? Where $(\mu_m)_{water} = 0.0706$ cm^2/g; $\rho = 1 g/cm^3$