# *Lecture5*

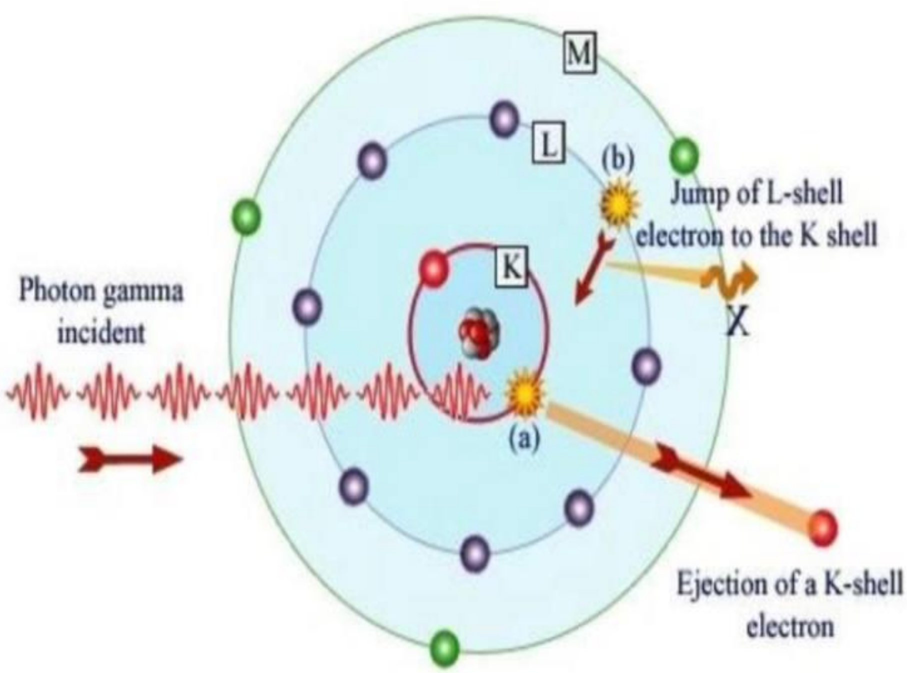
## *Interaction of Gamma-rays with Matter*

The processes that lose energy in **gamma rays** when interacting with matter **differs** 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**.

### 1. Photoelectric Effect

The photoelectric effect is clear to photons energy in the range between. **0.05 to 0.1 MeV**. In this process, the **incident photon energy** is absorbed by one of the **electrons** **bound** to the atomic **nucleus** and gives its **fully** **energy** to the **electron**, thus the electron is **released from** the atom with a **kinetic energy** as in the equation below:

$T_e = h\upsilon - I_B$, where: $T_e$= Kinetic energy, $I_B$= Binding Energy and $h\upsilon$= Photon Energy.



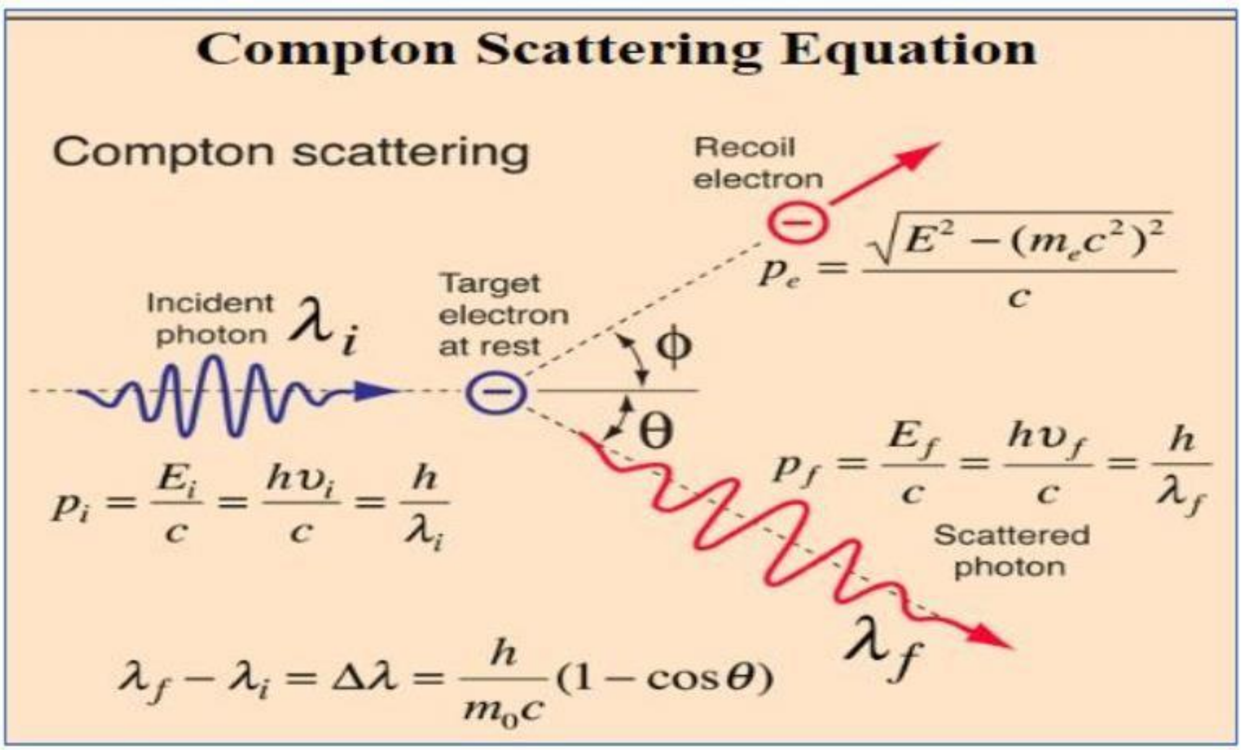
After the electron is **emitted** from the atomic orbit, its place will become **empty**, then it will be **filled** with an **electron** from the **outer orbits**, where this process is accompanied by the **emission of continuous radiation**, which is called **continuous X-ray**.

- ✓ The photoelectric phenomenon occurs only in orbits close to nucleus. **Why**?

## 2. Compton Scattering

The effect of Compton scattering is clear for **photons** with **energy** ranging from (**0.1 to 10 MeV**). In this process, the incident gamma ray (**photons**) **interacts** with one of the **outer orbital electrons** in the atom, (**free electrons**), and transfers a **portion** of the **photon energy** to these **free electrons**.

The lost energy of the incident photon is calculated by the **change** in the **wavelength** of the photon **before** and **after** the **collision** with **electrons**.



**where**:

$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

هذه المعادلة الرياضية لظاهرة كومتون توضح ان التغيير في الطول الموجي للفوتونات المتشتتة $\Delta\lambda$ يعتمد على زاوية التشتت $\theta$.

$\frac{h}{m_0 c} = 0.024$ Å *is called* ***Compton wavelength***.

Where:

$h = 6.626 * 10^{-34}\ J.s$ (Planck's constant)

$m_0 = 9.1 * 10^{-31}\ kg$ (*the rest mass of electron*)

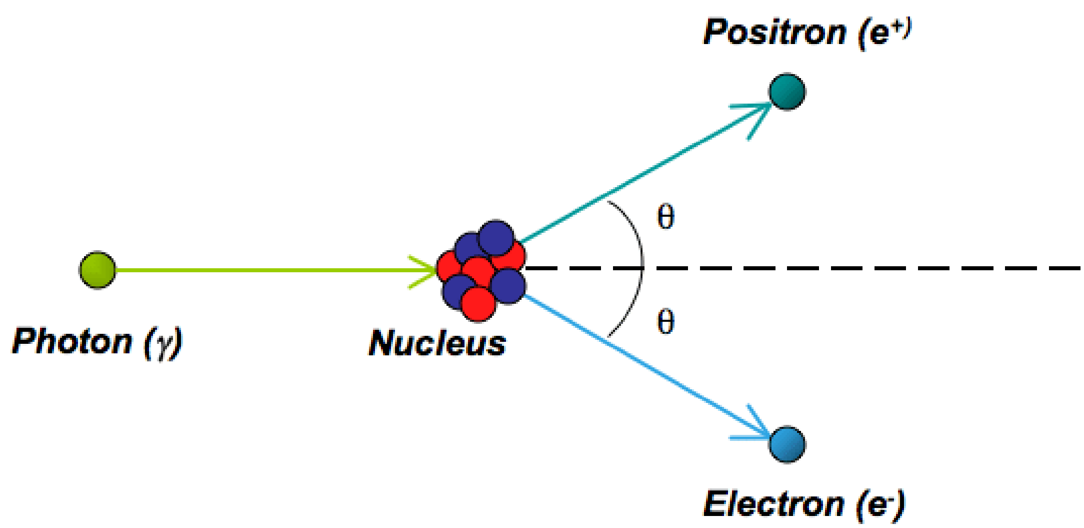
$c = 3 * 10^{8}\ {}^{m}/_{s}$ ( *the light velocity*)

***Therefore***, When

θ=0, $\Delta\lambda = 0$, θ=90, $\Delta\lambda = 0.024$Å and, θ=180, $\Delta\lambda = 0.048$Å

## 3. Pair Production

In this type of interaction, the **gamma ray** is **absorbed** by the material to **produce** an **electron**-**positron** **pair**.



The scientist Dirac was able to prove this process by assuming the existence of an electron in two energy levels, so the **value** of the **free electron energy** is **either**

$E \geq m_0c^2$ or $E \leq m_0c^2$, and there is no energy for the electron between these two levels, so this region was called **Forbidden Region**.

An electron moving from one level to another will **leave** a **hole**, and this represents the **positron**. A **positron** is a particle that has the same properties as an electron except that it has a positive charge.

The **process** of producing the pair usually **occurs** in the **electric field of the nucleus** of the atom, in this field the transfer of energy to the electron and positron occurs, and thus the nucleus **maintains** energy as follows:

$$h\upsilon = m_{0_{e^-}}c^2 + m_{0_{e^+}}c^2 + K_{e^-} + K_{e^+} + K_n$$

**Where**:

$h\nu$ is the photon energy.

$m_{0_{-e}}c^2 + m_{0_{+e}}c^2$ is rest mass of electron and positron respectively.

$K_{e^-} + K_{e^+}$ is the kinetic enery of lectron and positron respectively

$K_n$ is the kinetic enery of the nucleus.

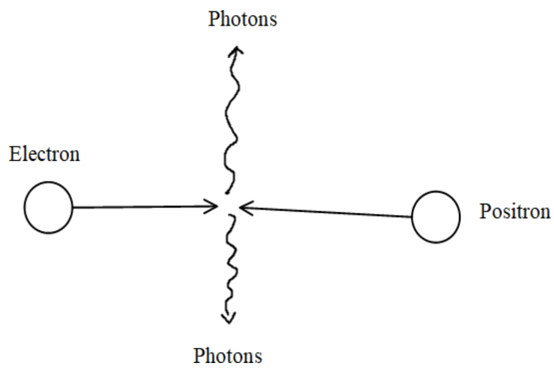
Because the **nucleus** is **heavier** than an **electron** and a **positron**, so the ***k*** ***energy*** of the nucleus is **neglected** and so, the **photon energy** becomes:

$$h\upsilon = 2m_0c^2 + K_{e^-} + K_{e^+}$$

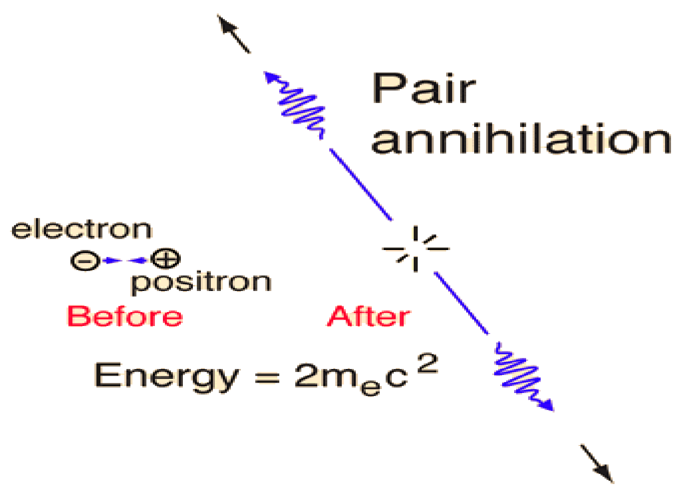
Where:

$2m_0c^2 = 1.022\ MeV$

For the **pair production** process there is an **opposite** process that may occur immediately **after** the formation of the positron in the material. This process is called the **electron - positron annihilation process**.




As the positron, after its formation, **slows down** as a result of **colliding** with **atoms** and doubles with the **electron**, which **leads to** the **annihilation** of the **positron** with the **electron**, and this process results in the production of **two photons** with an energy of **0.55 MeV** and this is called **annihilation rays**.

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