Chapter # 2

GAMMA RAYS AND ANNIHILATION PROCESS

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LEARNING OBJECTIVES

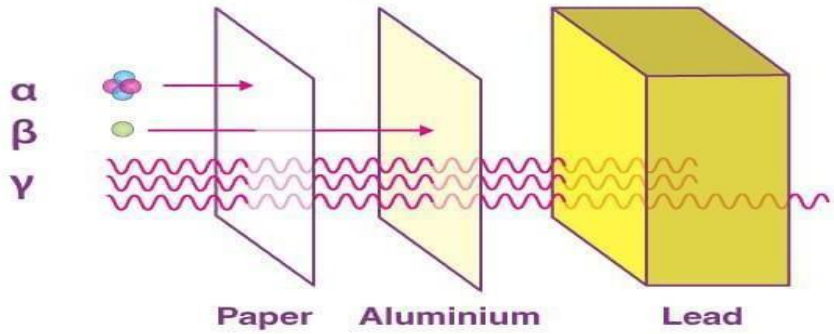
- History
- Gamma rays
- Sources
- What is annihilation event
- Matter-antimatter annihilation
- Energy release and Gamma rays emission
- Gamma rays photon from annihilation process
- Explain how these rays travel outside the body and can be detected
- Compton scattering
- Photoelectric effect
- Image creation by arrival time of gamma rays
- Creating an image from PET scanning

2.1 - History

Gamma rays, discovered in 1900 by **Paul Villard**, are a form of electromagnetic radiation produced by radioactive decay, while PET scanning, developed in the 1950s and 1960s, uses gamma rays emitted from radioactive tracers to visualize metabolic activity in the body.
Paul Villard, a French chemist and physicist, discovered gamma radiation in 1900 while studying radiation emitted from radium.

2.2 – GAMMA RAYS

- Gamma rays have the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum usually produced by radioactive decay.
- Gamma radiation is highly penetrating and interacts with matter through ionization via three processes; photoelectric effect, Compton scattering or pair production.
- Due to their **high penetration power**, the impact of gamma radiation can occur throughout a body, however they are more penetrating than other ray.



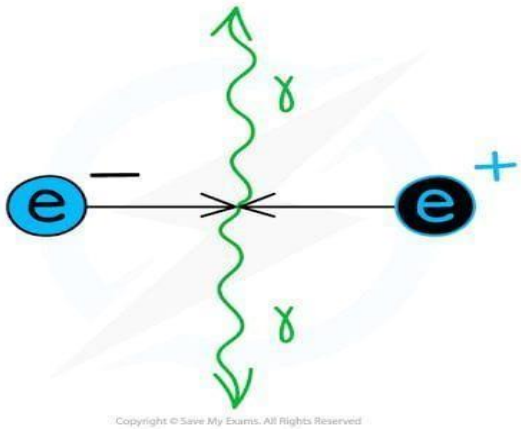
SOURCES:-

1. Natural sources as they are produced by the hottest and most energetic objects in the universe, such as neutron stars, supernova explosions, and regions around black holes.
2. On Earth, gamma waves are generated by nuclear explosions, radioactive decay and lightning also.
3. Artificial sources do include nuclear fission and fusion reactions.

2.3 – ANNIHILATION EVENTS

Annihilation

Annihilation refers to the process where a particle and its antiparticle (like a positron and an electron) collide and convert their mass entirely into energy, typically in the form of photons (gamma rays), which move in opposite direction and conserve momentum



Matter-antimatter annihilation:

When an electron, a matter particle, collides with a positron, an antimatter particle, they annihilate each other as the energy in the two particles is carried away by two real photons to conserve energy. The same phenomenon occurs as all matter annihilates an equal quantity of antimatter. In the case of charged particles like the proton and the antiproton, their opposite charges cancel .

- Common annihilation events are Electron-Positron annihilation.

Energy release and gamma-ray emission :

The annihilation peak is located at an energy value of 0.51 MeV and is the result of the absorption of one of the two 0.51-MeV gamma-ray photons following positron annihilation and 511 keV in electron- positron annihilation process.

2.4 – DETECTION OF GAMMA RAYS

Unlike optical light and x-rays, gamma rays cannot be captured and reflected by mirrors. Gamma-ray wavelengths are so short that they can pass through the space within the atoms of a detector. Gamma-ray detectors typically contain:-

Compton scattering:

- As gamma rays pass through, they collide with electrons in the crystal. This process is called Compton scattering, wherein a gamma ray strikes an electron and loses energy, similar to what happens when a cue ball strikes an eight ball. These collisions create charged particles that can be detected by the sensor

Photoelectric effect:-

- The phenomenon in which electrically charged particles are released from or within a material when it absorbs electromagnetic radiation. The effect is often defined as the ejection of electrons from a metal plate when light falls on it.

Detection of Gamma Rays Outside the Body:

Types of gamma-ray detectors are

1 . Scintillation detectors:-

These detectors use materials like sodium iodide (NaI) or lanthanum bromide (LaBr3) that emit light (scintillate) when struck by gamma rays. This light is then converted into an electrical signal using a photomultiplier tube.

2 . Photomultiplier tubes:-

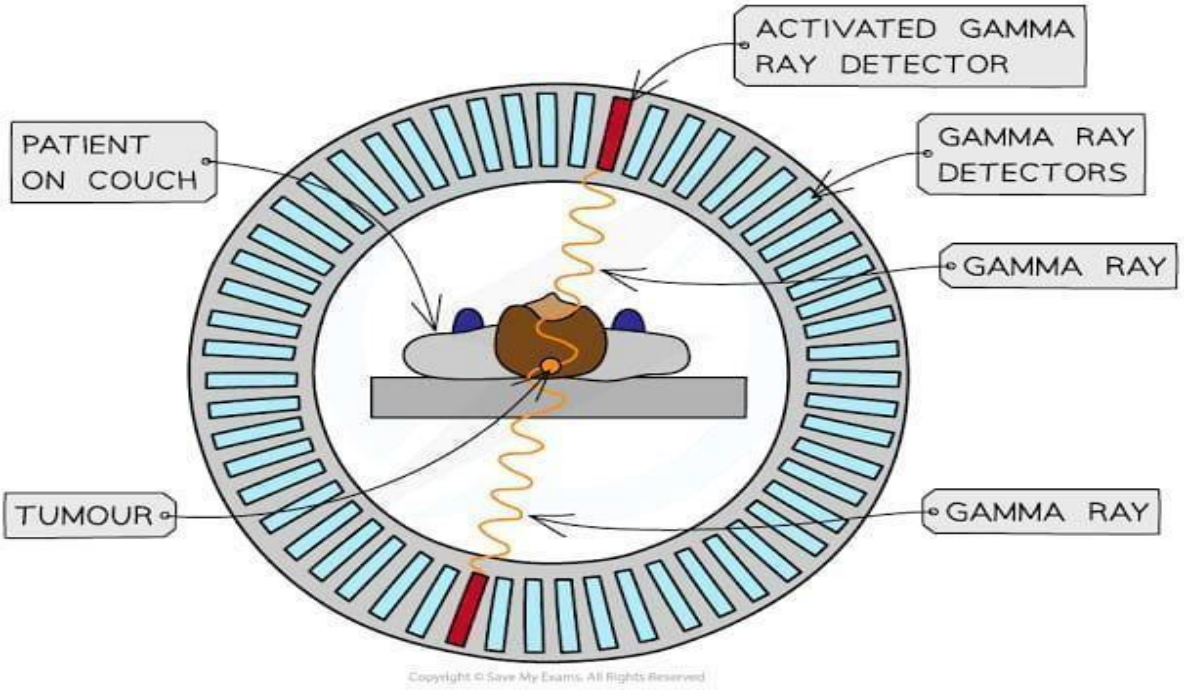
These detectors work by amplifying the electrons generated by a photocathode exposed to a photon flux.

3. Semiconductor detectors:-

A Semiconductor Detector is a device that operates by transferring electrons from the valence to the conducting band when ionizing radiation interacts with it. It is commonly made of silicon or germanium and is used for detecting radiations.

4. Pet Scanner:-

Positron imaging tomography scanning is an imaging modality primarily used in oncology. In this technique, radioactive isotopes(tracers) are used to measure various metabolic processes in body. The tracers are inhaled, swallowed or injected depending upon the sites of body examined.



Gamma camera:-

An isotope emits gamma rays that easily pass through the body to a detector outside the body. In this way, the radioactive isotope can be followed as it flows through a particular organ in the body.

Factors affecting detection:

Factors affecting detection efficiency are:-

1. Absorption of trace's particles in different body parts.
2. Scattering of it's particles.
3. Attenuation of particles in tissues of body.

2.5 – IMAGE CREATION BY ARRIVAL TIME OF GAMMA RAYS

- An image of the tracer concentration in the tissue can be created by processing the arrival time of the gamma rays photons emitted by the tracer by using
  different methods and techniques including PET scanning and many more.

Creating an image from PET scanning :

- The γ rays travel in straight lines in opposite directions when formed from a positron-electron annihilation.
- This is due to the conservation of momentum. They hit the detectors in a line – known as the line of response.
- The tracers will emit lots of γ rays simultaneously, and the computers will use this information to create an image.
- The more photons formed at a particular point, the more tracer that is present in the tissue being studied, and this will appear as a bright point on the image
- An image of the tracer concentration in the tissue can be created by processing the arrival times of the gamma-ray photons.