Gamma rays characteristics

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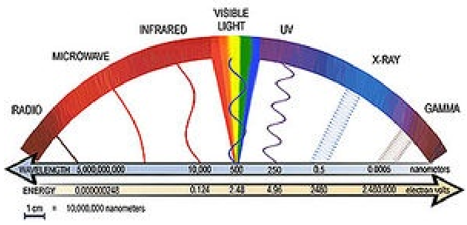
Introduction

Gamma radiation, also known as gamma rays, refers to electromagnetic radiation of an extremely high frequency and therefore consists of high-energy photons. Gamma rays are ionizing radiation, and are thus biologically hazardous. Paul Villard, a French chemist and physicist, discovered gamma radiation in 1900, while studying radiation emitted from radium. Villard's radiation was named "gamma rays" by Ernest Rutherford in 1903.[1]

What characterises gamma radiation is the transition in an unstable nucleus from a high energy state to a lower energy state. The results are photons with tiny wavelengths and intense frequencies, thus the photons have a very high state of energy. Due to the high energy of gamma radiation it penetrates more objects compared to alpha and beta radiation, because of this it has its benefits as well limitations. Since the particles from a gamma decay are photons they have no mass or charge, therefore gamma radiation can be referred to as electromagnetic radiation. In addition to this characteristic, photons do not ionize matter directly, instead the matter is ionized indirectly. There three key interactions between gamma rays and matter which will be addressed in this paper: photoelectric effect, Compton scattering, pair production. [2]



Electromagetic Spectrum

In Clinical Medicine

Clinically, gamma radiations are used extensively in diagnostic processes and radiation therapy. Gamma rays are produced in labs through the process of nuclear collisions. The high-energy nuclei needed for the collisions are accelerated by devices such as the cyclotron and synchrotron. By using these accelerators Gamma rays are produced in what is known as the Bremsstrahlung process. Gamma rays can kill living cells, a fact which is made of use of in radiation therapy, where gamma rays are used to kill cancerous cells and prevent tumour growth.The beams are aimed from different angles to concentrate the radiation on the growth while minimizing damage to surrounding tissues.

[3]

Gamma rays are also used for diagnostic purposes in nuclear medicine in imaging techniques. A number of different gamma-emitting radioisotopes are used. For example, in a PET scan a radiolabelled sugar called fluorodeoxyglucose emits positrons that are annihilated by electrons, producing pairs of gamma rays that highlight cancer as the cancer often has a higher metabolic rate than the surrounding tissues. [1]

Advantages and disadvantages of gamma radiation

Advantages

- Low cost
- Easily available resources
- Mobile sources
- High resolution
- High sensitivity and specificity
- Possibility of early cancer detection

Disadvantages

- Can kill regular cells
- Unsafe to use on pregnant women
- Can cause nausea, hair loss, skin burns and diminished organ function
- Exposure to lethal dose will usually result in death within two months

The Three Key Interactions of Gamma Radiation with Matter

In the photoelectric effect a photon undergoes an interaction with an atomic election to which it transfers its energy. The result being an emission a photoelectron and the interactive photon disappearing. The kinetic energy of the emitted photoelectron is equal to the energy of the incident gamma photon ($h \times v$) minus the binding energy of the photoelectron in its original shell (E_b); the equation being $E_e = h \times v - E_b$. Therefore, the photoelectric effect only occurs when the photon reaches or exceeds the threshold energy, being the binding energy of the electron. There is a following reaction to this effect, when the photoelectron leaves the atom there becomes a vacancy in that electron layer. Hence an electron from a lower layer will fill this vacancy and another electron will fill that electrons vacancy and so on. This reaction can therefore generate a cascade of more characteristic X-rays. [2]

Another interaction is Compton scattering. In this interaction there is a decrease of energy in the photon, rather more specific, there is a decrease in the photons frequency, this interaction is explained as the Compton effect. This effect occurs when a photon crashes into a charged particle, usually an electron, causing an inelastic scatter of the photon. When the photon hits the particle it deflects with an angle based from its original direction. The deflection decreases the photons frequency, while transferring some of its energy to the recoiling electron. The effect can be calculated using the Compton formula, $\Delta\lambda = \lambda^{\prime} - \lambda = \frac{h}{m_e c}(1 - \cos(\theta))$. [2]

The third key interaction is called pair production. This interaction becomes possible when the photons energy levels exceed 1.02 MeV [1] . Generally, this phenomenon of nature is when energy is directly converted to matter. The phenomena can be observed in a way of a particle and antiparticle, the scenario is usually represented in the formation of a positron and an electron. This occurs when the electromagnetic energy of the photon reaches above the rest mass of two electrons, a threshold energy. According to the conservation law of energy the kinetic energy of motion will split between the two particles. To make this scenario possible it is essential to have the presence of an electric field of a heavy atom to satisfy conservation of momentum and energy. Therefore, the atomic nucleus must receive some momentum making it not possible for pair production of a photon to occur, hence an anti-particle of the electron exists, the positron. When the positron comes to rest it will interact with another electron, resulting in an annihilation of the two particles completing the conversion of their rest mass to pure energy. This energy will be in the form of two oppositely directed gamma rays. [2]

Conclusion

Gamma rays have good affects and bad affects on nature. The dangers of gamma rays are not easy to deal with. With exposure to gamma rays, you can be easily affected with the risk of mutations or cancer in tissue. The use of gamma rays have revolutionised radiation therapy. Forthcoming systems are being designed with the aim of "low cost" clinical applications. New prototypes are being designed and built. The future of nuclear imaging holds cheaper, safer instruments that provide a higher resolution and are more sensitive to detect and quantify disease faster and more accurately that are more accessible and easier to use.

References:

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