Introduction

Electromagnetic (EM) radiation is classified by wavelength into radio, microwave, infrared, the visible region we perceive as light, ultraviolet, X-ray and gamma (γ) ray. The behavior of EM radiation depends on its wavelength. Higher frequencies have shorter wavelengths, and lower frequencies have longer wavelengths as shown in Fig 1. Radiation is emitted and absorbed in tiny "packets" called photons, the smallest unit of light. Photons are emitted when electrons in an atom jump from one orbit to another.

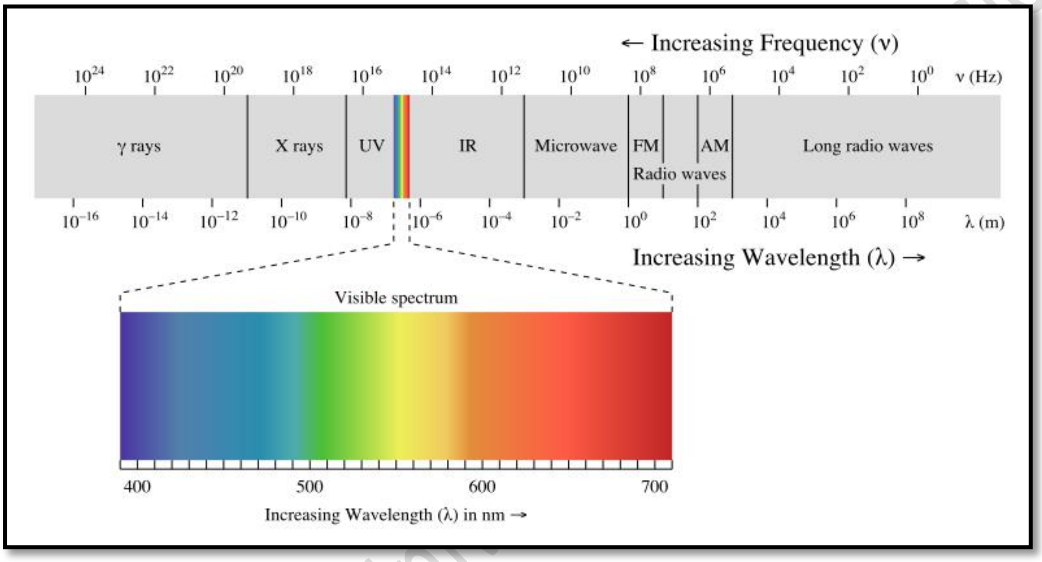

Figure 1: Electromagnetic Spectrum

Notes:

- For a given frequency f of the radiation, each photon has a fixed amount of energy E which is

$$E = h\,f \;\ldots\ldots\ldots\; (1)$$

Where h is **Planck's constant**, equal to (**6.63×10 $^{-34}$ Joule. Sec**)

- The wavelength (λ) is the distance between 2 peaks of the wave.
- Frequency (f) is the number of wave/second.
- The relationship between wavelength and frequency is given by:

Speed of light = wavelength × frequency

$$c = \lambda \times f \ldots\ldots\ldots\; (2) \qquad \text{where } c = 3\times10^{8}\ m.s^{-1}$$

- 1 eV = 1.6 × 10^{-19} Coulomb × 1 Volute = 1.6 × 10^{-19} Joule
- The term of radiation does not mean only electromagnetic radiation, but also all kinds of particle beams such as alpha, beta particles and neutrons.

Classification of radiation

Radiation, the transport of energy by electromagnetic waves or atomic particles, can be classified into two main categories depending on its ability to ionize matter. The ionization potential of atoms, i.e. the minimum energy required to ionize an atom, ranges from a few electronvolts for alkali elements to 24.6 eV for helium.

- ✓ Non-ionizing radiation cannot ionize matter because its energy per quantum is below the ionization potential of atoms. Ultraviolet, visible light, infrared photons, microwaves and radio waves are examples of non-ionizing radiation.
- ✓ Ionizing radiation can ionize matter either directly or indirectly because its quantum energy exceeds the ionization potential of atoms. X rays, γ rays, energetic neutrons, electrons, protons and heavier particles are examples of ionizing radiation.

Types of nuclear radiation

- **Alpha particles (α):** Alpha particles are positively charged particles emitted by a heavy radioactive element, such as radium, thorium, uranium, and plutonium. The alpha particles are a portion of the parent nucleus that contains two protons and two neutrons. The emitted alpha particles are monoenergetic, their energy is in the range of a few MeV. An alpha particle interacts strongly and has a very short range-a few cm in air.
- **Beta Particle (β):** A beta particles are a high-energy, high-speed electron or positron emitted by the radioactive decay of an atomic nucleus during the process of beta decay. There are two forms of beta decay, β^- decay and β^+ decay, which produce electrons and positrons respectively. Beta particles can pass through a sheet of paper, but may be stopped by a thin sheet of aluminum.
- **Gamma-ray (γ):** A gamma ray, also known as gamma radiation, is a penetrating form of electromagnetic radiation arising from the radioactive decay of atomic nuclei. It consists of the shortest wavelength electromagnetic waves, typically shorter than those of X-rays. Because of their high energy, they can pass through many kinds of materials, including human tissue. Very dense materials, such as lead, are commonly used as shielding to slow or stop gamma photons.

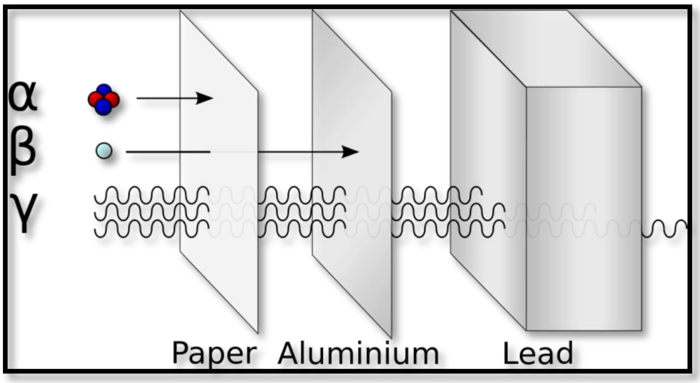

Figure (2): Types of Nuclear Radiation

Nuclear radiation sources

The radiation comes from two sources: natural or background radiation and human-made radiation.

1- Natural or background radiation

Natural or background radiation is the radiation emitted by radioisotope that exist inside the earth, as well as radiation incident upon the earth from outer space. Natural radiation comes from primary sources: cosmic, terrestrial and internal sources.

1.1 Cosmic radiation

The earth, and all living things on it, are continually bombarded by high-energy particles that originate in outer space called cosmic rays. These cosmic rays interact with nuclei of atmospheric constituents, producing a cascade of interactions and secondary reaction products that contribute to cosmic ray exposure, which decrease in intensity with the depth in the atmosphere. The cosmic ray consists of 87% protons, 11% alpha particles, about 1% nuclei with low atomic number, and about 1% electrons of high kinetic energy. The cosmic rays have a high penetrating energy 10^{20} eV or more. The interaction of cosmic ray in the atmosphere produces a number of radionuclides called cosmogenic radionuclides, including ^{3}H, ^{7}Be, ^{14}C, ^{22}Na.

1.2 *Terrestrial radiation*

Radioactive material is found throughout nature. It occurs naturally in the soil, water, and vegetation. The primordial radionuclides whose half-lives are sufficiently long to have survived in detectable quantities since the formation of the earth, together with their radioactive daughters. The primordial radionuclides can be divided into those that occur singly and those that are components of chain series.

The major isotopes of concern for terrestrial radiation are uranium and its decay products, such as thorium, radium, and radon. Low levels of uranium, thorium, and their decay products are found everywhere. Some of these materials are ingested with food and water, while others, such as radon, are inhaled. The dose from terrestrial sources varies in different parts of the world. Locations with higher concentrations of uranium and thorium in their soil have higher dose levels.

There are three chains of naturally radionuclides in nature, these are:

- ***Thorium series***: Thorium series starting with ^{232}Th which is an alpha-particle emitter of half-life 1.41×10^{10} years and ending with stable ^{208}Pb. The atomic mass number of ^{232}Th is exactly divisible by 4. Since all disintegrations in the series are accomplished by the emission of either an alpha particle of 4 atomic mass units, or a beta particle, it follows that the mass numbers of all members of thorium series are exactly divided by 4. This series, therefore, is called the (4n) series. The thorium series consists of 13 isotopes.

- ***Uranium series:*** Uranium series starting with ^{238}U which is an alpha-particle emitter and ending with stable ^{206}Pb. The uranium series consists of isotopes whose numbers are divided by 4, and leave a remainder of 2. This series, therefore, is called the (4n + 2) series. The uranium series consists of 20 isotopes.
- ***Actinium series:*** Actinium series is called the (4n + 3) series starting with ^{235}U which is an alpha-particle emitter and ending with stable ^{207}Pb. This series consists of 15 isotopes shown in figure 3.

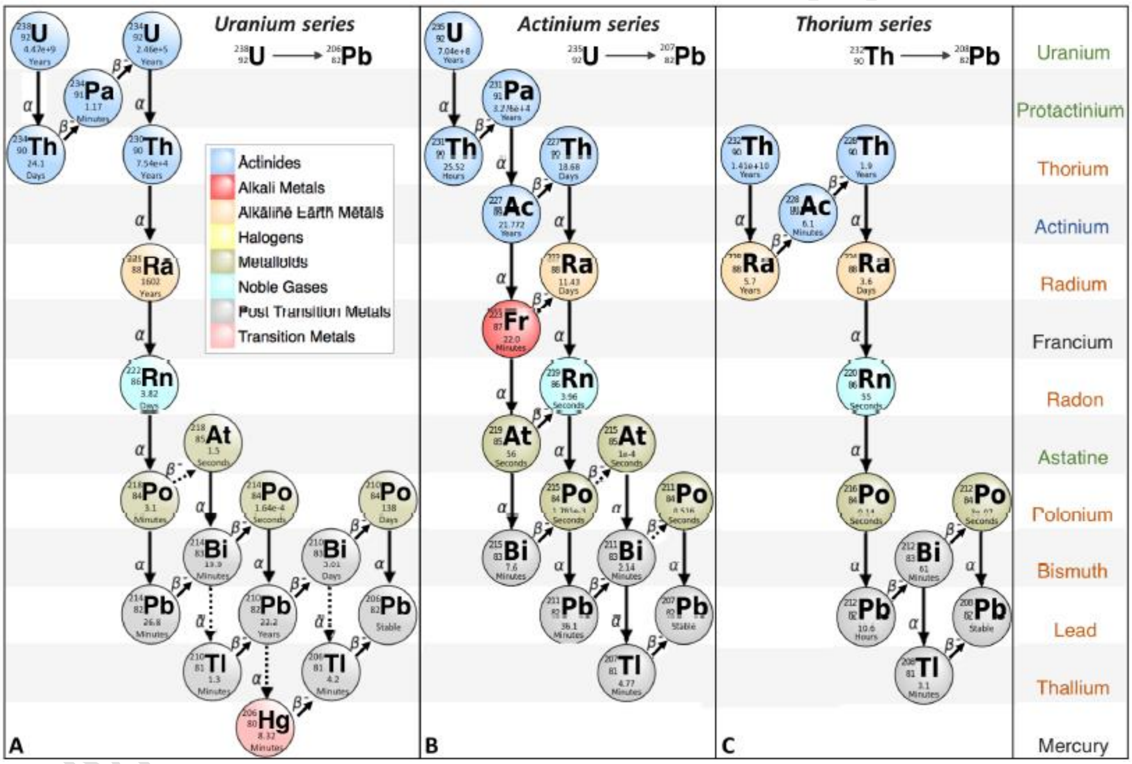

Figure 3: Natural radiation series decay

1.3 Internal radiation within human body: The human body contains trace amounts of radioactive materials, the most important of which are ^{14}C and ^{40}K. In addition to the possibility of entering ^{222}Rn and ^{220}Rn gases in the human body resulting from the decay of radium isotopes ^{226}Ra and ^{224}Ra present in the soil through the respiratory system. Quantities of other radioactive materials can also enter into the body by ingestion of food and water.

2- Human made radiation

Natural and artificial radiation sources are identical in their nature and their effect. Humans are using the radioactivity for one hundred years, and through its use, added to natural inventories. Its amount is small compared to the natural amount discussed above due to the short half-lives of many of the nuclides, and it demonstrate a marked decrease since the halting of above ground testing of nuclear weapons.

Two important categories of artificial radionuclides-include those, which appear in nuclear power plants from the fission of uranium and other nuclear reactions, and the radionuclides and labeled compounds, which are specially produced for application in various fields of human activity. Large varieties of radioactive nuclides are produced in minute amounts in nuclear research laboratories in the form of by products from the investigation of nuclear processes. The most significant source of man-made radiation exposure to the general public is from medical procedures, such as diagnostic x-rays, nuclear medicine, and radiation therapy. Some of the major isotopes would be I-131, Co-60, Sr-90, Cs-137, and others. In addition, members of the public are exposed to radiation from consumer products, such as tobacco (polonium-210), building materials, televisions, luminous watches, airport x-ray systems, smoke detectors (americium), etc.

<u>Ionizing radiation exposure to the public :</u>

Exposure the public to the sources of radiation was estimated by the National Council on Radiation Protection and Measurements (NCRP), as shown in the following chart, the natural sources of radiation account for about 82% of all public exposure while man-made sources account for the remaining 18%.