الأسبوع الثاني

Chapter Two (Radiation)

Radiation occurs naturally in the environment that called background radiation; therefore, radionuclide is of naturally present in air, water, soil, sediments, wood, rocks, building materials, and food. Natural radiation exists everywhere around the Earth in different levels. This means radiation can found all around us. Our natural environment, the food we eat, the water we drink, and the air we breathe may contain or being affected by some radioactive materials.

Radioactive contamination is a result of spreading radioactive isotopes during the nuclear tests, nuclear explosion, nuclear wastes and depleted Uranium.

2.1 Type of Radiation

The four major types of radiation are:

- Gamma (γ) radiation - high-energy electromagnetic waves;
- Beta (β) radiation - emission of electrons or positrons;
- Alfa (α) radiation - emission of Helium nucleus (He_2^4);
- Neutron radiation - emission of high or low energy neutrons;

Gamma Rays

A gamma ray is a packet of high-energy electromagnetic waves (or photons). Gamma photons are the most energetic in the electromagnetic spectrum, emitting from the nucleus of some unstable (radioactive) nucleus. Gamma photon have no rest mass, no electrical charge, they are pure electromagnetic energy. High energy gamma photons travel at the speed of light in vacuum and can cover hundreds of meters in the air before dispersing their energy, They can easily pass through different types of materials, including human tissue, so both external and internal exposure to gamma rays have to be considered.

Gamma radiation has enough energy to pass entirely through the human body, potentially exposing all internal organs. High-energy gamma radiation, having a very small cross-section of interaction, passes through the human body practically without interacting with tissue.

The speed of gamma photons (*C*) is independent of their wavelength, frequency, and energy, and it is the same as that of all other types of electromagnetic radiation ($C=3.10^8$ m/sec in vacuum). Their wavelength (λ), frequency (ν) and energy (E) are correlated by the following equations

$$\lambda = \frac{C}{v} \ , \qquad E = hv \qquad (2.1)$$

Where h is the blank constant

Unstable nuclide move from higher energy state to a lower energy state by emitting a gamma ray, gamma radiation also can be produce by other forms of radiation, such as alpha or beta, through the secondary nuclear reactions (decays). The mechanism involves a nucleus emitting α or β particles, and the daughter nucleus can also be in an excited state. Emission of gamma rays from an excited nuclear state typically requires only 10^{-12} seconds, followed by another radioactive decay that produces other radioactive particles.

For example, ^{60}Co decays to an excited ^{60}Ni by beta decay. Then the ^{60}Ni drops down to the ground state by emitting two gamma rays in sequence (1.17 MeV then 1.33 MeV), as shown in Figure 2.1.

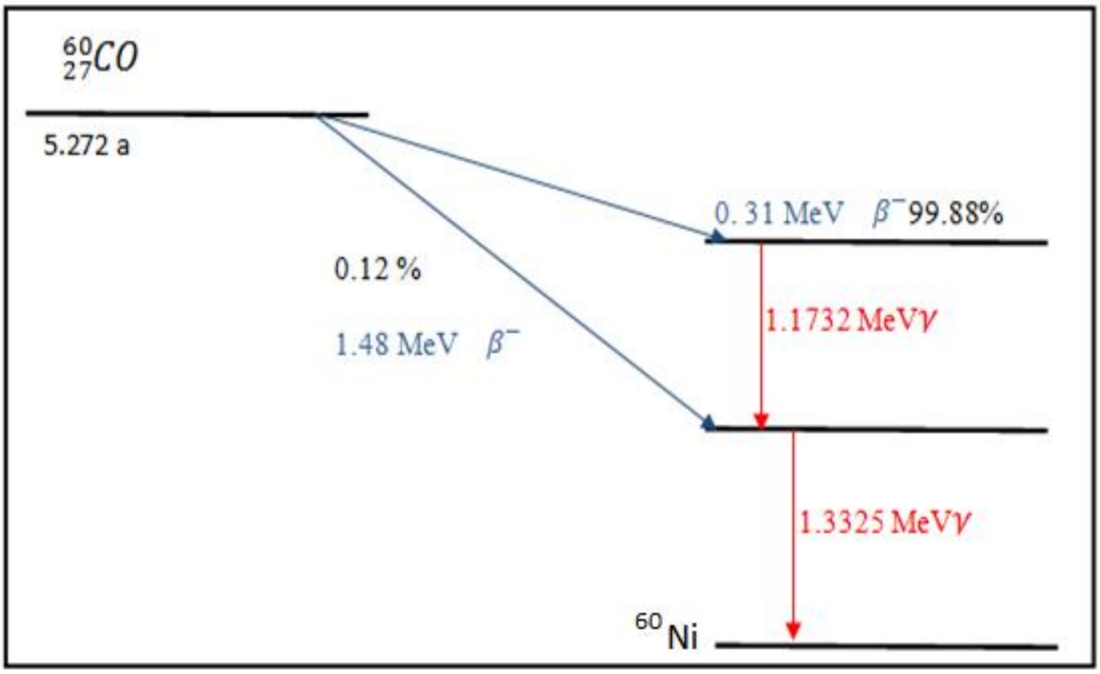


Figure 2.1. The scheme of decay of ^{60}CO to ^{60}Ni

Beta particles (β)

Beta particles (β) are subatomic particles ejected from the nucleus of some radioactive atoms, equivalent to electrons. The difference is that beta particles originate in the nucleus and electrons originate outside the nucleus. Beta particles have an electrical charge of (1e). Beta particles have a mass of 549 millionth of one atomic mass unit, which is about 1/2000 of the mass of a proton or neutron. The speed of individual beta particles depends on how much energy they have.

Direct exposure to beta particles is a relatively small hazard; it may cause skin to redden or even burn. The beta-emission from inhaled or ingested substances, however, is the greatest concern. Beta particles released directly into living tissue can cause damage at the molecular level, which can disrupt cell function.

Beta particles do not exist in the unstable nucleus before emission, they are produced from sub-nuclear transformation, whereby a neutron changes to a proton (β- particle is emitted) thus:

$$n \rightarrow p + e^{-} + v^{-} \qquad (2.2)$$

Alternatively, a proton changes to a neutron (a β+ particle is emitted):

$$p \rightarrow n + e^{+} + v \qquad (2.3)$$

Whereas a neutrons outside a nucleus undergoes negative beta decay and transforms into proton with a half-decay time (t½ =12 min. 16 sec.), much lighter protons cannot be transformed into a neutron except within a nucleus.

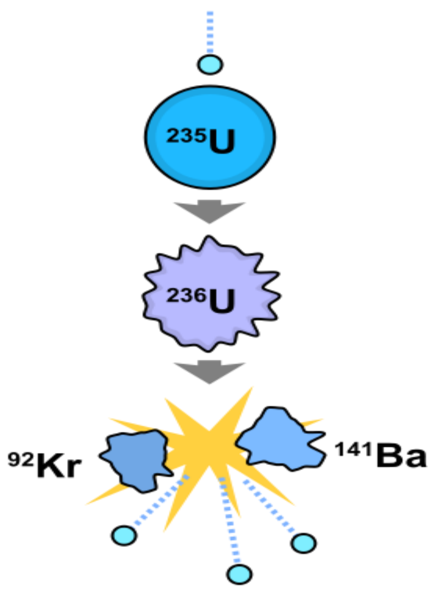
Alpha particles (α)

An alpha particle consists of two protons and two neutrons bound together into a particle identical to a helium nucleus. They are generally produced in the process of alpha decay, but may also be made by other means. The symbol for the alpha particle is α or α^{2+}. Because they are identical to the helium nuclei, they are also sometimes written as ${}^{4}_{2}He^{2+}$, indicating a Helium ion with a +2 charge (missing its two electrons). If the ion gains electrons from its environment, the alpha particle can be written as a normal (electrically neutral) Helium atom. The most well known source of alpha particles is alpha decay of large atoms heavier than 106 units of atomic weight.

When an atom emits an alpha particle, the atom's mass number decreases by four, due to the loss of the four nucleons in the alpha particle, so the atomic number of the atom goes down by exactly two, because of the loss of two protons, the atom becomes a new element. All of the larger radioactive nuclei, such as Uranium, Thorium, Actinium, and Radium commonly emit alpha particles. Unlike other types of decay, alpha decay must have a minimum size atomic nucleus that can support it. The smallest nuclei that have to date been found to be capable of alpha emission are the lightest nuclides of Tellurium (element 52), with a mass numbers between 106 and 110. The process of alpha-emission sometimes leaves the nucleus in an excited state, with the emission of a gamma ray required in order to remove the excess energy.

Neutron radiation

Neutron radiation is a kind of ionizing radiation that consists of free neutrons. As a result of nuclear fission, free neutrons are released from atoms, and these free neutrons react with the nuclei of other atoms to form new isotopes which may produce radiation (In nuclear physics, nuclear fission is either a nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts (lighter nuclei). The fission process often produces free neutrons and photons (in the form of gamma rays), and releases a very large amount of energy even by the energetic standards of radioactive decay).



An induced fission reaction. A neutron is absorbed by a uranium-235 nucleus, turning it briefly into an excited uranium-236 nucleus, with the excitation energy provided by the kinetic energy of the neutron plus the forces that bind the neutron. The uranium-236, in turn, splits into fast-moving lighter elements (fission products) and releases three free neutrons. At the same time, one or more "prompt gamma rays" (not shown) are produced, as well.

Neutrons may be emitting from nuclear fusion or nuclear fission, or from other types of nuclear reactions, such as radioactive decay or reactions with highly energetic particles, either coming as cosmic rays or created in particle accelerators

Neutron radiation was discovered through observing a Beryllium (atomic No. 4) nucleus reacting with an alpha particle, thus transforming into a Carbon (atomic No. 6) nucleus and emitting a neutron. ($Be + \alpha \rightarrow C + n$).