Chapter 1: What is Radioactivity?

Natural and Man-Made Radiation

We are constantly exposed to naturally occurring and man-made radiation in our environment. The level of exposure varies based on geographic location, altitude, personal activities, and occupation.

Generally, most radiation exposure comes from natural background radiation. Medical procedures are another significant source, especially for individuals who undergo frequent imaging that uses ionizing radiation. However, exposure from these sources is typically well below levels known to be harmful to human health.

Primary sources of radiation exposure include:

Natural Background Radiation

This is radiation present in the Earth's environment and atmosphere from natural sources, such as rocks, soil, and cosmic rays.

Medical Radiation

Diagnostic procedures using radioisotopes are now routine. The most common radioisotope used in diagnosis is technetium-99 (Tc-99). Nuclear medicine uses radiation to provide diagnostic information about the function of specific organs.
Radiotherapy uses radiation to weaken or destroy targeted cells, typically to treat medical conditions like cancer.

Radioisotopes are also used for sterilizing medical equipment.

Demand for medical radioisotopes is increasing by up to 5% annually.

Consumer Products

Some consumer products emit low levels of radiation, including smoke detectors, certain building materials, and some types of jewelry containing radioactive materials.

Nuclear Industry

This category includes radiation exposure from nuclear power plants, nuclear research facilities, and other nuclear-related industries.

Radioactive decay

Radioactivity refers to the spontaneous emission of radiation from the nucleus of an atom. Atoms are composed of a central nucleus, which contains positively charged protons and uncharged neutrons, surrounded by negatively charged electrons. In stable atoms, the forces within the nucleus keep it intact and prevent any spontaneous emission of particles or energy.

However, in some atoms, the nucleus may be unstable due to an imbalance between the number of protons and neutrons or other factors. This instability leads to a process called radioactive decay, in which the unstable nucleus undergoes a spontaneous transformation to achieve a more stable state. During this process, various types of radiation are emitted from the nucleus.

There are three primary types of radiation emitted during radioactive decay:

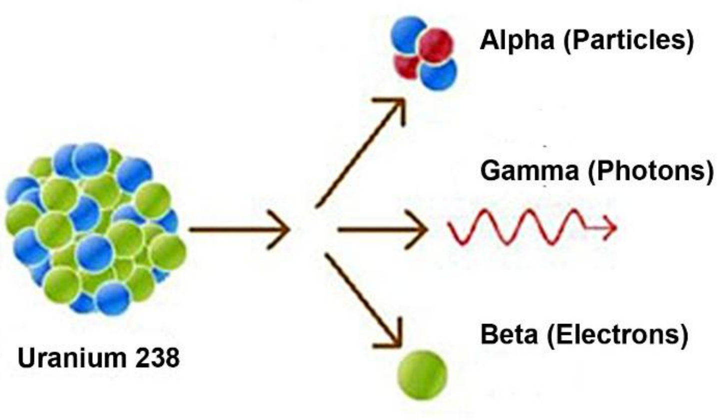
Alpha particles (α): These are made up of two protons and two neutrons, which are essentially the same as the nucleus of a helium atom. Alpha particles have a positive charge and are relatively large and heavy.

Beta particles (β): Beta particles can be either electrons (β-) or positrons (β+). β- particles are essentially high-speed electrons, while β+ particles are positively charged electrons, also known as positrons.

Gamma rays (γ): Gamma rays are electromagnetic radiation similar to X-rays but with higher energy. They have no mass or charge and are highly penetrating.

Radioactive decay is a random process, and the rate of decay of a particular radioactive substance is characterized by its half-life, which is the time it takes for half of the radioactive nuclei to decay. The concept of half-life allows us to estimate the rate of decay and the amount of radioactivity present at any given time.

Radioactivity is a natural phenomenon and is also artificially produced in various processes, such as nuclear power generation, medical imaging, and industrial applications. It has both beneficial and harmful effects, depending on its application and level of exposure. Proper handling, containment, and monitoring of radioactive materials are essential to minimize potential risks to human health and the environment.



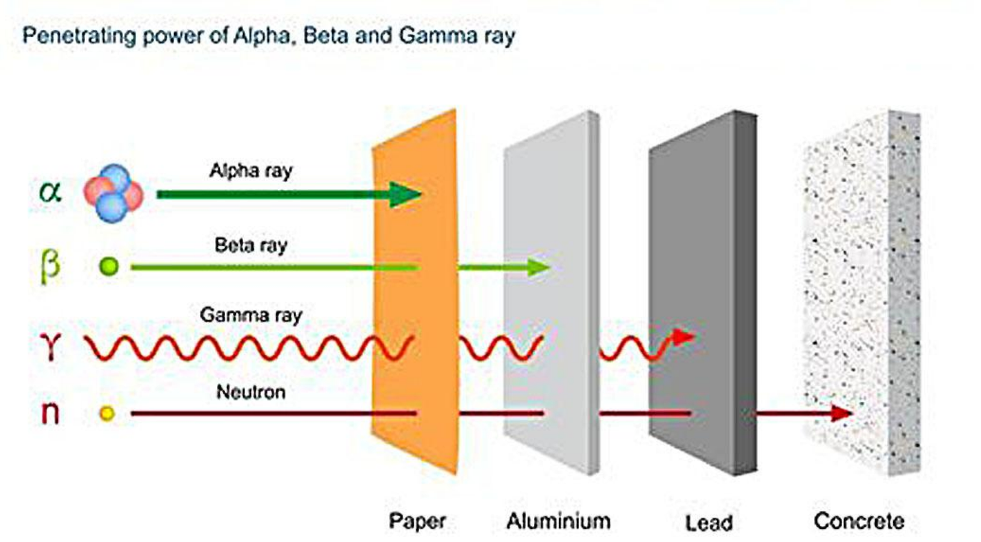
Efficiency of Shielding

Radiation Type:

Different types of radiation have different danger levels. For example, alpha particles can be blocked by a sheet of paper and are not very dangerous outside the body, but can cause significant damage if ingested or inhaled. Beta particles are more penetrating and can cause skin burns, while gamma rays are highly penetrating and can cause internal damage even from a distance.

Each type of emission has different penetrating power in the matter and different ionization energy. They can cause damage to life in different ways.

Though the most massive and most energetic of radioactive emissions, the alpha particle is the shortest in range because of its strong interaction with matter. The electromagnetic gamma ray is extremely penetrating, even penetrating considerable thicknesses of concrete. The electron of beta radioactivity strongly interacts with matter and has a short range.



Chapter 2: Effects of Radiation on Human Health

The harmful amount of radiation exposure to human health depends on the type of radiation, the energy of the radiation, the duration and the individual's sensitivity to radiation.

In general, ongoing exposure to lower levels of radiation may increase the risk of cancer or other long-term effects. Exposure to high levels of ionizing radiation, such as from radiation therapy or nuclear accidents, can cause acute effects, such as radiation sickness

Radiation Dose:

Radiation dose is the amount of radiation absorbed by the organism within a period of time

The radiation dose that a person has received is decisive for the extent of the damage. In radiation medicine, the unit of total absorbed dose is the Gray. One Gray (Gy) is equal to one Sievert (Sv). If the human body was exposed to less than one Gray, disorders of the hematopoietic system may occur. If a person was exposed to three Gray, he or she will have burn-like injuries to the skin and mucous membranes. Above a dose of five Gray, damage to the gastrointestinal tract also occurs. Higher doses cause damage to the brain and spinal cord. If a person has received more than twenty Gray, the chance of survival is minimal.

Small doses of energy do not immediately lead to a cell damage. Larger doses however can lead to DNA damages. If the damage is not repaired completely or not correctly, then the affected cells can degenerate into tumor cells years later. However, many factors play a role in the development of a cancerous tumor, such as diet, lifestyle or even the genetically determined efficiency of the body's own repair systems.

The danger level of radiation exposure can be categorized based on the amount of radiation dose received. The unit of measurement for radiation dose is the Sievert (Sv), or a smaller unit, the millisievert (mSv). Exposure to less than 100 mSv is considered low risk, 100-500 mSv is moderate risk, and exposure to more than 500 mSv is high risk.

Reference Doses for Human Organs

- **Round-trip flight (London–Beijing):** 0.1 mSv (counter display: 30,000).
- **One mammography screening:** 0.5 mSv (counter display: 150,000).
- **Annual natural background exposure:** 2 mSv (counter display: 600,000). This dose is tolerated by the human body via natural regeneration.
- **100 mSv to 1.0 Sv:** Increased cancer risk.
- **Sv to 10 Sv:** Severe organ damage.
- **>10 Sv:** Lethal.

Recommended Maximum Dose Levels

The dangerous dose levels for radiation exposure depend on several factors, including the type of radiation, the duration of exposure, and the sensitivity of the exposed individual. However, here are some general guidelines for the recommended maximum doses for different types of radiation exposure:

Natural background radiation

On average, people are exposed to about **2-3 millisieverts (mSv) of radiation per year** from natural sources, such as cosmic rays and radioactive materials in the earth's crust. This level of exposure is **considered safe**.

Occupational exposure

Workers in industries that handle radioactive materials or perform tasks that involve exposure to radiation may be subject to regulatory limits on their exposure. In the United States, the Occupational Safety and Health Administration (OSHA) sets a **permissible exposure** limit of **50 mSv per year** for radiation workers.

Long-term exposure

Long-term exposure to lower levels of radiation can increase the risk of cancer and other health problems. The risk increases with higher doses and longer exposure times. The **risk of cancer** from radiation exposure is generally estimated to **increase by about 5% per 100 mSv of exposure**.

Acute radiation sickness

Exposure to a high dose of radiation over a short period of time can cause acute radiation sickness, which can be life-threatening. The **threshold for acute radiation sickness** is generally considered to be **around 1,000 mSv**.

Three Rules of Thumb to Protect Yourself from Nuclear Radiation

FIRST >> Increase distance

Dose rate is inversely proportional to the square of the distance!

Example:
2 m distance, compared to 1 m >> Reduction of dose rate by a factor of 4.
4 m distance, compared to 1 m >> Reduction of dose rate by a factor of 16

SECOND >> Reduce time of exposure

Half time of exposure >> Half radiation dose

THIRD >> Provide adequate shielding

Example: Concrete, 20 cm thick >> 85% reduction of gamma dose rate