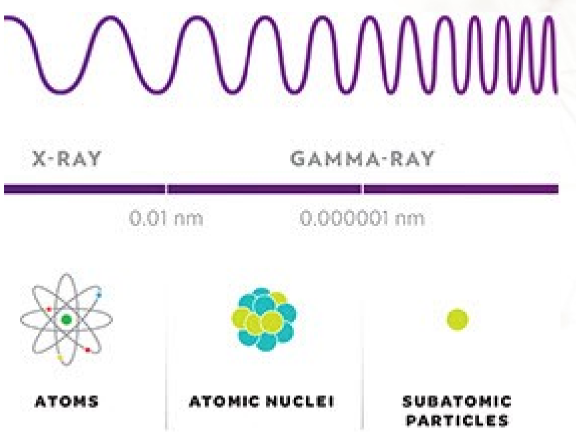
Radiation Info Sheet

Ionizing Radiation

Ionizing radiation may exist in the form of a high-energy photon or charged particles. When ionizing radiation passes through matter, some of the energy is absorbed and electrons are knocked out of atoms. This creates a trail of positive ions.

In living organisms this residual energy can be damaging to tissue, cellular processes or DNA, especially if received in large amounts within a short period. This is the main mechanism by which ionizing radiation can cause immediate harm or long-term illness (e.g. cancer). However, at levels of exposure associated with natural and man-made radiation sources in the environment around us, our bodies are generally able to deal with the residual energy in a similar manner that they have adapted to deal with environmental levels of chemical and biological toxins.



Ionizing side of the electromagnetic spectrum.

X-rays and gamma rays have large amounts of energy and can ionize atoms in most types of matter. Although the atmosphere surrounding the Earth blocks most of the x-rays and gamma rays emitted by the Sun some do manage to get through. On the other hand, the atmosphere itself is also a significant source of ionizing radiation: when cosmic rays (mostly protons) interact with the upper atmosphere they create secondary x-rays and subatomic particles, such as muons, which contribute to our background radiation exposure.

Geiger counters can detect ionizing radiation.

As mentioned earlier, ionizing radiation can exist in the form of moving particles. When radioactive elements and isotopes decay, they eject particles. These particles include photons, alpha particles, beta particles and neutrinos. Because ionizing radiation cannot be detected by our senses, we cannot see, smell or taste it. To detect ionizing radiation we must use special devices such as Geiger-Müller counters (often referred to as simply “Geiger counters”), dosimeters or cloud chambers.

Nuclear Radiation

While non-ionizing radiation and x-rays are a result of electron transitions in atoms or molecules, there are three forms of ionizing radiation that are a result of activity within the nucleus of an atom. These forms of nuclear radiation are alpha particles (α-particles), beta particles (β^- particles) and gamma rays (γ-rays).

Alpha particles are heavy positively charged particles made up of two protons and two neutrons. They are essentially a helium nucleus and are thus represented in a nuclear equation by either α or $^{4}_{2}He$.

Beta particles come in two forms: β^+ and β^-. β^- particles are just electrons that have been ejected from the nucleus. This is a result of sub-nuclear reactions that result in a neutron decaying to a proton. The electron is needed to conserve charge and comes from the nucleus. It is **not** an orbital electron. β^+ particles are positrons ejected from the nucleus when a proton decays to a neutron. A positron is an anti-particle that is similar in nearly all respects to an electron but has a positive charge.

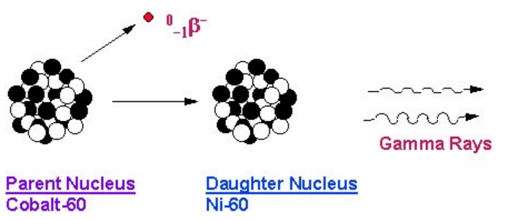
Gamma rays are photons of high energy electromagnetic radiation (light). Gamma rays generally have the highest frequency and shortest wavelengths in the electromagnetic spectrum. There is some overlap in the frequencies of gamma rays and x-rays; however, x-rays are formed from electron transitions while gamma rays are formed from nuclear transitions.

Gamma Rays

The third letter of the Greek alphabet is gamma (γ). Henri Becquerel is credited with discovering gamma radiation in 1896. Gamma rays are a highly penetrating ionizing electromagnetic radiation in the form of photons (light). They have the highest frequency and shortest wavelength in the electromagnetic spectrum.

Most electromagnetic radiation (radio waves through x-rays, including visible light) is released when an electron transitions from a higher energy level to a lower one, such as indicated in the diagram. By conservation of energy, the energy of the released photon equals the change in energy of the electron.

Similarly, gamma rays are produced when the nucleus of an atom is in an excited state (called a metastable state or an isomer) and then releases energy, becoming more stable. The reaction looks something like this: $A^* \rightarrow A + \gamma$, where A^* represents the excited state of the nucleus. The resulting daughter nucleus, *A*, has the same atomic number as the parent nucleus, but a slightly smaller mass due to the release of energy.



Gamma radiation.

Nuclei often reach excited states from another form of radioactive decay. For example, ^{60}Co decays by beta decay to an excited form of nickel, $^{60}Ni^*$. It then releases two gamma rays in succession as it decays to a more stable energy in the nucleus. The series of reactions is described by the following equations:

$^{60}Co \rightarrow {}^{60}Ni^* + e^- + \overline{\nu} + 0.31$ MeV (β^- decay)

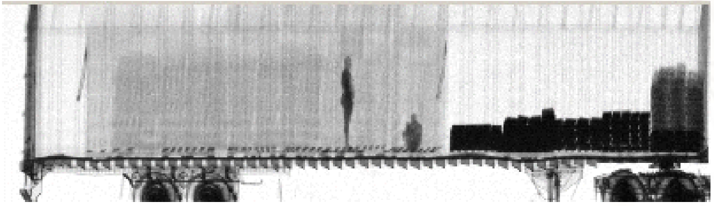
$^{60}Ni^* \rightarrow {}^{60}Ni^* + \gamma + 1.17$ MeV

$^{60}Ni^* \rightarrow {}^{60}Ni + \gamma + 1.33$ MeV

In the first equation, the energy describes the energy of the electron, while in the second and third, it describes the energy of the gamma rays.

Gamma rays can also be formed from subatomic particle interactions, such as electron-positron annihilation. When matter and anti-matter collide, they annihilate each other and release energy. In the case of electron-positron annihilation, this is in the form of two gamma rays equivalent in energy to the energy of the electron and positron.

Gamma rays are the most penetrating of all of the forms of radiation. Gamma rays can be absorbed by denser materials (notice the blacker areas in the photo above), while passing through less dense materials. Gamma rays can interact with cells and DNA causing cell damage. While we all receive regular doses of gamma radiation from naturally occurring processes (such as radioactive decay), exposure to gamma radiation should be limited.



A gamma ray photograph of a transport truck showing two stowaways.

X-Rays

X-rays are a form of electromagnetic radiation. They have wavelengths shorter than those of visible or ultraviolet light, and the photons have higher energies. Scientists have been studying x-rays since the late 1880's. It was the German Physicist Wilhelm Conrad Röntgen who gave them the name x-rays in 1895. X-rays are actually particles of light that travel with a very small wavelength and a very high frequency. Because of this, x-rays can transfer a lot of energy and can pass directly through some types matter.

After seeing Röntgen's x-ray photographs, doctors around the world quickly saw the medical possibilities of this new technology and began to build their own x-ray machines. On February 7, 1896, the first medical x-ray in Canada was taken in Montreal by Professor John Cox to find a bullet in a man's leg.

As you can see from the x-ray photograph on the right, x-rays have enough energy to pass through the soft tissues of the body but not enough to pass through bone or metal. If you have ever had a medical or dental x-ray, you were exposed to a level of ionizing radiation that is judged to be safe given the benefit to your health offered by the procedure.

An x-ray image of Wilhelm Röntgen's wife's hand.

X-rays are now used in a variety of applications such as x-ray astronomy, material testing, luggage inspection at air ports and examining microscopic objects.