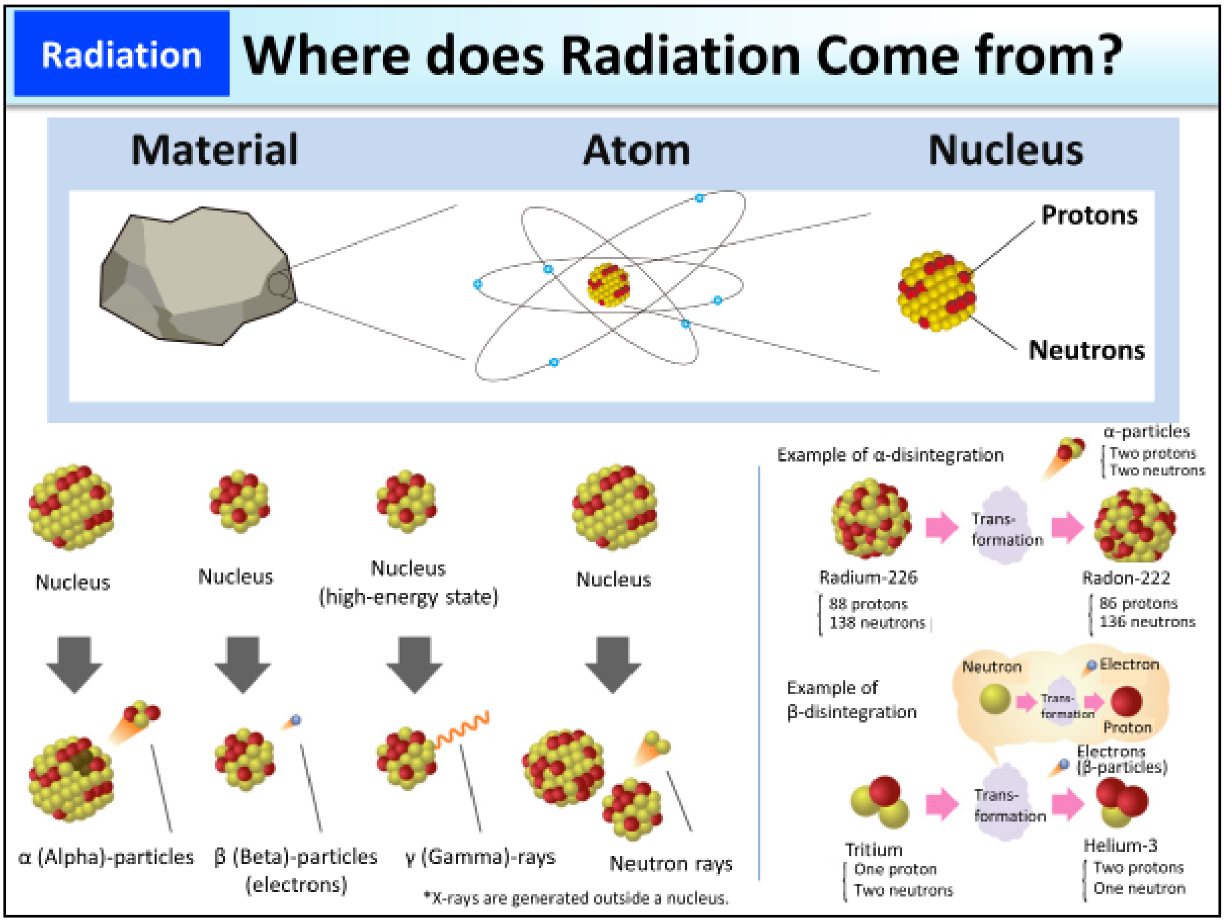

α (alpha)-particles, β (beta)-particles, γ (gamma)-rays, and X-rays were the names given to them because they were not elucidated at the time of their discoveries. Today, α-particles are found to be helium nuclei with two protons and two neutrons, flying out at high speed; β-particles are electrons that are ejected from a nucleus. A helium nucleus weighs about 7,300 times more than an electron. Normally, nuclei have high energy and are therefore still unstable immediately after emission of α-particles or β-particles, so they will further emit γ-rays in order to become stable. However, some do not emit γ-rays.

While α-particles, β-particles, and γ-rays are emitted from a nucleus, X-rays are electromagnetic waves that are generated outside a nucleus. Unlike X-rays, γ-rays are generated from a nucleus, but both are electromagnetic waves. A neutron is a particle that constitutes a nucleus. Neutrons that are ejected from a nucleus with kinetic energy, e.g. during the fission of the nucleus, are called neutron beams.

(Related to p.14 of Vol. 1, "Types of Radiation," and p.15 of Vol. 1, "Types of Ionizing Radiation")

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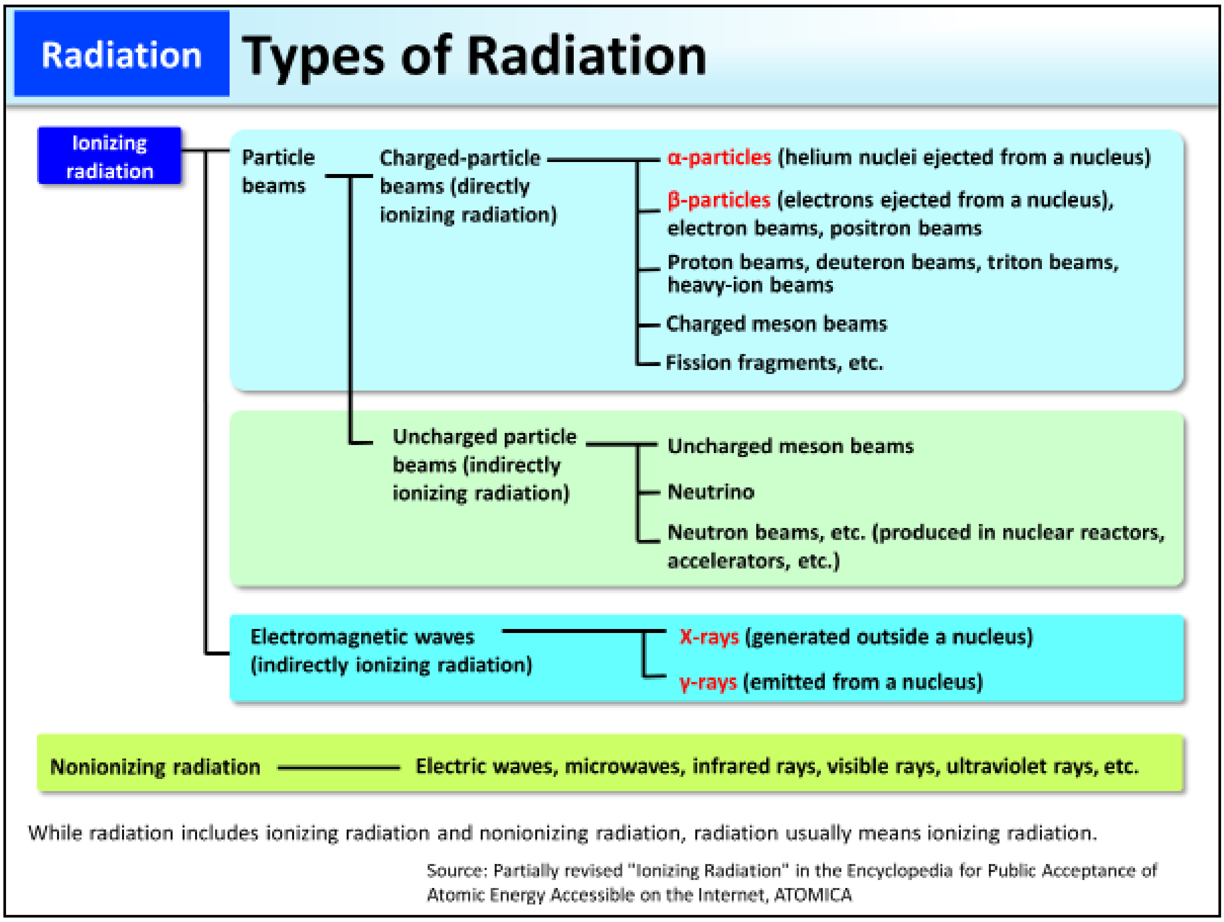

Radiation generally means ionizing radiation. Ionizing radiation, which has the ability to ionize atoms that make up a substance (separate the atoms into positively charged ions and negatively charged electrons), is categorized into particle beams and electromagnetic waves.

Particle beams include α (alpha)-particles, β (beta)-particles, neutron beams, etc. (p.13 of Vol. 1, “Where does Radiation Come from?”). Particle beams include charged (ionized) particle beams and uncharged particle beams. γ (gamma)-rays and X-rays are types of electromagnetic waves.

Some forms of electromagnetic waves, such as electric waves, infrared rays, and visible rays, do not cause ionization, and they are called nonionizing radiation. Ultraviolet rays are generally categorized as nonionizing radiation although some ultraviolet rays do cause ionization (p.15 of Vol. 1, “Types of Ionizing Radiation”).

(Related to p.19 of Vol. 1, “Types of Radiation and Biological Effects,” and p.20 of Vol. 1, “Penetrating Power of Radiation”)

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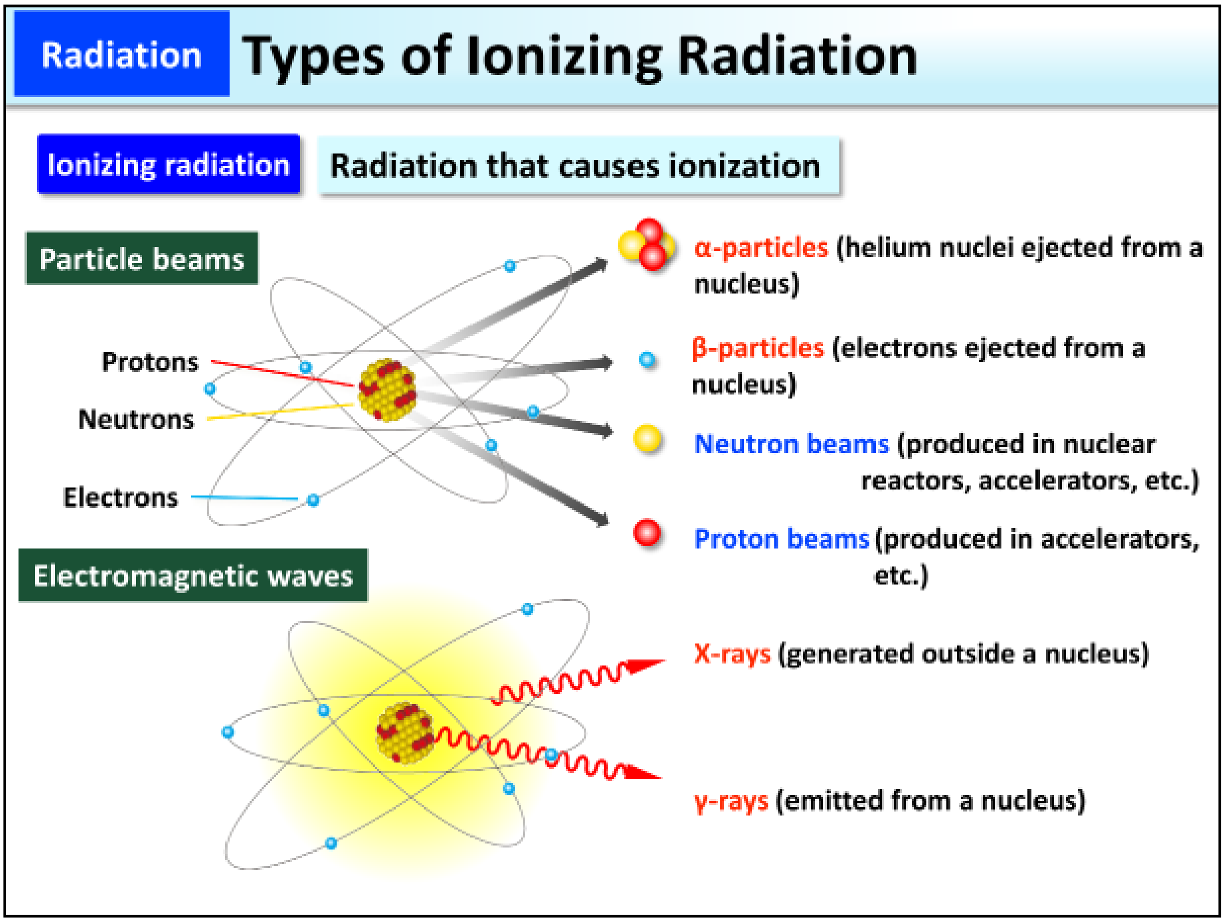

Particle beams include α (alpha)-particles, β (beta)-particles, neutron beams, etc.

α-particles are helium nuclei consisting of two protons and two neutrons that have been ejected at high speed, while β-particles are electrons ejected from a nucleus. Particle beams also include neutron beams and proton beams.

γ-rays and X-rays are types of electromagnetic waves. While α-particles, β-particles, and γ-rays are emitted from a nucleus, X-rays used in X-ray examination for medical checkups and the like are electromagnetic waves generated outside a nucleus. X-rays generated in X-ray tubes are used in X-ray examination. X-rays include braking X-rays and characteristic X-rays (p.16 of Vol. 1, “X-rays for Medical Use and Generators”).

(Related to p.13 of Vol. 1, “Where does Radiation Come from?,” and p.14 of Vol. 1, “Types of Radiation”)

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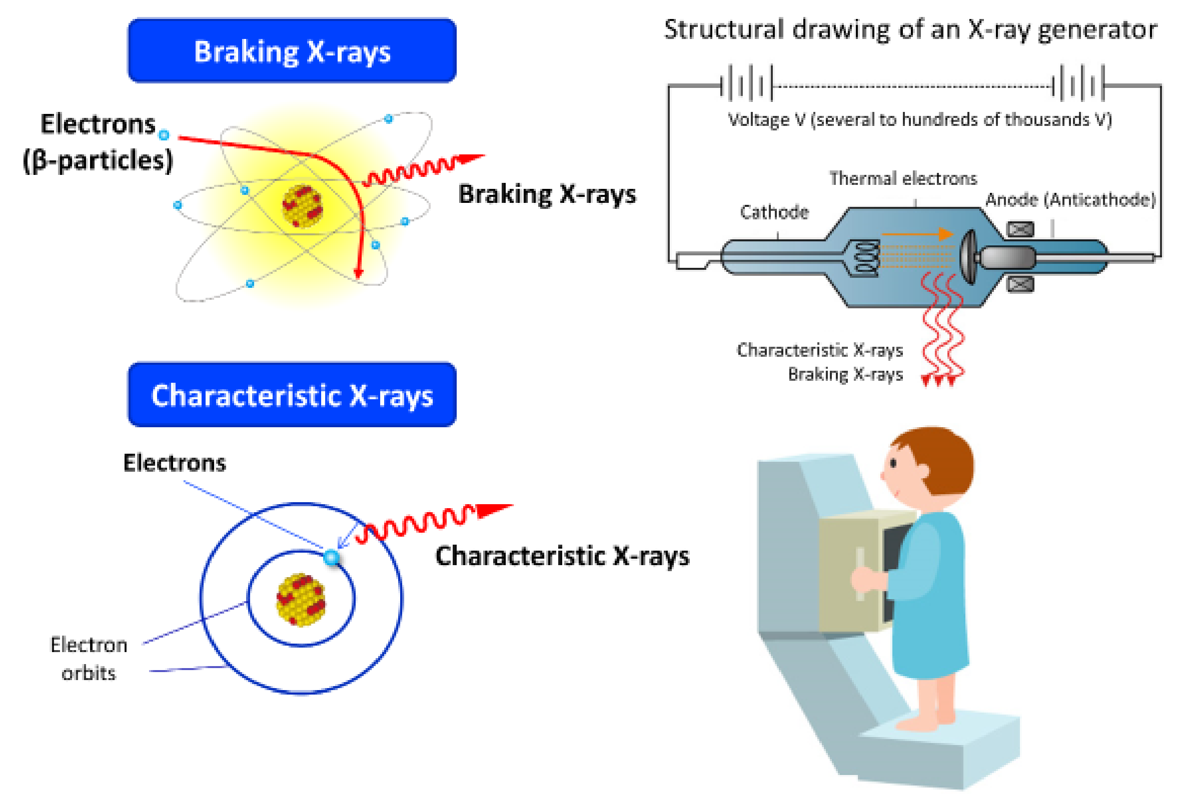
Radiation X-rays for Medical Use and Generators



X-ray examination uses X-rays generated in X-ray tubes. A high voltage is applied between a cathode and an anode (tungsten, molybdenum, copper, etc.) inside an X-ray tube so that thermal electrons migrate from the cathode to the anode in a vacuum at high speed. X-rays generated when the direction of propagation of the thermal electrons changes as they are attracted to the nucleus of the anode are called braking X-rays. When an electron is ejected from the inner electron orbit of the anode nucleus, another electron migrates (transitions) to this vacancy from the outer electron orbit. X-rays generated thereby are called characteristic X-rays. Most of the X-rays generated in X-ray tubes are braking X-rays.

Generation of X-rays stops when the X-ray tube is switched off.

X-ray generators used in the field of medicine are either for diagnosis or for treatment. The energy and amount of X-rays are adjusted to match the purpose of imaging and the part to be imaged. In chest roentgenography (diagnosis), the amount of radiation a patient receives in one imaging session is approx. 0.06 mSv.

(Related to p.63 of Vol. 1, “Exposure Dose from Natural and Artificial Radiation,” and p.76 of Vol. 1, “Radiation Doses from Medical Diagnosis”)

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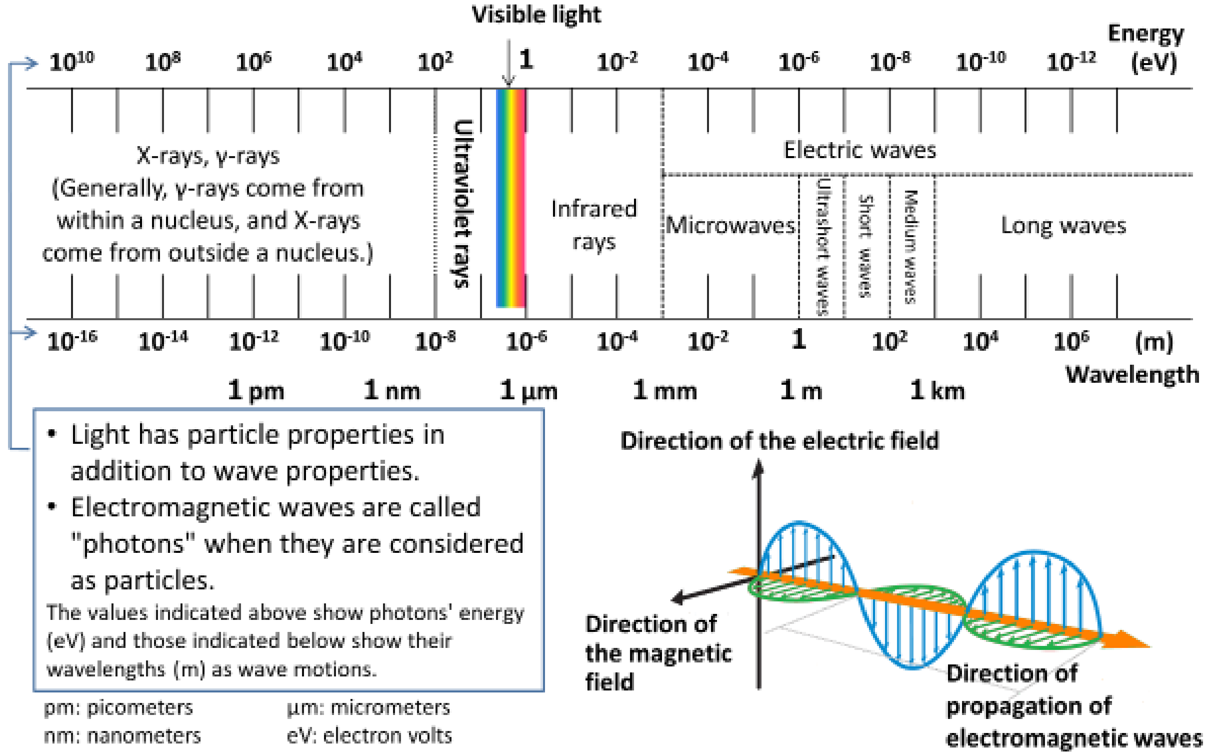
Radiation Types of Electromagnetic Waves



Electromagnetic waves are waves that propagate through space while an electric field and a magnetic field interact with each other. The shorter the wavelength is (the higher the frequency is), the higher the energy of an electromagnetic wave. The energy of radiation is expressed in electron volts (eV). 1 eV equals 1.6 x 10^{-19} Joule (J).

While X-rays and γ-rays differ in the mechanisms of how they are generated, they are both electromagnetic waves with high energy.

Thus, an electromagnetic wave sometimes behaves like a wave and may be expressed as a waveform perpendicular to its direction of propagation, as shown in the figure above.

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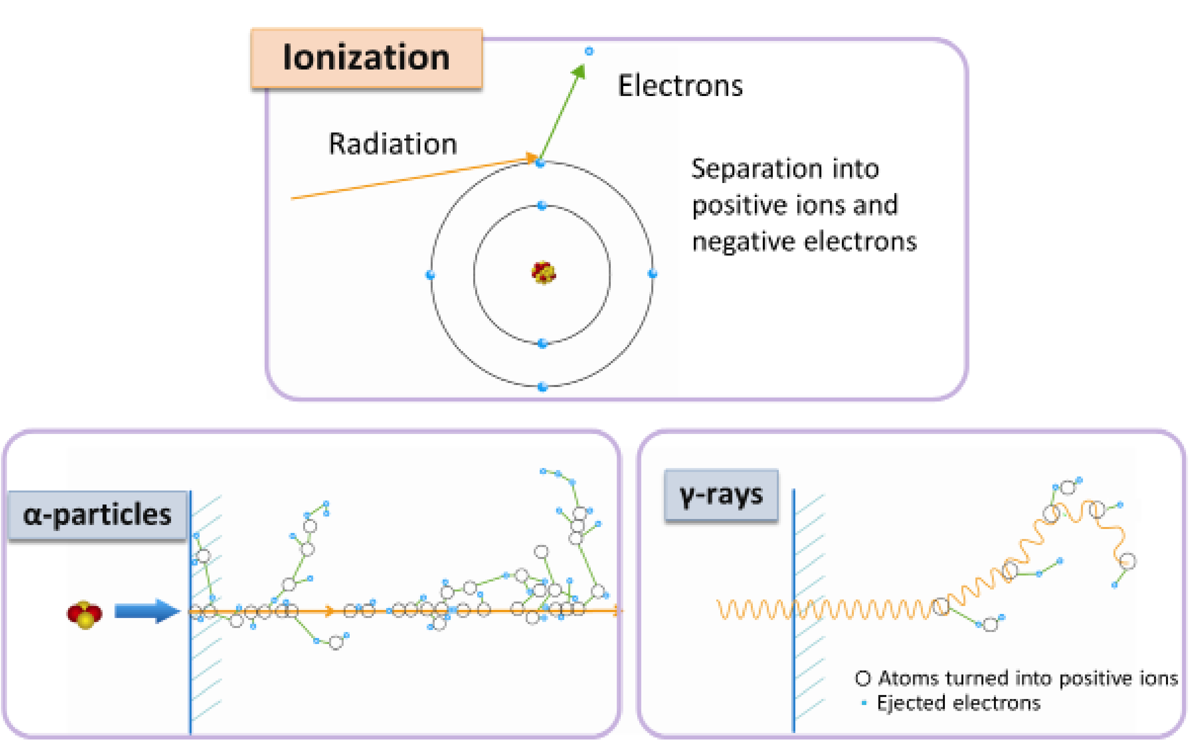
Radiation | Ionization of Radiation - Property of Ionizing Radiation



When radiation passes through a substance, its energy causes ejection of orbital electrons of the atoms that make up the substance, separating the atoms into positively charged atoms (or positive ion molecules) and free electrons. This is called ionization.

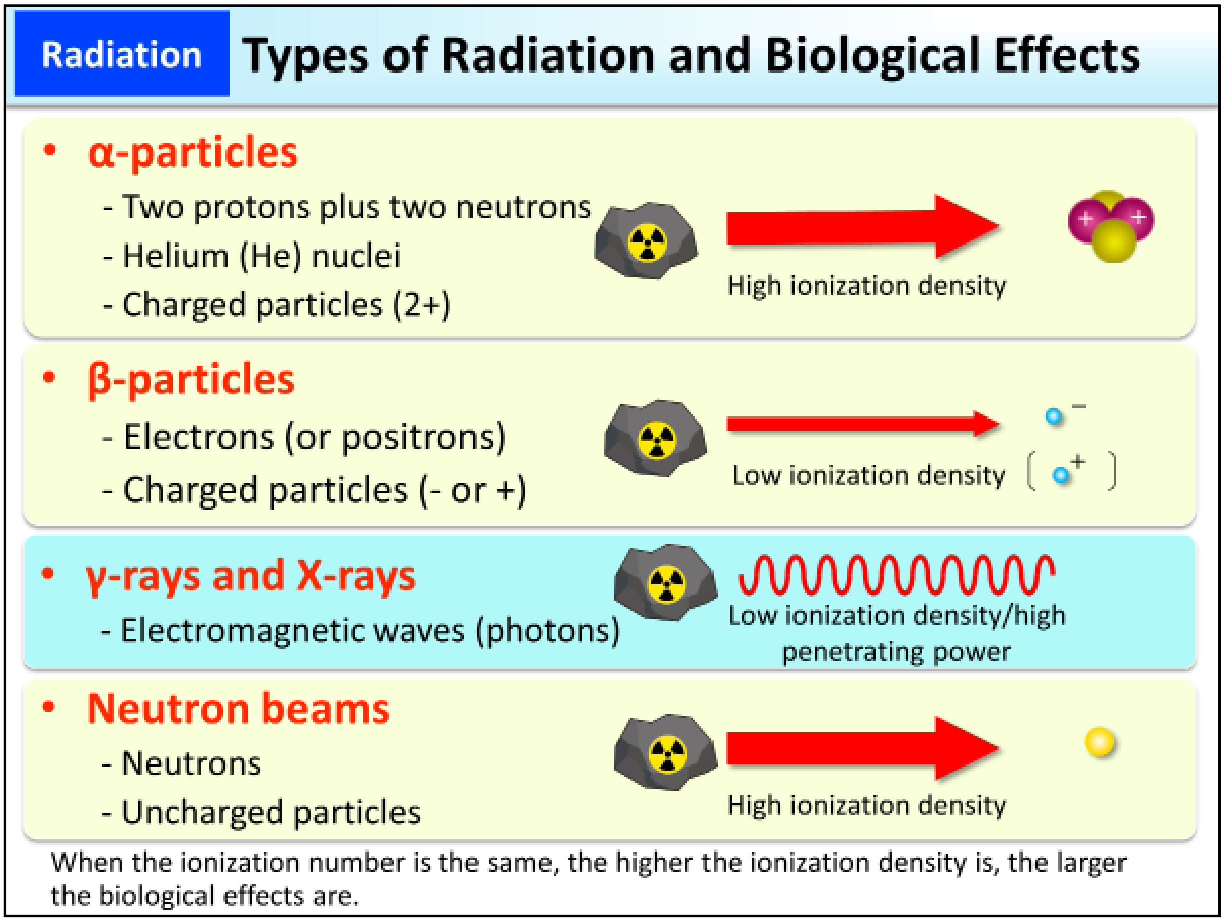
Ionizing radiation that causes ionization ionizes substances either directly or indirectly.

Charged particle beams, such as α-particles and β-particles, ionize substances directly. In particular, α-particles have high ionization density, causing ionization at a density hundreds of times as high as that of β-particles, etc.

γ-rays and X-rays ionize substances indirectly using secondary electrons generated through their interaction with the substances.

(Related to p.14 of Vol. 1, “Types of Radiation”)

Included in this reference material on March 31, 2013
Updated on March 31, 2015



External exposure to α-particles does not cause problems because α-particles have weak penetrating power against biological tissues and cannot penetrate the horny layer of the skin (layer of dead cells on the skin surface). However, internal exposure to any radioactive material that emits α-particles causes large amounts of local ionization, i.e., high-density ionization, within tissues, providing concentrated energy. This significantly damages DNA and has strong biological effects.

β-particles cause direct ionization of the substance it passes through, as do α-particles, but because of their low ionization density, their biological effects are not as strong as those of α-particles. Penetrating power of β-particles is also weak but stronger than that of α-particles, and external exposure to β-particles could affect the skin and subcutaneous tissues.

γ-rays and X-rays reach deep organs and tissues because of their strong penetrating power but do not have high ionization density. Their biological effects are similar to those of β-particles.

Since a neutron has a mass almost equal to that of a proton, a neutron beam stops efficiently when colliding with a proton. Since the human body contains a large amount of water, neutrons lose their energy as they collide with hydrogen nuclei (protons) that make up water molecules.

(Related to p.15 of Vol. 1, “Types of Ionizing Radiation,” and p.18 of Vol. 1, “Ionization of Radiation - Property of Ionizing Radiation”)

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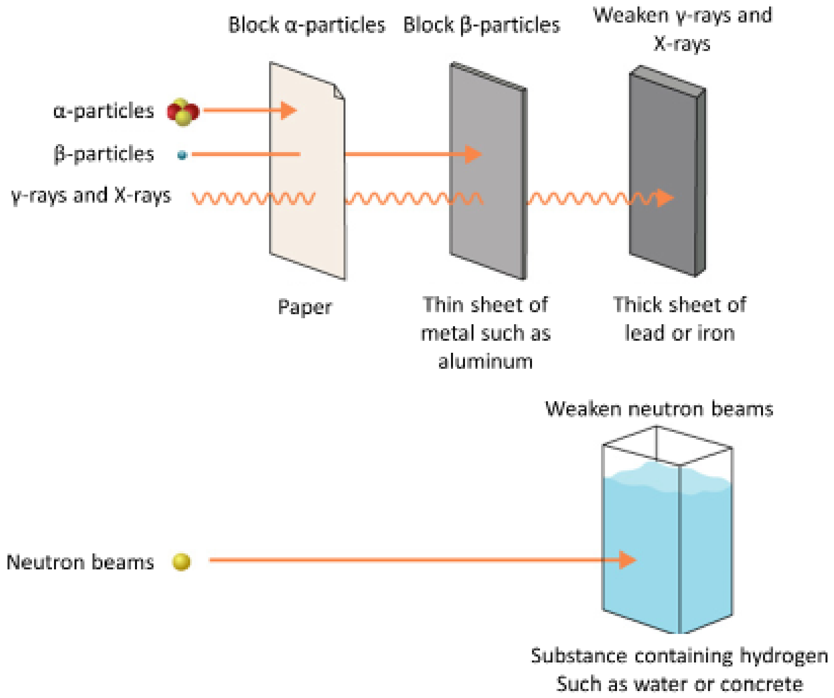
Radiation

Penetrating Power of Radiation

Radiation can be blocked by various substances.



Charged particles or electromagnetic waves interact with a substance, lose their energy (speed), and eventually stop.

Since α-particles cause a large amount of ionization, a sheet of paper is enough to stop them. β-particles travel several meters in the air, and a 1 cm thick plastic sheet or a 2-4 mm thick aluminum plate is enough to stop them, depending on how much energy they have. γ-rays and X-rays have higher penetrating power than α-particles or β-particles, travel several tens to hundreds of meters in the air (depending on their energy) and gradually lose their energy as they collide with atoms in the air. As γ-rays and X-rays can be shielded using thick plates of high-density lead or iron, those from radiation generators can be blocked using iron and the like.

Uncharged neutrons lose their energy through collision and are absorbed through interaction with substances. That is, neutrons lose their energy (speed) by directly colliding with nuclei that make up substances. They lose their energy most effectively by colliding with protons (hydrogen nuclei) that are almost equal in mass to them.

(Related to p.21 of Vol. 1, “Penetrating Power of Radiation within the Body”)

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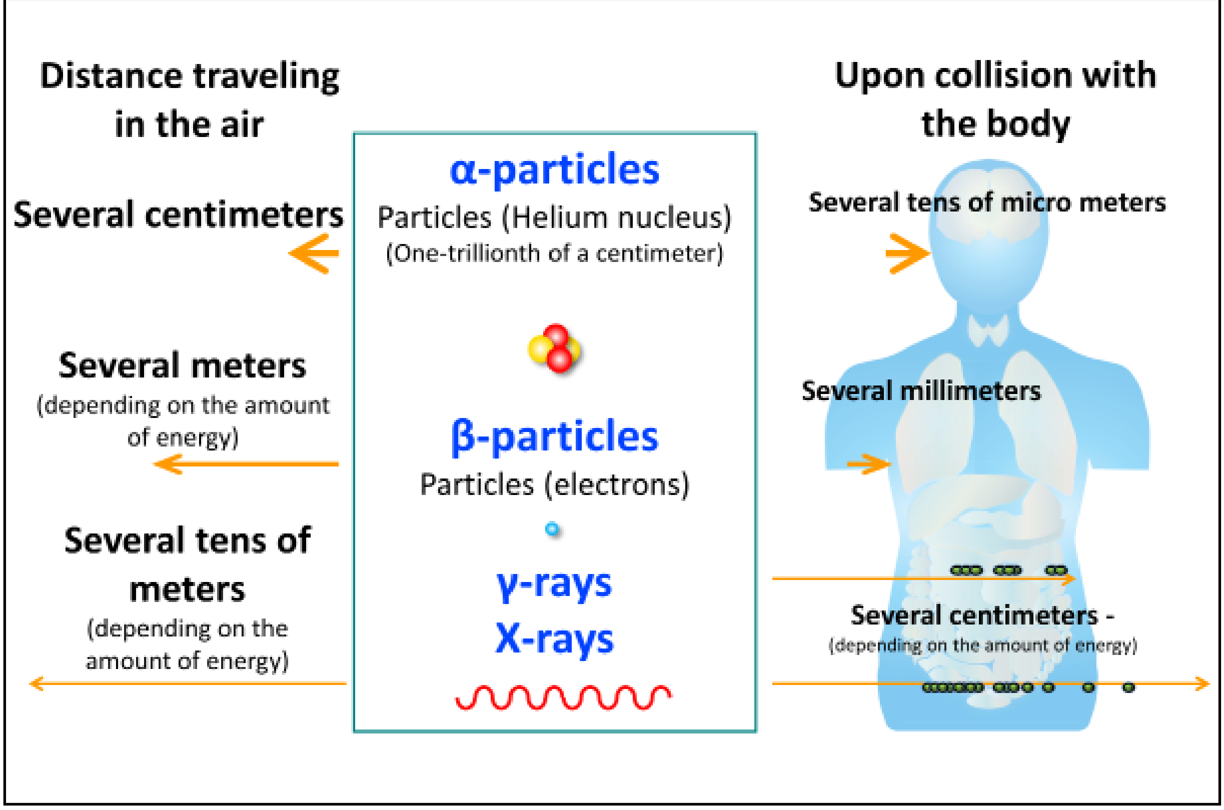
Updated on March 31, 2016

Radiation Penetrating Power of Radiation within the Body



The easiness to penetrate through the air or the human body varies depending on the types of radiation. Therefore, the types of radiation (α-particles, β-particles, or γ-rays) and radioactive materials (nuclides) that cause problems differ for external exposure and internal exposure.

α-particles can travel only several centimeters in the air and a sheet of paper is enough to stop them. In the case of external exposure, α-particles do not reach deeper than the layer of dead cells (horny layer) on the skin surface and do not cause effects. However, if an alpha-emitting radionuclide enters the body, it will provide energy intensively to nearby cells where it is deposited.

Since β-particles travel only several meters in the air, they hardly contribute to exposure when a radiation source is located away from the body. When the surface of the body is exposed to β-particles, their energy is imparted to the skin and subcutaneous tissues; when β-particles enter the body, their energy is imparted to a radius of several millimeters around the relevant spot.

γ-rays and X-rays have high penetrating power and travel several tens to hundreds of meters in the air. When they collide with the human body, they can reach deep into the body or sometimes pass through it. Their energy is imparted to the part they pass through. In X-ray examination, the parts of the body X-rays can easily pass through (lungs, etc.) appear in black while the parts they cannot easily pass through (bones, etc.) appear in white.
(Related to p.22 of Vol. 1, “Penetrating Power and Range of Effects on the Human Body”)

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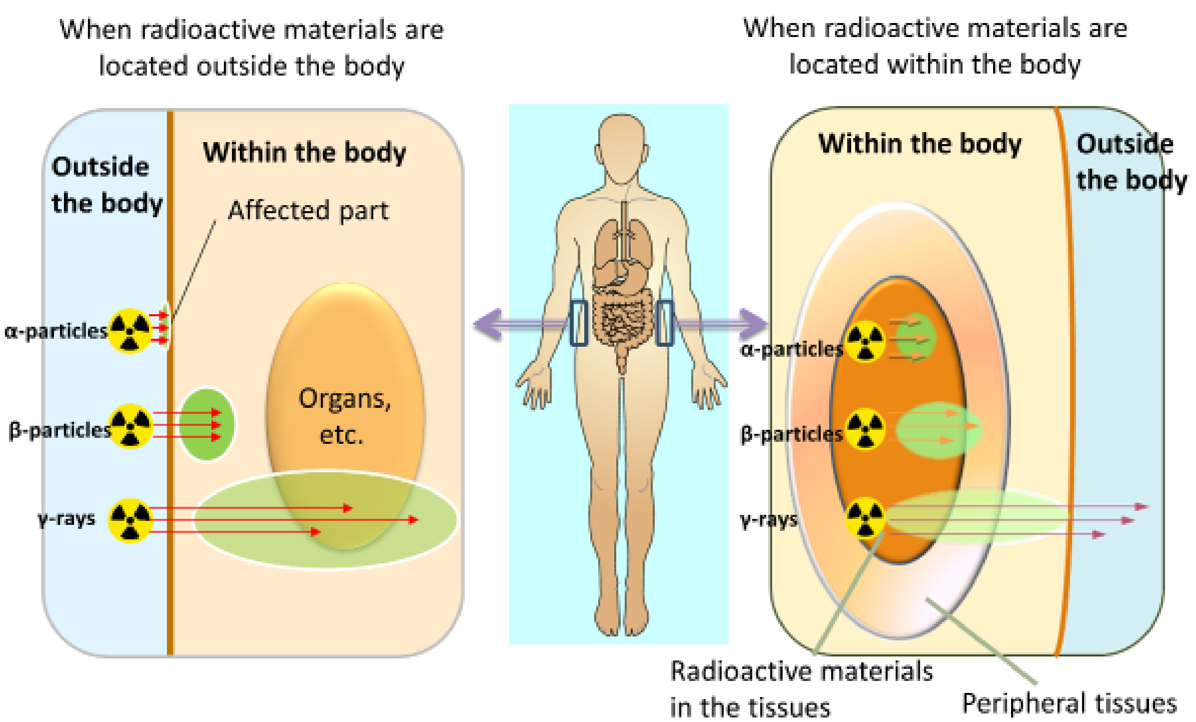
Radiation

Penetrating Power and Range of Effects on the Human Body



In the case of external exposure, α-particles do not have any effect as they stop at the horny layer on the surface of the body (the penetrating distance of α-particles is about several tens of micrometers). β-particles pass through the skin (their penetrating distance is about several millimeters) and can cause burn-like symptoms when doses are very high, but do not reach deep into the body. γ-rays reach important organs deep inside the body. Thus, the major concern in the case of external exposure is with γ-rays.

On the other hand, in the case of internal exposure, all radioactive materials that emit α-particles, β-particles, or γ-rays could affect cells within the body. Given the distance α-particles travel, their effects are confined to tissues where radioactive materials exist, but due to their significant biological effects, particular caution is required in relation to internal exposure. γ-rays can affect the entire body because they travel long distances.

Some radioactive materials such as uranium, once entering the human body, may also cause metallic toxicity, etc., in addition to causing internal exposure.
(Related to p.21 of Vol. 1, “Penetrating Power of Radiation within the Body”)

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