Radiation

Radiation is energy given off from atoms in the form of particles and waves. Radiation is everywhere–in, around, and above our world. Think of it as a natural energy force that surrounds us. Nuclear science is the study of the structure, properties, and interactions of atomic nuclei. Nuclear scientists calculate and measure the masses, shapes, sizes, and decays of nuclei at rest and in collisions. They ask questions such as: Why do nucleons stay in the nucleus? What combinations of protons and neutrons are possible? What happens when nuclei are compressed or rapidly rotated? What is the origin of the nuclei found on Earth?

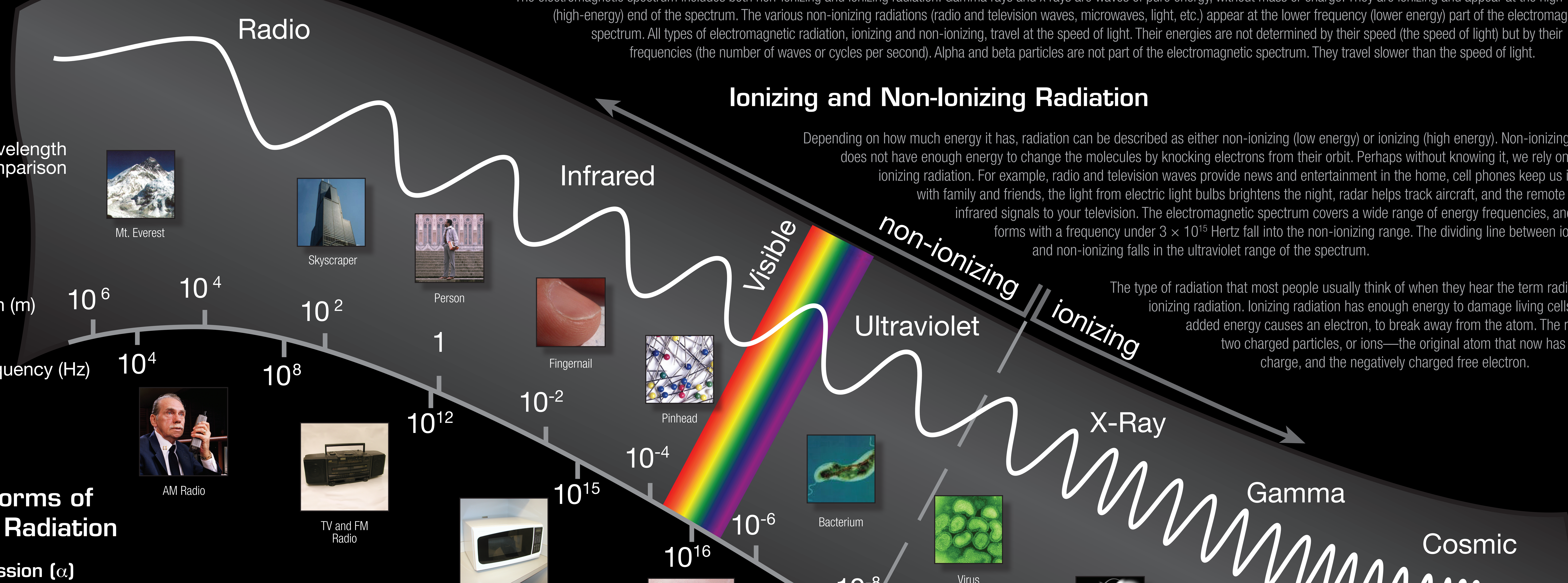
The Electromagnetic Spectrum

The electromagnetic spectrum includes both non-ionizing and ionizing radiation. Gamma rays and x rays are waves of pure energy, without mass or charge. They are ionizing and appear at the high-frequency (high-energy) end of the spectrum. The various non-ionizing radiations (radio and television waves, microwaves, light, etc.) appear at the lower frequency (lower energy) part of the electromagnetic spectrum. All types of electromagnetic radiation, ionizing and non-ionizing, travel at the speed of light. Their energies are not determined by their speed (the speed of light) but by their frequencies (the number of waves or cycles per second). Alpha and beta particles are not part of the electromagnetic spectrum. They travel slower than the speed of light.

Ionizing and Non-Ionizing Radiation

Depending on how much energy it has, radiation can be described as either non-ionizing (low energy) or ionizing (high energy). Non-ionizing radiation does not have enough energy to change the molecules by knocking electrons from their orbit. Perhaps without knowing it, we rely on non-ionizing radiation. For example, radio and television waves provide news and entertainment in the home, cell phones keep us in touch with family and friends, the light from electric light bulbs brightens the night, radar helps track aircraft, and the remote sends infrared signals to your television. The electromagnetic spectrum covers a wide range of energy frequencies, and those forms with a frequency under 3×10^{15} Hertz fall into the non-ionizing range. The dividing line between ionizing and non-ionizing falls in the ultraviolet range of the spectrum.

The type of radiation that most people usually think of when they hear the term radiation is ionizing radiation. Ionizing radiation has enough energy to damage living cells. The added energy causes an electron, to break away from the atom. The result is two charged particles, or ions—the original atom that now has a positive charge, and the negatively charged free electron.



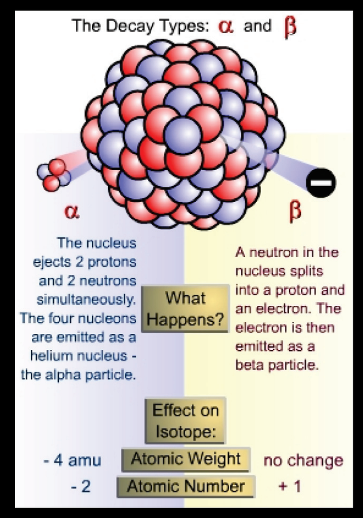
Other Forms of Ionizing Radiation

Alpha emission (α)

In alpha decay, the nucleus of an atom emits an alpha particle, which consists of two protons and two neutrons. This particle is equivalent to a helium nucleus ($^{4}_{2}He$). An example of alpha decay is shown in the following equation for radon-226:

$$^{226}_{88}Ra > ^{226}_{86}Rn + ^{4}_{2}He.$$

After alpha decay, the mass of the resulting nuclide is 4 units less, and the atomic number is 2 units less, than that of the parent nuclide. Therefore, the resulting atoms are different elements with different chemical properties than the original atoms. This change is known as transmutation.



Beta emission (β)

In beta decay, the nucleus emits a beta particle, which is similar to an electron, and an neutron is converted to a proton. This is represented by the equation:

$$^{1}_{0}n > ^{1}_{1}p + ^{0}_{-1}e \text{ (or } \beta^{-}).$$

As a result of these changes, the resulting nucleus will always have an atomic number that is one more than that of the original atom, but the mass of the transformed atom will stay virtually the same. An example of beta emission is the decay of carbon-14 to nitrogen:

$$^{14}_{6}C > ^{14}_{7}N + \beta^{-}.$$

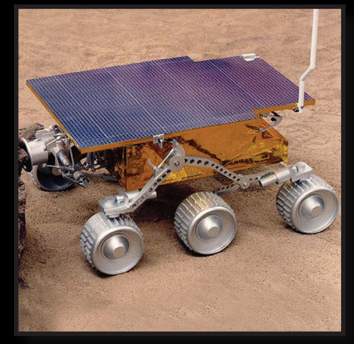
Applications

Radioactive Dating

Naturally occurring radioactive isotopes are used to date objects that were once living, such as wood. For example, from a study of artifacts found at the site, scientists determined that Stonehenge was built nearly 4,000 years ago.

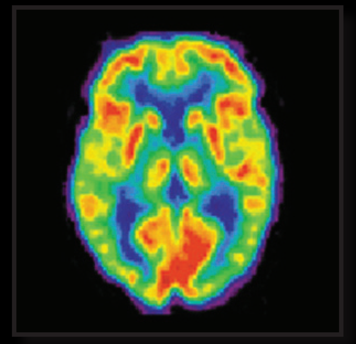
Nuclear Reactors

Nuclear reactors use fission to produce electric power. Reactors and most other nuclear applications generate radioactive waste. Disposal of this waste is a subject of current research.



Space Exploration

Sojourner used alpha particles to identify chemical elements present in Martian rocks. On Earth, nuclear reactions are used in many areas from criminal investigations to art authentication.



Nuclear Medicine

Radioactive isotopes are commonly used in the diagnosis and treatment of disease. Positron emitters are used in Positron Emission Tomography (PET) to generate images of brain activity.

The Harnessed Atom

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