Radioactivity and man

Radioactivity

Radioactivity is the phenomenon in which some unstable nuclei transform into others with the emission of particles. Radioactivity is as old as the Universe and is present everywhere: in the stars, in the Earth and in our own bodies. In fact, man has been exposed to radiation since when he appeared on Earth. Radioactivity was discovered at the end of the 19th Century thanks to the work of Henry Becquerel and Pierre and Marie Curie who in 1903 received the Nobel Prize in Physics for their important contribution to scientific knowledge. They discovered that certain minerals possessed the property of spontaneously emitting radiation: these minerals, such as uranium, radium and polonium, for example, were called “active” and the phenomenon regarding the emission of radiation was called “radioactivity”.

Atoms and matter

All matter that surrounds us is made up of atoms. Every atom consists of protons and neutrons, which together form the nucleus, surrounded by a cloud of negatively-charged electrons.

Within the atom, the nucleus is made up of positively charged protons and by neutrons that lack electric charge and are therefore neutral (as their name indicates). Atoms are electrically neutral because the number of protons is equal to the number of electrons. The total number of protons in the nucleus (and therefore of electrons in the outer cloud) determines the identity of a chemical element: for example, the chemical element with 8 protons is oxygen, the one with 26 protons is iron, the one with 79 protons is gold and the one with 92 protons is uranium.

Isotopes

A chemical element can have, besides the fixed number of protons that characterise it, a varying number of neutrons: in this case there will be different isotopes of the same element. For example, iron present in nature has four isotopes with 26 protons but with 28, 30, 31 and 32 neutrons respectively. Isotopes of the same element can be distinguished by their mass numbers (neutrons + protons): hence you can find iron-54, iron-56 etc.

There are about 90 elements that occur in nature (ranging from the lightest, hydrogen, to the heaviest, uranium) and nearly 270 isotopes. Among these elements, about twenty have only one stable isotope (for example, sodium, cobalt, arsenic and gold) while others have at least two stable isotopes (for example, chlorine has two, zinc has five and lead has ten). In addition to the isotopes present in nature (natural isotopes) nowadays there are a great number of artificial, man-made isotopes, such as cobalt-60 (27 protons, 33 neutrons), used in radiotherapy or plutonium-239 (94 protons, 145 neutrons) used as a nuclear fuel.

A question of stability

Almost all natural isotopes are stable contrary to artificial isotopes that are unstable, i.e. they tend to arrange themselves spontaneously in new nuclear structures that are energetically more favourable. The transformation of an isotope into another is called disintegration or decay, and unstable isotopes are known as radioactive isotopes (radioisotopes or radionuclides). This process of spontaneous disintegration of atomic nuclei, during which ionising radiation is emitted, is called radioactivity. Ionising radiation is any particulate or electromagnetic radiation capable of modifying the structure of matter with which it interacts. In the case of biological tissues, this interaction can damage the cells. In the majority of cases the damage is repaired by the normal defence mechanisms in the organism but at times the affected cells could be impaired with negative consequences on the health of the individuals exposed. The extent of the damage also depends on the magnitude and length of exposure.

The time taken for an isotope to decay can be short or very long. The half-life of a radioactive isotope is defined as the time it takes for half of the atoms of a pure sample of the isotope to undergo decay into another element. The half-life is a measure of the stability of an isotope: the shorter the half life, the less stable the atom is. For example, the half-life of uranium-238 (92 protons and 146 neutrons), one of the isotopes that has been present in the Earth’s crust since its formation, is 4.47 billion years. At present, the amount of uranium-238 left after decay is about half the original quantity present on Earth, which has been estimated to be about 4.5 billion years old.

How is radioactivity measured?

Radioactivity is measured in disintegrations per second and its unit of measure is the Becquerel (Bq), in honour of the physicist Henry Becquerel who discovered the spontaneous emission of radiation from uranium in 1896. As mentioned above, the radiation produced by the disintegration of radioisotopes interacts with matter, transferring energy. The magnitude and the gravity of the effects depend on the dose and the type of radiation received. For example, small doses of ultraviolet radiation from the Sun are harmless to man, but an excessive exposure can cause sun burns. The unit of measure of the absorbed dose is the gray (1 Gy = 1 joule absorbed by 1 kg of matter). To give a measure of the biological effects caused by radiation the concept of equivalent dose has been introduced. This allows the evaluation of the damage caused by the same dose of different types of ionising radiation. In this case, the unit of measure is the sievert (Sv). For a chest X-ray, 0.14 mSv are administered (mSv = millisievert, i.e. one thousandth of a Sv), for a mammography, 1mSv.

Exposure to radiation

Since his appearance on Earth, man has been exposed to natural radiation to which he has adapted perfectly. The dose of natural radiation to which each living organism is exposed every year is about 2.4 mSv. This natural radiation comes from two sources: the Earth, deriving from radionuclides present in the Earth's crust such as potassium-40, uranium, thorium and radon (the gas that is the largest component of natural radiation) and outer space, in the form of cosmic rays.

In addition to natural radiation, there is man-made radiation, which can be produced in different ways. The most important is radiation for medical diagnostic purposes and radiotherapy. Radioactive elements can also be released into the atmosphere as a result of atomic experiments and nuclear power plant accidents (e.g. Chernobyl).

Man can be exposed to radiation in two ways:

- external exposure (or irradiation) that occurs when the radiation source is outside the organism;
- internal exposure, or internal contamination, that occurs when an individual ingests or inhales radioisotopes.

Ionising radiation can have immediate or long-term effects on man. The former can be observed a short time after exposure to radiation and depending on the magnitude of the dose can be mild, such as nausea and vomiting, or more serious, such as damage to the hematopoietic tissue. Long-term effects include cancer and leukaemia.

Radioprotection

Once the harmful health effects of exposure to ionising radiation were ascertained, it became essential to formulate adequate protection measures. As a consequence radioprotection was born, a set of measures aimed at guaranteeing protection of workers, the population and the environment against the risks of ionising radiation.

The basic rules of radioprotection are the following:

- move away from the source of radiation, since the intensity of radiation decreases with increasing distance from the source (for example: nuclear power plants are surrounded by a "respect zone" which prevents the establishment of human activities in the immediate neighbourhood)
- interpose shielding material between the source and humans (for example: in nuclear plants, the protection of workers and the surrounding environment is ensured by radiation shields made of thick walls of lead, steel, concrete or other special materials)
- reduce the length of time of exposure to radiation to a minimum.

Source: ISPRA (ex A.N.P.A.)