# Radioactive isotope

## Introduction:

**Radioactive isotope**, also called **radioisotope, radionuclide,** or **radioactive nuclide**, any of several species of the same chemical element with different masses whose nuclei are unstable and dissipate excess energy by spontaneously emitting radiation in the form of alpha, beta, and gamma rays.

**Radioisotopes** are **radioactive isotopes** of an element. They can also be defined as atoms that contain an unstable combination of neutrons and protons, or excess energy in their nucleus.

Every chemical element has one or more radioactive isotopes. For example, hydrogen, the lightest element, has three isotopes with mass numbers 1, 2, and 3. Only hydrogen-3 (tritium), however, is a radioactive isotope, the other two being stable. More than 1,000 radioactive isotopes of the various elements are known. Approximately 50 of these are found in nature; the rest are produced artificially as the direct products of nuclear reactions or indirectly as the radioactive descendants of these products.

Radioactive isotopes have many useful applications. In medicine, for example, cobalt-60 is extensively employed as a radiation source to arrest the development of cancer. Other radioactive isotopes are used as tracers for diagnostic purposes as well as in research on metabolic processes. When a radioactive isotope is added in small amounts to comparatively large quantities of the stable element, it behaves exactly the same as the ordinary isotope chemically; it can, however, be traced with a Geiger counter or other detection device. Iodine-131 has proved effective in treating hyperthyroidism. Another medically important radioactive isotope is carbon-14, which is used in a breath test to detect the ulcer-causing bacteria *Heliobacter pylori*.

In industry, radioactive isotopes of various kinds are used for measuring the thickness of metal or plastic sheets; their precise thickness is indicated by the strength of the radiations that penetrate the material being inspected. They also may be employed in place of large X-ray machines to examine manufactured metal parts for structural defects. Other significant applications include the use of radioactive isotopes as compact sources of electrical power—e.g., plutonium-238 in spacecraft. In such cases, the heat produced in the decay of the radioactive isotope is converted into electricity by means of thermoelectric junction circuits or related devices.

## *How do radioisotopes occur?*

The unstable nucleus of a radioisotope can occur naturally, or as a result of artificially altering the atom. In some cases a nuclear reactor is used to produce radioisotopes, in others, a cyclotron. Nuclear reactors are best-suited to producing neutron-rich radioisotopes, such as molybdenum-99, while cyclotrons are best-suited to producing proton-rich radioisotopes, such as fluorine-18.

The best known example of a naturally-occurring radioisotope is **uranium**. All but 0.7 per cent of naturally-occurring uranium is uranium-238; the rest is the less stable, or more radioactive, uranium-235, which has three fewer neutrons in its nucleus.

# *Radioactive decay*

Atoms with an unstable nucleus regain stability by shedding excess particles and energy in the form of radiation. The process of shedding the radiation is called **radioactive decay**. The radioactive decay process for each radioisotope is unique and is measured with a time period called a **half-life**. One half-life is the time it takes for half of the unstable atoms to undergo radioactive decay.

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## How are radioisotopes used?

Radioisotopes are an essential part of **radiopharmaceuticals**. In fact, they have been used routinely in medicine for more than 30 years. On average, one in every two Australians can expect, at some stage in their life, to undergo a nuclear medicine procedure that uses a radioisotope for diagnostic or therapeutic purposes.

Some radioisotopes used in nuclear medicine have short half-lives, which means they decay quickly and are suitable for diagnostic purposes; others with longer half-lives take more time to decay, which makes them suitable for therapeutic purposes.

Industry uses radioisotopes in a variety of ways to improve productivity and gain information that cannot be obtained in any other way.

Radioisotopes are commonly used in **industrial radiography**, which uses a gamma source to conduct stress testing or check the integrity of welds. A common example is to test aeroplane jet engine turbines for structural integrity.

Radioisotopes are also used by industry for gauging (to measure levels of liquid inside containers, for example) or to measure the thickness of materials.

Radioisotopes are also widely used in **scientific research** and are employed in a range of applications, from tracing the flow of contaminants in biological systems to determining metabolic processes in small Australian animals.

They are also used on behalf of international nuclear safeguards agencies to detect clandestine nuclear activities from the distinctive radioisotopes produced by weapons programs.

## What is a radioactive source?

A sealed radioactive source is an encapsulated quantity of a radioisotope used to provide a beam of ionising radiation. Industrial sources usually contain radioisotopes that emit gamma rays or X-rays.

## What are some commonly-used radioisotopes?

Radioisotopes are used in a variety of applications in medical, industrial, and scientific fields. Some radioisotopes commonly-used in industry and science can be found in the tables below. Medical radioisotopes are described in the next section.

## Radioisotopes in medicine

Nuclear medicine uses small amounts of radiation to provide information about a person's body and the functioning of specific organs, ongoing biological processes, or the disease state of a specific illness. In most cases the information is used by physicians to make an accurate diagnosis. In certain cases radiation can be used to treat diseased organs or tumours.

## How are medical radioisotopes made?

Medical radioisotopes are made from materials bombarded by neutrons in a **reactor**, or by protons in an accelerator called a **cyclotron**. ANSTO uses both of these methods. Radioisotopes are an essential part of radiopharmaceuticals. Some hospitals have their own cyclotrons, which are generally used to make radiopharmaceuticals with short half-lives of seconds or minutes.

## What are radiopharmaceuticals?

A **radiopharmaceutical** is a molecule that consists of a radioisotope tracer attached to a pharmaceutical. After entering the body, the radio-labelled pharmaceutical will accumulate in a specific organ or tumour tissue. The radioisotope attached to the targeting pharmaceutical will undergo decay and produce specific amounts of radiation that can be used to diagnose or treat human diseases and injuries. The amount of radiopharmaceutical administered is carefully selected to ensure the safety of each patient.

## Common radiopharmaceuticals

About 25 different radiopharmaceuticals are routinely used in Australia's nuclear medicine centres.

The most common is **technetium-99m**, which has its origins as uranium silicide sealed in an aluminium strip and placed in the OPAL reactor's neutron-rich reflector vessel surrounding the core. After processing, the resulting molybdenum-99 precursor is removed and placed into devices called technetium generators, where the molybdenum-99 decays to technetium-

99m. These generators are distributed by ANSTO to medical centres throughout Australia and the near Asia Pacific region.

A short half-life of 6 hours, and the weak energy of the gamma ray it emits, makes technetium-99m ideal for imaging organs of the body for disease detection without delivering a significant radiation dose to the patient. The generator remains effective for several days of use and is then returned to ANSTO for replenishment.

Another radiopharmaceutical produced in OPAL is **iodine-131**. With a half-life of eight days, and a higher-energy beta particle decay, iodine-131 is used to treat thyroid cancer. Because the thyroid gland produces the body's supply of iodine, the gland naturally accumulates iodine-131 injected into the patient. The radiation from iodine-131 then attacks nearby cancer cells with minimal effect on healthy tissue.