Radionuclide:

A **radionuclide** (**radioactive nuclide**, **radioisotope** or **radioactive isotope**) is an atom that has excess nuclear energy, making it unstable. This excess energy can be used in one of three ways:

(i) emitted from the nucleus as gamma radiation;

(ii) transferred to one of its electrons to release it as a conversion electron; or

(iii) used to create and emit a new particle (alpha particle or beta particle) from the nucleus.

During those processes, the radionuclide is said to undergo radioactive decay. These emissions are considered ionizing radiation because they are powerful enough to liberate an electron from another atom. The radioactive decay can produce a stable nuclide or will sometimes produce a new unstable radionuclide which may undergo further decay.

Radioactive decay is a random process at the level of single atoms: it is impossible to predict when one particular atom will decay. However, for a collection of atoms of a single element the decay rate, and thus the half-life ($t_{1/2}$) for that collection, can be calculated from their measured decay constants. The range of the half-lives of radioactive atoms has no known limits.

Methods of analysis of Radionuclide:

Radionuclides occur naturally or are artificially produced in nuclear reactors, cyclotrons, particle accelerators or radionuclide generators.

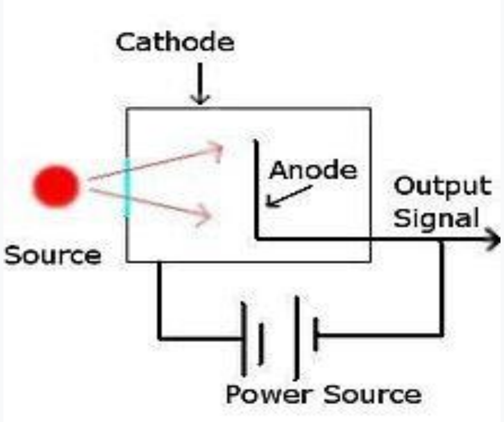
Synthetic radionuclides are deliberately synthesised using nuclear reactors, particle accelerators or radionuclide generators:

- As well as being extracted from nuclear waste, radioisotopes can be produced deliberately with nuclear reactors, exploiting the high flux of neutrons present. These neutrons activate elements placed within the reactor. A typical product from a nuclear reactor is iridium-192. The elements that have a large propensity to take up the neutrons in the reactor are said to have a high neutron cross-section.
- Particle accelerators such as cyclotrons accelerate particles to bombard a target to produce radionuclides. Cyclotrons accelerate protons at a target to produce positron-emitting radionuclides, e.g. fluorine-18.
- Radionuclide generators contain a parent radionuclide that decays to produce a radioactive daughter. The parent is usually produced in a nuclear reactor. A typical example is the technetium-99m generator used in nuclear medicine. The parent produced in the reactor is molybdenum-99.

Radiation detectors:

(i) Gas ionization detectors

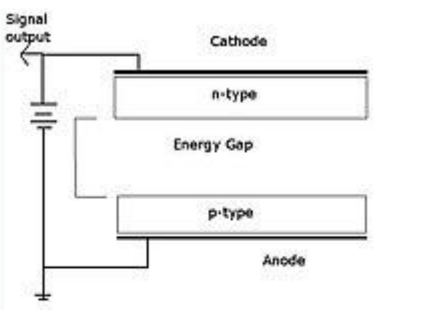
Gaseous ionization detectors collect and record the electrons freed from gaseous atoms and molecules by the interaction of radiation released by the source. A voltage potential is applied between two electrodes within a sealed system. Since the gaseous atoms are ionized after they interact with radiation they are attracted to the anode which produces a signal. It is important to vary the applied voltage such that the response falls within a critical proportional range.



Schematic of an ionization detector

(ii) Solid-state detectors

The operating principle of Semiconductor detectors is similar to gas ionization detectors: expect instead of ionization gas atoms, free electrons and holes are produced which create a signal at the electrodes. The advantage of solid-state detectors is the greater resolution of the resultant energy spectrum. Usually NaI (Tl) detectors are used; for more precise applications Ge (Li) and Si (Li) detectors have been developed. For extra sensitive measurements high-pure germanium detectors are used under a liquid nitrogen environment.



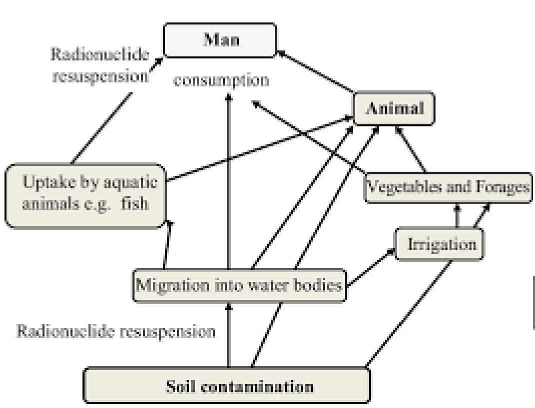
Schematic of a solid-state detector

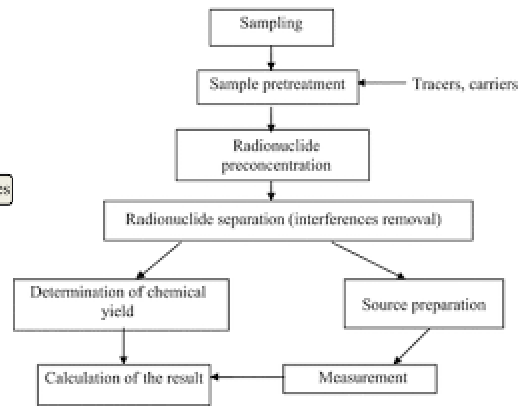
(iii) Scintillation detectors

Scintillation detectors uses a photo luminescent source (such as ZnS) which interacts with radiation. When a radioactive particle decays and strikes the photo luminescent material a photon is released. This photon is multiplied in a photomultiplier tube which converts light into an electrical signal. This signal is then processed and converted into a channel. By comparing the number of counts to the energy level (typically in keV or MeV) the type of decay can be determined.

Chemical separation techniques:

Due to radioactive nucleotides have similar properties to their stable, inactive, counterparts similar analytical chemistry separation techniques can be used. These separation methods include precipitation, Ion Exchange, Liquid-Liquid Extraction, Solid Phase Extraction, Distillation, and Electrodeposition.





Uses:

Radionuclides are used in two major ways: either for their radiation alone (irradiation, nuclear batteries) or for the combination of chemical properties and their radiation (tracers, biopharmaceuticals).

- In biology, radionuclides of carbon can serve as radioactive tracers because they are chemically very similar to the nonradioactive nuclides, so most chemical, biological, and ecological processes treat them in a nearly identical way. One can then examine the result with a radiation detector, such as a Geiger counter, to determine where the provided atoms were incorporated. For example, one might culture plants in an environment in which the carbon dioxide contained radioactive carbon; then the parts of the plant that incorporate atmospheric carbon would be radioactive. Radionuclides can be used to monitor processes such as DNA replication or amino acid transport.
- In nuclear medicine, radioisotopes are used for diagnosis, treatment, and research. Radioactive chemical tracers emitting gamma rays or positrons can provide diagnostic information about internal anatomy and the functioning of specific organs, including the human brain. This is used in some forms of tomography: single-photon emission computed tomography and positron emission tomography (PET) scanning and Cherenkov luminescence imaging. Radioisotopes are also a method of treatment in hemopoietic forms of tumors; the success for treatment of solid tumors has been limited. More powerful gamma sources sterilise syringes and other medical equipment.
- In food preservation, radiation is used to stop the sprouting of root crops after harvesting, to kill parasites and pests, and to control the ripening of stored fruit and vegetables.
- In industry, and in mining, radionuclides are used to examine welds, to detect leaks, to study the rate of wear, erosion and corrosion of metals, and for on-stream analysis of a wide range of minerals and fuels.

- In spacecraft, radionuclides are used to provide power and heat, notably through radioisotope thermoelectric generators (RTGs).
- In astronomy and cosmology, radionuclides play a role in understanding stellar and planetary process.
- In particle physics, radionuclides help discover new physics (physics beyond the Standard Model) by measuring the energy and momentum of their beta decay products.
- In ecology, radionuclides are used to trace and analyze pollutants, to study the movement of surface water, and to measure water runoffs from rain and snow, as well as the flow rates of streams and rivers.
- In geology, archaeology, and paleontology, natural radionuclides are used to measure ages of rocks, minerals, and fossil materials.