Health Physics Society
Fact Sheet
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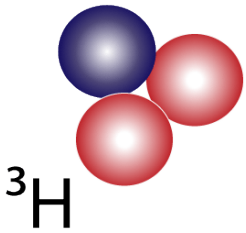
Health Physics Society
Specialists in Radiation Safety

# Tritium




## *General information*

Tritium is the only *radioactive isotope*[1] of hydrogen and it is commonly represented by the chemical symbol H-3, $^3H$, or simply T. Being *radioactive* causes tritium to undergo a process of *radioactive decay*. During this decay process, the tritium atom transforms into a nonradioactive helium atom and, in the process, emits a form of *ionizing radiation* known as a *beta particle*. The emission of this beta particle during the decay process is what makes tritium a potentially hazardous material.

The chemical behavior of tritium is the same as that of hydrogen. This means that tritium, just like stable hydrogen, can exist in a gaseous state or, more commonly, in the form of water, $H_20$. In fact, tritium atoms have a tendency to replace one or both of the stable hydrogen atoms in water to become a part of the water molecule. The resulting compound is known as tritiated water, with the chemical formula HTO or $T_2O$. Tritiated water is colorless and odorless, just like regular water, and can exist alongside regular water molecules. Given the chemical properties of tritium and the fact that roughly two-thirds of human body mass is composed of water, it is very common for tritium to exist within the human body.

## *Biological and health effects*

The half-life of tritium is 12.3 years; for a given amount of tritium, half the atoms will undergo radioactive decay (emitting the beta particle discussed above) in 12.3 years. The beta particle that is emitted by tritium has a very low energy. As a result, these particular beta particles can only travel about 6 millimeters (mm) in air. A typical beta particle not from tritium can travel a meter or more. In human tissue, tritium's beta particle cannot penetrate the typical thickness of the dead layer of skin that exists on the outside of the human body. For this reason, the beta particle emitted by tritium is generally only considered to be hazardous if a large quantity of tritium is, or has the potential to be, taken into the body by inhalation, skin absorption, and ingestion of tritiated water. Tritium mostly behaves just like ordinary water in the body, distributing equally throughout the body's water and excreted in the same ways as water, such as in the forms of urine and sweat.

Tritium does not have chemically toxic effects and its potential to be hazardous to human health is solely because it emits ionizing radiation (the beta particle). This radiation exposure may very slightly increase the probability that a person will develop cancer during his or her lifetime. However, it is important to understand that an individual's cancer risk is affected by many factors, including heredity (passed down from your parents and grandparents), lifestyle, smoking, and numerous environmental factors, of which radiation exposure is one of many. The rate of cancer is also considerable, with approximately 45% of individuals being diagnosed with cancer in their lifetimes (ACS 2020). It is also important to note that everyone is exposed to radiation every day and, on average, the vast majority of an individual's radiation exposure in the United States results from medical procedures and naturally occurring radiation. In fact, humans have always been exposed to radiation and our bodies have mechanisms that act to repair damage to our cells that is caused by radiation. While it has been determined that exposure to high levels of ionizing radiation can cause cancer, this effect has not been observed for lower doses on the order of background radiation doses, including with tritium (HPS 2019).

[1] Words in italics are defined in the Glossary on page 3.

## *Applications*


***Tritium Exit Sign***
*Photo courtesy of ANS Nuclear Café*

Tritium is found in a range of common consumer items because it can be used in combination with phosphors to make materials that are self-luminous (glow in the dark), meaning that these items will produce light without any electrical power supply. It is important to understand that tritium itself does not produce visible light or glow in the dark and that the tritium in these devices only serves to energize the light-producing phosphors in these items. These items include gun sights, watch dials, key chains, and exit signs. In general, the larger the device, the more tritium it likely contains. In any case, the thin plastic or glass cover blocks all the beta radiation from escaping, yet allows the benefit of the illumination to be seen.

Tritium is a prospective fuel in the effort to develop commercially viable nuclear fusion reactors. Tritium is also a critical component in modern nuclear weapons, and an inventory of tritium is maintained for this purpose. In the life sciences, tritium is often bound to *organic* compounds and used as a radioactive tracer to study the metabolism of that compound in a biological system, such as an organism or cell.

## *Tritium in our environment*

Tritium exists throughout our worldwide environment in the atmosphere, ground water, soil, rivers, lakes, streams, and oceans from both natural and man-made production. It is generated naturally in the atmosphere through interactions between nitrogen in the air and radiations originating from outer space, known as cosmic rays. Tritium is also produced by man-made nuclear reactions. These are generally limited to those that occur within a nuclear reactor, during the detonation of a nuclear weapon, or in particle accelerators. Tritium's concentration in the environment is ever-changing, increasing with natural processes and human activities and decreasing through radioactive decay.

Over time, tritium released into the environment becomes distributed by the same process that transports water (referred to as the hydrological cycle or water cycle). This process tends to dilute tritium releases by spreading them out, largely preventing any accumulation in the environment. However, the distribution and dilution of tritium is not immediate and, therefore, individuals in close proximity to tritium releases are generally expected to be exposed to a greater amount than others who are farther away. In practice, this means that organizations that safely and legally release small amounts of tritium, such as nuclear power plants, are required to ensure that their releases will not cause any member of the public an exposure above the public dose limit. If severely damaged, some self-luminous consumer products–such as exit signs that contain tritium–can release tritium to the environment as well. This means it is important to dispose of these products in accordance with local and state regulations.

## *Regulations and protection*

In the United States, the primary federal regulatory agencies that are concerned with tritium are the Environmental Protection Agency (EPA), Nuclear Regulatory Commission (NRC), and Department of Energy (DOE). Additionally, many individual states now run their own NRC-sponsored regulatory programs for radioactive materials. The DOE and Department of Defense manage the tritium used in nuclear weapons. The regulations in place are aimed at limiting the amount of radiation dose to any individual member of the public as well as that which radiation workers can receive in the occupational setting.

Since tritium exists throughout the environment, the protection of the general public with regard to tritium is largely the responsibility of the companies and entities that produce or possess tritium and the government agencies that regulate them. It is required for an organization that may possess items such as tritium exit signs to ensure that they are maintained and disposed of properly.

## *Detection*

Ionizing radiation can be detected using instruments, but since tritium emits only a very weak beta particle it is very difficult to detect with normal radiation-detection instrumentation. In fact, the most common portable radiation-detection instruments, such as Geiger counters, are usually not capable of detecting tritium. The most reliable and widespread method for detecting tritium is known as liquid scintillation counting, typically available only in laboratory spaces. Tritium can also be "sniffed" or introduced into an ionization chamber that can measure radiation dose rates. The difficulty in detecting tritium has led the EPA and NRC to limit tritium releases, as discussed above.

## *Summary*

Tritium is a radioactive form of hydrogen that is produced by both natural and man-made processes. It mostly exists in the form of tritiated water and generally behaves as such in both the environment and the body. For this reason, tritium is widely dispersed in the environment, a very small addition to other radiation background levels. Due to its chemical properties and weak radioactive emissions, tritium is considered one of the least harmful radionuclides. Despite this fact, it is important to be aware that tritium is used in some common devices, such as tritium exit signs, that can release tritium if they are improperly disposed of or damaged.

## *Glossary*

*Beta Particle*
A type of radiation, identical to an electron, emitted from the nucleus of an atom during the process of radioactive beta decay.

*Ionizing Radiation*
Electromagnetic waves or particles of high-enough energy to create ions, that is, to remove electrons from an atom.

*Organic*
A compound containing carbon and generally involved in the chemistry of living organisms.

*Radiation*
Energy in the form of electromagnetic waves or particles.

*Radioactive*
A property of material that tends to undergo spontaneous radioactive decay and can result in the emission of ionizing radiation.

*Radioactive Decay*
The process by which an unstable atomic nucleus emits radiation and transforms into a different element or into a lower-energy state of the same element.

*Radioactive Isotope*
Unstable (radioactive) atoms of the same element that have nuclei containing the same number of protons but different numbers of neutrons.

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The Health Physics Society is a nonprofit scientific professional organization whose mission is excellence in the science and practice of radiation safety. Formed in 1956, the Society has approximately 3,500 scientists, physicians, engineers, lawyers, and other professionals. Activities include encouraging research in radiation science, developing standards, and disseminating radiation safety information. The Society may be contacted at 950 Herndon Parkway, Suite 450, Herndon, VA 20170; phone: 703-790-1745; fax: 703-790-2672; email: HPS@BurkInc.com.