**Heavy Water**

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*Not to be confused with hard water or tritiated water.*

|  |  |
| --- | --- |
| **Deuterium oxide** | |
|  | |
| **IUPAC name**  [2H]2-water | |
| **Other names**  Deuterium monoxide Deuterium oxide, Water-*d*2 | |
| **Identifiers** | |
| CAS number | 7789-20-0 Y |
| PubChem | 24602 |
| ChemSpider | 23004 Y |
| UNII | J65BV539M3 Y |
| EC number | 232-148-9 |
| KEGG | D03703 Y |
| MeSH | Deuterium+oxide |
| ChEBI | CHEBI:41981 Y |
| ChEMBL | CHEMBL1232306 N |
| RTECS number | ZC0230000 |
| Gmelin Reference | 97 |
| Jmol-3D images | Image 1 |
| **Properties** | |
| Molecular formula | 2H2O |
| Molar mass | 20.0276 g mol−1 |
| Exact mass | 20.023118178 g mol−1 |
| Appearance | Very pale blue, transparent liquid |
| Density | 1.107 g cm−3 |
| Melting point | 3.8 °C, 277 K, 39 °F |
| Boiling point | 101 °C, 374 K, 214 °F |
| Solubility in water | Reacts |
| log P | −1.38 |
| Viscosity | 0.00125 Pa s (at 20 °C) |
| Dipole moment | 1.87 D |
| **Hazards** | |
| MSDS | External MSDS |
| NFPA 704 | 0  1  1 |
| N (verify) (what is: Y/N?) Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa) | |
| Infobox references | |

**Heavy water** is water highly enriched in the hydrogen isotope deuterium; e.g., heavy water used in CANDU reactors is 99.75% enriched by hydrogen atom-fraction (in ordinary water, the deuterium-to-hydrogen ratio is about 156 deuterium atoms per million hydrogen atoms). The term "heavy water" today is somewhat colloquial, and pure heavy water for research and commercial use is generally commercially offered, and referred to, as **deuterium oxide.** It is not radioactive. It is about 11% denser than water, but otherwise, is physically and chemically similar. However, the difference (especially the biological properties) is larger than in most other isotope-substituted compounds because deuterium is unique among heavy stable isotopes in being twice as heavy as the lightest isotope. This difference increases the strength of water's hydrogen-oxygen bond, and this in turn is enough to cause differences that are important to some biochemical reactions. The human body naturally contains deuterium equivalent to five grams of heavy water, which is harmless. When a large fraction of water (> 50%) in higher organisms is replaced by heavy water, however, the result is cell dysfunction and death.

Heavy water was first produced in 1932, a few months after the discovery of deuterium. With the discovery of nuclear fission in late 1938, and the need for a neutron moderator that captured few neutrons, heavy water became an important component of early nuclear energy programs during World War II (1939–1945). Partly because of Nazi Germany's overreliance on heavy water, it didn't produce a functioning reactor for the duration of the war. Since then, heavy water is an essential component in some types of reactor, either for power or for nuclear-weapons isotopes, such as plutonium-239. These heavy water reactors have the advantage of being able to run on natural uranium without the use of hazardous graphite moderators. Most modern reactors use enriched uranium and normal "light water" (H2O) moderator.

**Other meanings**

**Semi-heavy water**

**Semi-heavy water**, HDO, exists whenever there is water with light hydrogen (protium, 1H) and deuterium (D or 2H) in the mix. This is because hydrogen atoms (hydrogen-1 and deuterium) are rapidly exchanged between water molecules. Water containing 50% H and 50% D in its hydrogen actually contains about 50% HDO and 25% each of H2O and D2O, in dynamic equilibrium. In regular water, about 1 molecule in 3,200 is HDO (one hydrogen in 6,400 is D). By comparison, heavy water D2O occurs at a proportion of about 1 molecule in 41 million (i.e., one in 6,4002). This makes semi-heavy water far more common than "normal" heavy water.

**Heavy-oxygen water**

Water enriched in the heavier oxygen isotopes 17O and 18O is also commercially available, e.g. for use as a non-radioactive isotopic tracer. It qualifies as 'heavy water' in being denser than normal water (H218O is as dense as D2O, H217O is halfway between H2O and D2O), but is rarely called heavy water, since it doesn't contain the deuterium which gives D2O its unusual nuclear and biological properties. It is more expensive than D2O due to the more difficult separation of 17O and 18O.

**Physical properties (with comparison to light water)**

|  |  |  |
| --- | --- | --- |
| **Property** | **D2O (Heavy water)** | **H2O (Light water)** |
| Freezing point (°C) | 3.82 | 0.0 |
| Boiling point (°C) | 101.4 | 100.0 |
| Density at STP (g/mL) | 1.1056 | 0.9982 |
| Temp. of maximum density (°C) | 11.6 | 4.0 |
| Dynamic viscosity (at 20 °C, mPa·s) | 1.25 | 1.005 |
| Surface tension (at 25 °C, μJ) | 7.193 | 7.197 |
| Heat of fusion (cal/mol) | 1,515 | 1,436 |
| Heat of vaporization (cal/mol) | 10,864 | 10,515 |
| pH (at 25 °C) | 7.41 (sometimes "pD") | 7.00 |
| Refractive index (at 20 °C, 0.5893 μm) | 1.32844 | 1.33335 |

*Physical properties obvious by inspection:* Heavy water is 10.6% denser than ordinary water, a difference which is not immediately obvious. One of the few ways to demonstrate heavy water's physically different properties without equipment is to freeze a sample and drop it into normal water (it will sink). If the water is ice-cold the higher melting temperature of heavy ice can also be observed – it melts at 3.8 °C, and thus holds up very well in ice-cold normal water.

An early experiment reported not the "slightest difference" in taste between ordinary and heavy water; on the other hand, rats given a choice between distilled normal water and heavy water were able to avoid the heavy water based on smell, and it may be possible that it has a different taste.

No physical properties are listed for "pure" semi-heavy water, because it is unstable as a bulk liquid. In the liquid state, a few water molecules are always in an ionized state, which means the hydrogen atoms can exchange among different oxygen atoms. Semi-heavy water can be created by a chemical method but would rapidly transform into a dynamic mixture of 25% light water, 25% heavy water, and 50% semi-heavy water (however if it were made in the gas phase and directly frozen to a solid, this semi-heavy ice would be stable).

**History**

Harold Urey discovered the isotope deuterium in 1931 and was later able to concentrate it in water. Urey's mentor Gilbert Newton Lewis isolated the first sample of pure heavy water by electrolysis in 1933. George de Hevesy and Hoffer used heavy water in 1934 in one of the first biological tracer experiments, to estimate the rate of turnover of water in the human body. The history of large-quantity production and use of heavy water in early nuclear experiments is given below. Emilian Bratu and Otto Redlich studied the auto dissociation of heavy water in 1934.

**Effect on biological systems**

Different isotopes of chemical elements have slightly different chemical behaviors, but for most elements the differences are far too small to use, or even detect. For hydrogen, however, this is not true. The larger chemical isotope-effects seen between protium (light hydrogen) versus deuterium and tritium manifest because bond energies in chemistry are determined in quantum mechanics by equations in which the quantity of reduced mass of the nucleus and electrons appears. This quantity is altered in heavy-hydrogen compounds (of which deuterium oxide is the most common and familiar) more than for heavy-isotope substitution in other chemical elements. This isotope effect of heavy hydrogen is magnified further in biological systems, which are very sensitive to small changes in the solvent properties of water.

Heavy water is the only known chemical substance that affects the period of circadian oscillations, consistently increasing the length of each cycle. The effect is seen in unicellular organisms, green plants, isopods, insects, birds, mice, and hamsters. The mechanism is unknown.

To perform their tasks, enzymes rely on their finely tuned networks of hydrogen bonds, both in the active center with their substrates, and outside the active center, to stabilize their tertiary structures. As a hydrogen bond with deuterium is slightly stronger than one involving ordinary hydrogen, in a highly deuterated environment, some normal reactions in cells are disrupted.

Particularly hard-hit by heavy water are the delicate assemblies of mitotic spindle formation necessary for cell division in eukaryotes. Plants stop growing and seeds do not germinate when given only heavy water, because heavy water stops eukaryotic cell division.

It has been proposed that low doses of heavy water can slow the aging process by helping the body resist oxidative damage via the isotope effect. A team at the Institute for the Biology of Ageing, located in Moscow, conducted an experiment to determine the effect of heavy water on longevity using fruit flies and found that while large amounts were deadly, smaller quantities increased lifespans by up to 30%.

**Effect on animals**

Experiments in mice, rats, and dogs have shown that a degree of 25% deuteration causes (sometimes irreversible) sterility, because neither gametes nor zygotes can develop. High concentrations of heavy water (90%) rapidly kill fish, tadpoles, flatworms, and *Drosophila*. Mammals, such as rats, given heavy water to drink die after a week, at a time when their body water approaches about 50% deuteration. The mode of death appears to be the same as that in cytotoxic poisoning (such as chemotherapy) or in acute radiation syndrome (though deuterium is not radioactive), and is due to deuterium's action in generally inhibiting cell division. It is more toxic to malignant cells than normal cells but the concentrations needed are too high for regular use. As in chemotherapy, deuterium-poisoned mammals die of a failure of bone marrow (bleeding and infection) and intestinal-barrier functions (diarrhea and fluid loss).

Notwithstanding the problems of plants and animals in living with too much deuterium, prokaryotic organisms such as bacteria, which do not have the mitotic problems induced by deuterium, may be grown and propagated in fully deuterated conditions, resulting in replacement of all hydrogen atoms in the bacterial proteins and DNA with the deuterium isotope. Full replacement with heavy atom isotopes can be accomplished in higher organisms with other non-radioactive heavy isotopes (such as carbon-13, nitrogen-15, and oxygen-18), but this cannot be done for the stable heavy isotope of hydrogen.

Deuterium oxide is used to enhance boron neutron capture therapy, but this effect does not rely on the biological effects of deuterium per se, but instead on deuterium's ability to moderate (slow) neutrons without capturing them.

**Toxicity in humans**

Because it would take a very large amount of heavy water to replace 25% to 50% of a human being's body water (which in turn is 70% of body weight) with heavy water, accidental or intentional poisoning with heavy water is unlikely to the point of practical disregard. For a poisoning, large amounts of heavy water would need to be ingested without significant normal water intake for many days to produce any noticeable toxic effects.

Oral doses of heavy water in the range of several grams, as well as heavy oxygen 18O, are routinely used in human metabolic experiments. See doubly labeled water testing. Since one in about every 6400 hydrogen atoms is deuterium, a 50 kg human containing 32 kg of body water would normally contain enough deuterium (about 1.1 gram) to make 5.5 grams of pure heavy water, so roughly this dose is required to double the amount of deuterium in the body.

The American patent U.S. Patent 5,223,269 is for the use of heavy water to treat hypertension (high blood pressure). A loss of blood pressure may partially explain the reported incidence of dizziness upon ingestion of heavy water. However, it is more likely that this symptom can be attributed to altered vestibular function.

**Heavy water radiation contamination confusion**

Although many people associate heavy water primarily with its use in nuclear reactors, *pure* heavy water is not radioactive. Commercial-grade heavy water is *slightly* radioactive due to the presence of minute traces of natural tritium, but the same is true of ordinary water. Heavy water that has been used as a coolant in nuclear power plants contains substantially more tritium as a result of neutron bombardment of the deuterium in the heavy water (tritium is a health risk when ingested in large quantities).

In 1990, a disgruntled employee at the Point Lepreau Nuclear Generating Station in Canada obtained a sample (estimated as about a "half cup") of heavy water from the primary heat transport loop of the nuclear reactor, and loaded it into the employee water cooler. Eight employees drank some of the contaminated water. The incident was discovered when employees began leaving bioassay urine samples with elevated tritium levels. The quantity of heavy water involved was far below levels that could induce heavy water toxicity, but several employees received elevated radiation doses from tritium and neutron-activated chemicals in the water. This was not an incident of heavy water poisoning, but rather radiation poisoning from other isotopes in the heavy water. Some news services were not careful to distinguish these points, and some of the public were left with the impression that heavy water is normally radioactive and more severely toxic than it is. Even if pure heavy water had been used in the water cooler indefinitely, it is not likely the incident would have been detected or caused harm, since no employee would be expected to get much more than 25% of their daily drinking water from such a source.

**Production**

On Earth, deuterated water, HDO, occurs naturally in regular water at a proportion of about 1 molecule in 3200. This means that 1 in 6400 hydrogen atoms is deuterium, which is 1 part in 3200 by weight (hydrogen weight). The HDO may be separated from regular water by distillation or electrolysis and also by various chemical exchange processes, all of which exploit a kinetic isotope effect. (For more information about the isotopic distribution of deuterium in water, see Vienna Standard Mean Ocean Water.)

The difference in mass between the two hydrogen isotopes translates into a difference in the zero-point energy and thus into a slight difference in the speed at which the reaction proceeds. Once HDO becomes a significant fraction of the water, heavy water will become more prevalent as water molecules trade hydrogen atoms very frequently. Production of pure heavy water by distillation or electrolysis requires a large cascade of stills or electrolysis chambers and consumes large amounts of power, so the chemical methods are generally preferred. The most important chemical method is the Girdler sulfide process.

An alternative process, patented by Graham M. Keyser, uses lasers to selectively dissociate deuterated hydrofluorocarbons to form deuterium fluoride, which can then be separated by physical means. Although the energy consumption for this process is much less than for the Girdler sulfide process, this method is currently uneconomical due to the expense of procuring the necessary hydrofluorocarbons.

As noted, modern commercial heavy water is almost universally referred to, and sold as, **deuterium oxide.** It is most often sold in various grades of purity, from 98% enrichment to 99.75% - 99.98% deuterium enrichment (nuclear reactor grade) and occasionally even higher isotopic purity.

**USSR/Russia**

Production was first started in 1934 in Dnepropetrovsk, but was interrupted during Operation Barbarossa. After 1946 five plants with summary annual production of 20 tons were constructed.

**United States**

In 1953, the United States began using heavy water in plutonium production reactors at the Savannah River Site. The first of the five heavy water reactors came online in 1953, and the last was placed in cold shutdown in 1996. The SRS reactors were heavy water reactors so that they could produce both plutonium and tritium for the US nuclear weapons program.

The U.S. developed the Girdler sulfide chemical exchange production process which was first demonstrated on a large scale at the Dana, Indiana plant in 1945 and at the Savannah River Plant, South Carolina in 1952. The SRP was operated by DuPont for the USDOE until 1 April 1989 at which time the operation was taken over by Westinghouse.

**India**

India is the world's largest producer of heavy water through its Heavy Water Board and also exports to countries like Republic of Korea and the US. Development of heavy water process in India happened in three phases: The first phase (late1950s to mid-1980s) was a period of technology development, the second phase was of deployment of technology and process stabilization (mid 1980s to early 1990s) and third phase saw consolidation and a shift towards improvement in production and energy conservation.

**Norway**

Main article: Norwegian heavy water sabotage



"Heavy water" made by Norsk Hydro

In 1934, Norsk Hydro built the first commercial heavy water plant at Vemork, Tinn, with a capacity of 12 tons per year. From 1940 and throughout World War II, the plant was under German control and the allies decided to destroy the plant and its heavy water to inhibit German development of nuclear weapons. In late 1942, a planned raid by British airborne troops failed, both gliders crashing. The raiders were killed in the crash or subsequently executed by the Germans. In the night of 27 February 1943 Operation Gunnerside succeeded. Norwegian commandos and local resistance managed to demolish small but key parts of the electrolytic cells, dumping the accumulated heavy water down the factory drains. Had the German nuclear program followed similar lines of research as the US Manhattan Project, the heavy water would have been crucial to obtaining plutonium from a nuclear reactor. The Norsk Hydro operation is one of the great commando sabotage operations of the war.

On 16 November 1943, the allied air forces dropped more than 400 bombs on the site. The allied air raid prompted the Nazi government to move all available heavy water to Germany for safekeeping. On 20 February 1944, a Norwegian partisan sank the ferry M/F *Hydro* carrying heavy water across Lake Tinn, at the cost of 14 Norwegian civilians' lives, and most of the heavy water was presumably lost. A few of the barrels were only half full, and therefore could float, and may have been salvaged and transported to Germany. (These events were dramatized in the 1965 movie, *The Heroes of Telemark*, and also in a level of the PlayStation 2/Xbox game, *Secret Weapons Over Normandy*.)

Recent investigation of production records at Norsk Hydro and analysis of an intact barrel that was salvaged in 2004 revealed that although the barrels in this shipment contained water of pH 14—indicative of the alkaline electrolytic refinement process—they did not contain high concentrations of D2O. Despite the apparent size of shipment, the total quantity of pure heavy water was quite small, most barrels only containing 0.5–1% pure heavy water. The Germans would have needed a total of about 5 tons of heavy water to get a nuclear reactor running. The manifest clearly indicated that there was only half a ton of heavy water being transported to Germany. The *Hydro* was carrying far too little heavy water for one reactor, let alone the 10 or more tons needed to make enough plutonium for a nuclear weapon.

**Canada**

As part of its contribution to the Manhattan Project, Canada built and operated a 6 tons per year electrolytic heavy water plant at Trail, BC, which started operation in 1943.

The Atomic Energy of Canada Limited (AECL) design of power reactor requires large quantities of heavy water to act as a neutron moderator and coolant. AECL ordered two heavy water plants which were built and operated in Atlantic Canada at Glace Bay (by Deuterium of Canada Limited) and Port Hawkesbury, Nova Scotia (by General Electric Canada). These plants proved to have significant design, construction and production problems and so AECL built the Bruce Heavy Water Plant (map location), which it later sold to Ontario Hydro, to ensure a reliable supply of heavy water for future power plants. The two Nova Scotia plants were shut down in 1985 when their production proved to be unnecessary.

The Bruce Heavy Water Plant in Ontario was the world's largest heavy water production plant with a capacity of 700 tons per year. It used the Girdler sulfide process to produce heavy water, and required 340,000 tons of feed water to produce one ton of heavy water. It was part of a complex that included 8 CANDU reactors which provided heat and power for the heavy water plant. The site was located at Douglas Point near Tiverton, Ontario on Lake Huron where it had access to the waters of the Great Lakes.

The Bruce plant was commissioned in 1979 to provide heavy water for a large increase in Ontario's nuclear power generation. The plants proved to be significantly more efficient than planned and only three of the planned four units were eventually commissioned. In addition, the nuclear power program was slowed down and effectively stopped due to a perceived oversupply of electricity, later shown to be temporary, in 1993. Improved efficiency in the use and recycling of heavy water plus the over-production at Bruce left Canada with enough heavy water for its anticipated future needs. Also, the Girdler process involves large amounts of hydrogen sulfide, raising environmental concerns if there should be a release. The Bruce heavy water plant was shut down in 1997, after which the plant was gradually dismantled and the site cleared.

Atomic Energy of Canada Limited (AECL) is currently researching other more efficient and environmentally benign processes for creating heavy water. This is essential for the future of the CANDU reactors since heavy water represents about 20% of the capital cost of each reactor.

**Iran**

On 26 August 2006, Iranian President Ahmadinejad inaugurated an expansion of the country's heavy-water plant near Arak. Iran has indicated that the heavy-water production facility will operate in tandem with a 40 MW research reactor that had a scheduled completion date in 2009.

**Pakistan**

The 50 MWt, heavy water and natural uranium research reactor at Khushab, in Punjab province, is a central element of Pakistan's program for production of plutonium, deuterium and tritium for advanced compact warheads (i.e. thermonuclear weapons). Pakistan succeeded in acquiring a tritium purification and storage plant, and deuterium and tritium precursor materials from two German firms.

**Other countries**

Argentina is a declared producer of heavy water, using an ammonia/hydrogen exchange based plant supplied by Switzerland's Sulzer company.

Romania produces heavy water at the Drobeta Girdler Sulfide plant and exports it occasionally.

France operated a small plant during the 1950s and 1960s.

**Applications**

**Nuclear magnetic resonance**

Deuterium oxide is used in nuclear magnetic resonance spectroscopy when the solvent of interest is water and the nuclide of interest is hydrogen. This is because the signal from the water solvent would interfere with the signal from the molecule of interest. Deuterium has a different magnetic moment from hydrogen and therefore does not contribute to the NMR signal at the hydrogen resonance frequency.

**Organic chemistry**

Deuterium oxide is often used as the source of deuterium for preparing specifically labelled isotopologs of organic compounds. For example, C-H bonds adjacent to ketonic carbonyl groups can be replaced by C-D bonds, using acid or base catalysis. Trimethylsulfoxonium iodide, made from dimethyl sulfoxide and methyl iodide can be recrystallized from deuterium oxide, and then dissociated to regenerate methyl iodide and dimethyl sulfoxide, both deuterium labelled. In cases where specific double labelling by deuterium and tritium is contemplated, the researcher needs to be aware that deuterium oxide, depending upon age and origin, can contain some tritium.

**Fourier transform spectroscopy**

Deuterium oxide is often used instead of water when collecting FTIR spectra of proteins in solution. H2O creates a strong band that overlaps with the amide I region of proteins. The band from D2O is shifted away from the amide I region.

**Neutron moderator**

Heavy water is used in certain types of nuclear reactors where it acts as a neutron moderator to slow down neutrons so that they are more likely to react with the fissile uranium-235 than with uranium-238 which captures neutrons without fissioning. The CANDU reactor uses this design. Light water also acts as a moderator but because light water absorbs more neutrons than heavy water, reactors using light water for a reactor moderator must use enriched uranium rather than natural uranium, otherwise criticality is impossible. A significant fraction of outdated power reactors, such as the RBMK reactors in the USSR, were constructed using normal water for cooling but graphite as a moderator. However, the danger of graphite in power reactors (graphite fires in part led to the Chernobyl disaster) has led to the discontinuation of graphite in standard reactor designs

Because they do not require uranium enrichment, heavy water reactors are of concern in regards to nuclear proliferation. The breeding and extraction of plutonium can be a relatively rapid and cheap route to building a nuclear weapon, as chemical separation of plutonium from fuel is easier than isotopic separation of U-235 from natural uranium. Among current and past nuclear weapons states, Israel, India, and North Koreafirst used plutonium from heavy water moderated reactors burning natural uranium, while China, South Africa and Pakistan first built weapons using highly enriched uranium.

However, in the U.S., the first experimental atomic reactor (1942), as well as the Manhattan Project Hanford production reactors which produced the plutonium for the Trinity test and Fat Man bombs, all used pure carbon (graphite) neutron moderators combined with normal water cooling pipes, and functioned with neither enriched uranium nor heavy water. Russian and British plutonium production also used graphite-moderated reactors.

There is no evidence that civilian heavy water power reactors, such as the CANDU or Atucha designs, have been used for military production of fissile materials. In states which do not already possess nuclear weapons, the nuclear material at these facilities is under IAEA safeguards to discourage any such diversion.

Due to its potential for use in nuclear weapons programs, the possession or import/export of large industrial quantities of heavy water are subject to government control in several countries. Suppliers of heavy water and heavy water production technology typically apply IAEA (International Atomic Energy Agency) administered safeguards and material accounting to heavy water. (In Australia, the *Nuclear Non-Proliferation (Safeguards) Act 1987*.) In the U.S. and Canada, non-industrial quantities of heavy water (i.e., in the gram to kg range) are routinely available without special license through chemical supply dealers and commercial companies such as the world's former major producer Ontario Hydro. Current (2006) cost of a kilogram of 99.98% reactor-purity heavy water, is about $600 to $700. Smaller quantities of reasonable purity (99.9%) may be purchased from chemical supply houses at prices of roughly $1 per gram.

**Neutrino detector**

The Sudbury Neutrino Observatory (SNO) in Sudbury, Ontario used 1000 tons of heavy water on loan from Atomic Energy of Canada Limited. The neutrino detector is 6,800 feet (2,100 m) underground in a mine, to shield it from muons produced by cosmic rays. SNO was built to answer the question of whether or not electron-type neutrinos produced by fusion in the Sun (the only type the Sun should be producing directly, according to theory) might be able to turn into other types of neutrinos on the way to Earth. SNO detects the Cherenkov radiation in the water from high-energy electrons produced from electron-type neutrinos as they undergo reactions with neutrons in deuterium, turning them into protons and electrons (only the electrons move fast enough to be detected in this manner). SNO also detects the same radiation from neutrino↔electron scattering events, which again produces high energy electrons. These two reactions are produced only by electron-type neutrinos. The use of deuterium is critical to the SNO function, because all three "flavors" (types) of neutrinos may be detected in a third type of reaction, neutrino-disintegration, in which a neutrino of any type (electron, muon, or tau) scatters from a deuterium nucleus (deuteron), transferring enough energy to break up the loosely bound deuteron into a free neutron and proton. This event is detected when the free neutron is absorbed by 35Cl− present from NaCl which has been deliberately dissolved in the heavy water, causing emission of characteristic capture gamma rays. Thus, in this experiment, heavy water not only provides the transparent medium necessary to produce and visualize Cherenkov radiation, but it also provides deuterium to detect exotic mu type (μ) and tau (τ) neutrinos, as well as a non-absorbent moderator medium to preserve free neutrons from this reaction, until they can be absorbed by an easily detected neutron-activated isotope.

**Metabolic rate testing in physiology/biology**

Heavy water is employed as part of a mixture with H218O for a common and safe test of mean metabolic rate in humans and animals undergoing their normal activities. This metabolic test is usually called the doubly labeled water test.

**Tritium production**

See also: Tritium#Deuterium

Tritium is the active substance in self-powered lighting and controlled nuclear fusion, its other uses including autoradiography and radioactive labeling. It is also used in nuclear weapon design for boosted fission weapons and initiators. Some is created in heavy water moderated reactors when deuterium captures a neutron. This reaction has a small cross-section (the imaginary neutron-capturing area around the nucleus) and produces only small amounts of tritium, although enough to justify cleaning tritium from the moderator every few years to reduce the environmental risk of tritium escape.

Producing a lot of tritium in this way would need reactors with very high neutron fluxes, or with a very high proportion of heavy water to nuclear fuel and very low neutron absorption by other reactor material. The tritium would then have to be recovered by isotope separation from a much larger quantity of deuterium, unlike production from lithium-6 (the present method), where only chemical separation is needed.

Deuterium's absorption cross section for thermal neutrons is 0.52 millibarns (barn=10−28 m2, milli=1/1000), while oxygen-16's is 0.19 millibarns and oxygen-17's is 0.24 barns. 17O makes up 0.038% of natural oxygen, making the overall cross section 0.28 millibarns. Therefore in D2O with natural oxygen, 21% of neutron captures are on oxygen, rising higher as 17O builds up from neutron capture on 16O. Also, 17O emits an alpha particle on capture, producing radioactive carbon-14.

* This page was last modified on 28 February 2012 at 13:33.