

Status of the current deuterium supply and view of the future

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Deuterium is a naturally-occurring, non-radioactive isotope of hydrogen. Hydrogen has one proton and one electron; deuterium has, in addition, one neutron.¹ Adding a second neutron yields tritium, which is radioactive. While the % of deuterium varies with location in the world, about 1 per 6600 hydrogen atoms is actually deuterium (0.015%). Every element has different isotopic forms. For example, 75% of the chlorine in table salt has 18 neutrons and 25% has 20 neutrons.

“Deuterium was discovered and named in 1931 by Harold Urey, earning him a Nobel Prize in 1934. This was followed by the discovery of the neutron in 1932,² which made the nuclear structure of deuterium obvious. Soon after deuterium’s discovery, Urey and others produced samples of "heavy water" in which the deuterium content had been highly concentrated.”³

Since the 1930’s, when it was discovered that compounds could be made that were deuterium-enriched, many uses for those ‘deuterated compounds’ have been discovered: use in metabolic studies, in the study of reaction mechanisms, and as NMR solvents. The source of the deuterium in all compounds is D₂O, isolated from water. D₂O (a liquid) can be reduced to D₂ (a gas) by electrolysis, and these are the two reagents that are used to make all deuterated compounds.

By far, the deuterated compound used in greatest amount is D₂O, also called ‘heavy water’. Vast amounts of D₂O are used to jacket so-called heavy water nuclear reactors because D₂O efficiently absorbs the flux of neutrons given off by nuclear fission and prevent those neutrons from causing damage to things near the nuclear power generating facilities. [CANDU reactors](#) were first developed in Canada during the late 1950s and 1960s, which provided the incentive for involved agencies in Canada to develop optimized method of making D₂O. Various technologies were invented to make D₂O with varying yields and efficiencies, the

¹ The neutron was first theorized by Ernest Rutherford in 1920.

² The British physicist Sir James Chadwick discovered neutrons in the year 1932. He was awarded the Nobel Prize in Physics in the year 1935 for this discovery.

³ <https://www.quora.com/How-much-does-deuterium-exist-in-all-of-the-water-on-the-Earth>

method used most being the [Girdler Sulfide](#) (“GS”) process invented in 1943. The large-quantity production and use of D₂O [has been described](#). Other technologies to make D₂O and the places those technologies are used can be found [online](#). In all these methods, the greatest cost is the cost of energy. The methods vary in the extent of adverse environmental impact.

The needs for D₂O in heavy water reactors were fully met by the early 1990s. This is in large part because used D₂O can be recycled. The specification for D₂O used with a heavy water reactor is 99.8% enrichment. Once the level declines to 99.6%, the heavy water is returned to a facility for re-processing back to 99.8% enrichment and to remove the tritium that forms. The re-processing of used heavy water is much less energy intensive than its manufacture, and therefore much less costly. One million kilograms of ultra-pure heavy water was lent to the [Sudbury Neutrino Observatory](#) in Ontario, Canada in 1999; its mission ended in 2006 and the heavy water in it is now being sold for other uses. Although there is optimism that synergy between hydrogen production and heavy water production may exist,⁴ for these reasons D₂O is no longer made from H₂O anywhere in the world that we know of. Stockpiles of D₂O have fulfilled the demand for deuterium for thirty years, and until recently there was no reason to think it would ever be necessary to make more D₂O. Facilities that were used to make heavy water are aging, as are the people expert in its production.

Nuclear power reactors that use light water exist, but these require 3-5% enriched ²³⁵U fuel. Heavy water reactors, currently about 11% of reactors world-wide, [are able to use naturally-occurring ²³⁸U as fuel](#).

The utilization of D₂O in heavy water reactors makes its production not only expensive, but geopolitically fraught. National regulatory agencies worldwide have in place strict requirements for the transport of D₂O.

Despite all this, debate is emerging over whether or not we must begin planning to make D₂O again. New uses for deuterium are emerging: in pharmaceuticals, in semiconductor manufacturing, in OLED screens. Perhaps even in the manufacture of alcoholic beverages with fewer deleterious health effects. Deuterated compounds may prove to have a wide range of improved properties and therefore

⁴ Alastair Miller, one of the long-standing pioneers in heavy water production methods, [has described his view](#) that current efforts to manufacture ‘green’ hydrogen for fuel will bring a side-benefit of cheaper heavy water production.

become products. This area of research is experiencing a rebirth, and learning how many products can be improved *via* deuteration- in ways that are economically-viable to manufacture- remains limited only by the creativity of chemists.