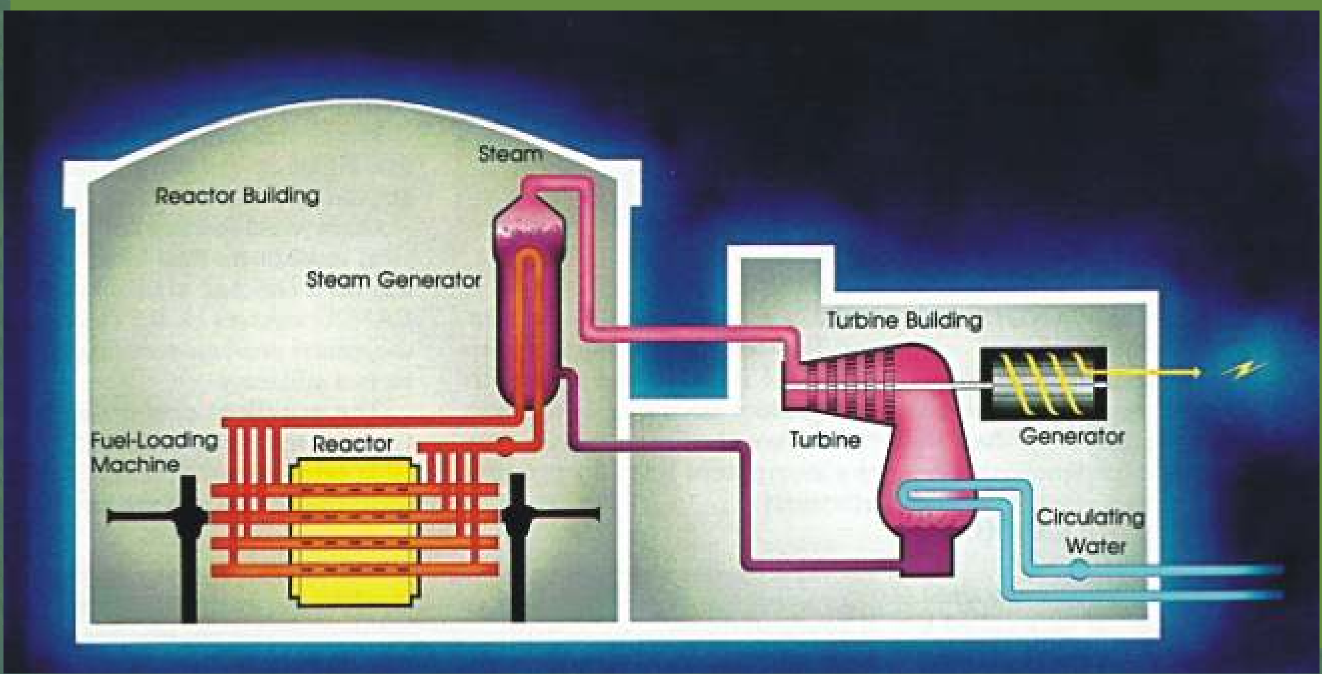
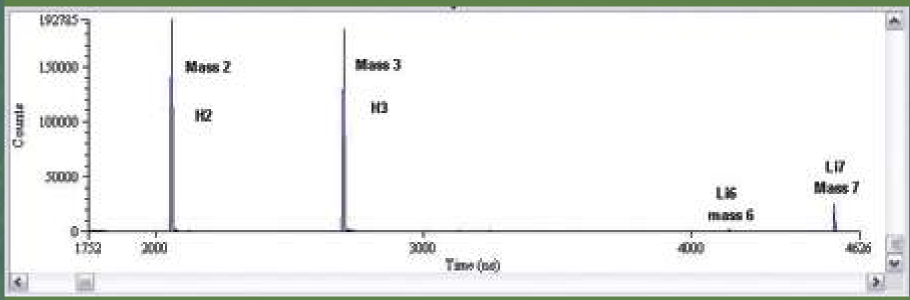
Analysis of Heavy Water with ICP-oTOF-MS

The CANDU reactor was designed by Atomic Energy Canada Limited (AECL) as an alternative to other reactor designs which uses slightly enriched uranium (2-5% U-235). The CANDU allows more local input in nations that do not have the capability to cast a pressure vessel. The CANDU fuel contains pellets of uranium dioxide with natural uranium (0.7% U_235). As a result, the CANDU is cheaper to fuel, and can theoretically give higher lifetime capacity factors.

The CANDU design consists of a horizontal calandria (vessel) which has tubes for the fuel rods and cooling water (heavy water). Around these tubes is heavy water, which acts as the moderator to slow down the neutrons. Heavy water consists of 2 atoms of deuterium (a non-radioactive isotype of hydrogen) and 1 atom of oxygen. Deuterium atoms represent about 1.5% of hydrogen found in nature. Deuterium is somewhat less effective moderator than hydrogen and also absorbs fewer neutrons. This allows the use of natural uranium as a fuel. Special processing plants, e.g. At the Bruce facility near Tiverton, Ontario, are used to separate heavy water from natural water. The deuterium separation is an added initial capital cost which, over the plant lifetime, is offset by the lower natural uranium fuel costs.





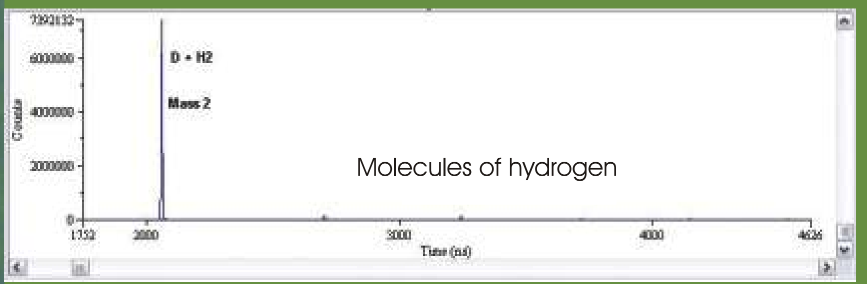
Mass spectrum (in time domain) of the region of a natural water spectrum from about mass 2 to mass 7. The x-axis is flight time in ns.

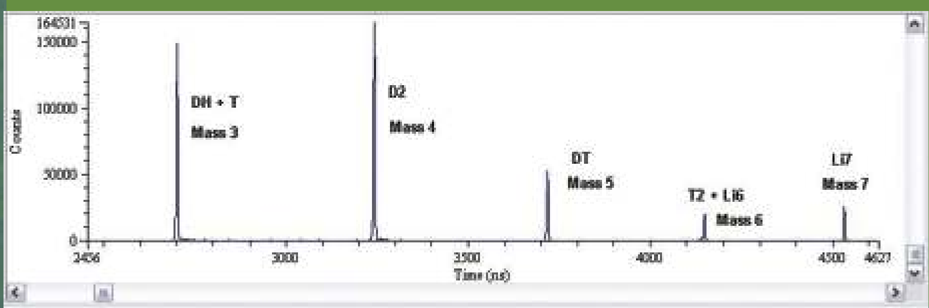
The flexibility of Time of Flight mass spectrometry means that it can simultaneously analyse very light ions whilst measuring heavy ions.

The solution contains Lithium and this is seen at the right of the spectrum. The two peaks at the left are mass 2 and 3 were identified as molecules of hydrogen.

Now a sample of heavy water was run. The sample volume was approximately 0.5ml and the data collected for the entire mass range. The spectrum from mass 2 to 7 is shown below.

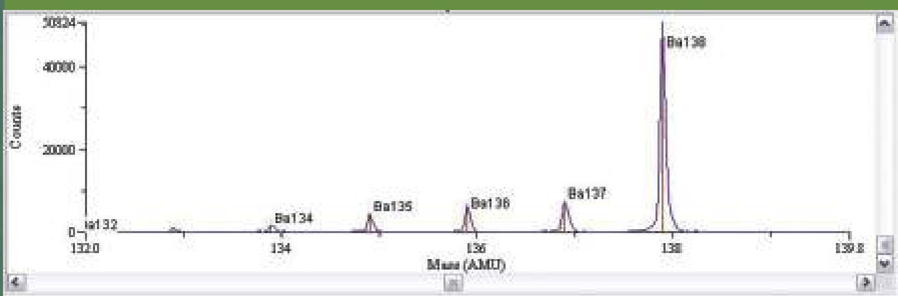
The signal at mass 2 increases by a factor of 40 and other molecules of hydrogen have been created. This is shown in the expanded spectra below from mass 3 to 7.

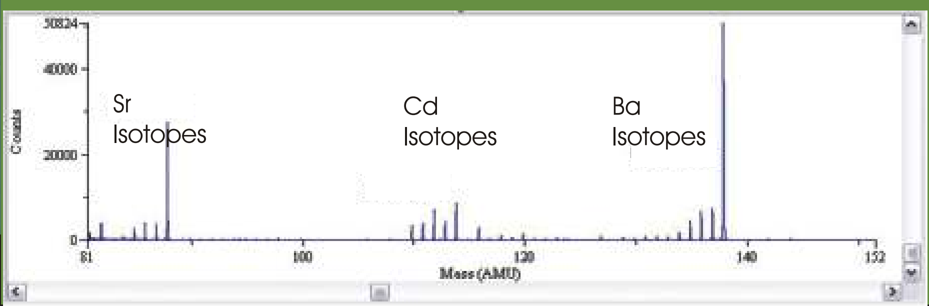




The peaks show the various combinations of D and H molecules. The presence of the peak at mass 5 indicates that there is also Tritium present in the sample. This could however be a more exotic molecule.

As well as the light ions present in bulk in the heavy water, there are also traces of heavier metals that are of interest to the heavy water reactor industry. The spectrum below shows the higher mass region of the spectrum.





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