ICP-oTOFMS

APPLICATION NOTES

Analysis of Heavy water using the Optimass

INTRODUCTION

The CANDU reactor was designed by Atomic Energy Canada Limited as an alternative to other reactor designs which use 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.

As can be seen in figure 1, 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 isotope of hydrogen) and 1 atom of oxygen. Deuterium atoms represent about 1.5% of hydrogen found in nature. Deuterium is less efficient as a moderator than hydrogen, thus allowing the use of natural uranium, instead of enriched 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.

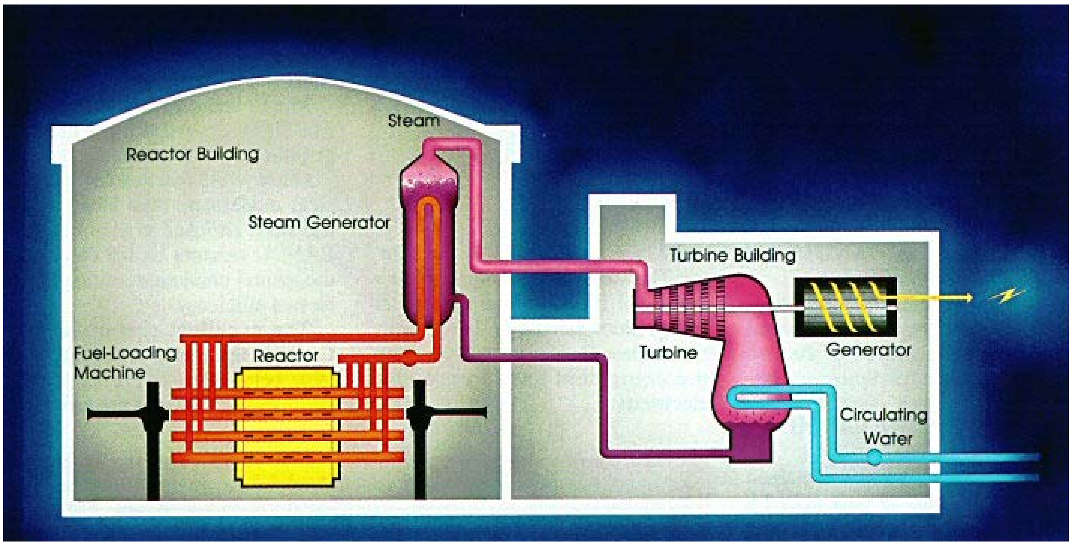

Figure 1: A schematic of the CANDU reactor.

As in the case of the pressurized water reactor, reactor cooling pumps circulate heavy water through the reactor then to the steam generators in a closed loop.

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The moderator heavy water system has a separate heat exchanger with circulation system for cooling the moderator.

AECL, the manufacturer of CANDU reactors, has also provided these reactors to governments/utilities in Argentina, India, Korea, Pakistan, and Romania.

Impurities known as reactor poisons can be present in the heavy water and lead to reduced nuclear fission due to the absorption of neutrons in the reactors core. In a CANDU reactor the poisons of interest are mainly Xe and Sm. These are produced in the reactor and reach an equilibrium value. Other poisons may also be of interest that are impurities in the production of heavy water includes Hf, Gd and Cd.

The Optimass can simultaneously be used to measure these impurities as well as the analysis of heavy water, in particular the various hydrogen molecules.

INSTRUMENTATION

The instrument used, the Optimass, allows simultaneous acquisition of the entire mass range from the light ions such as H_2 and H_3 to the heavy ions such as U238. The Optimass was optimized for sensitivity and resolution. The Smart Gate ion blanker was used to remove unwanted species, such as Ar.
A 5 second acquisition data collection time was used for the entire mass range. The sample volume was approximately 0.5 mL.

RESULTS

Figure 2 shows a mass spectrum of a natural water sample (in time domain shown in ns) from about mass 2 to mass 7.
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 and correspond to molecules of hydrogen.

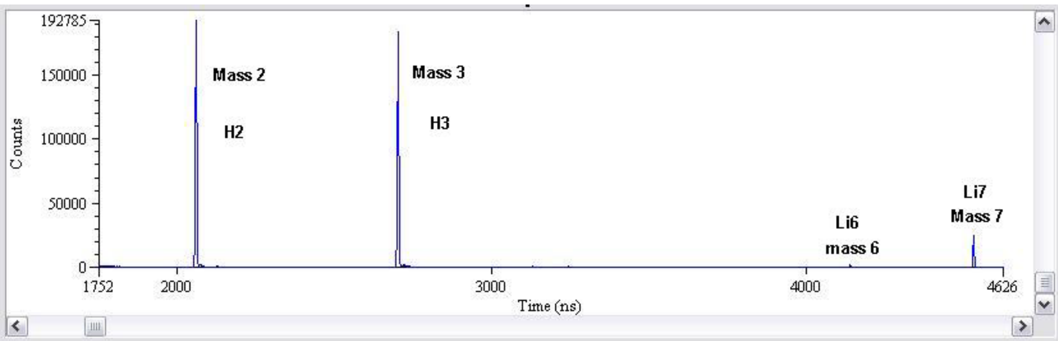

Figure 2: Mass Spectrum of Natural Water.

Figure 3 shows a mass spectrum of a heavy water sample (in the time domain shown in ns) from about mass 2 to mass 7.
The signal at mass 2 increases by a factor of 40.

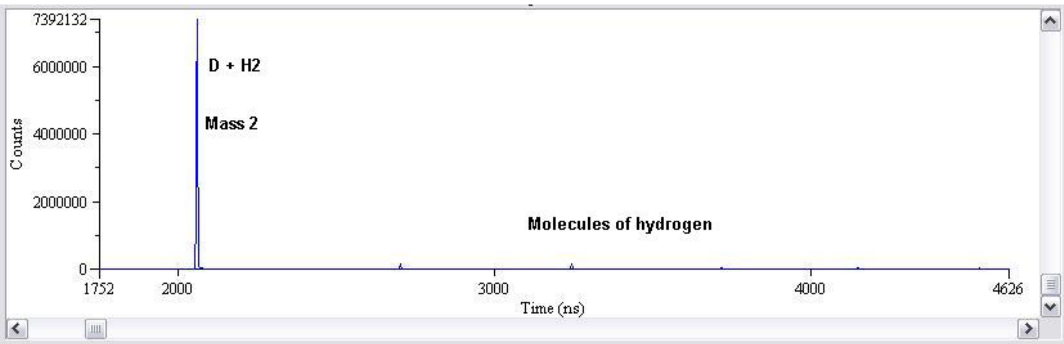

Figure 3: **Mass Spectrum of Heavy Water.**

Figure 4 shows the mass spectrum from mass 3 to mass 7 (in the time domain shown in ns). The spectrum now shows the other molecules of Deuterium and Hydrogen which have been created. The presence of the peak at mass 5 indicates that there is Tritium present in the sample. Compare this to Figure 5 which shows the mass spectrum for normal water.

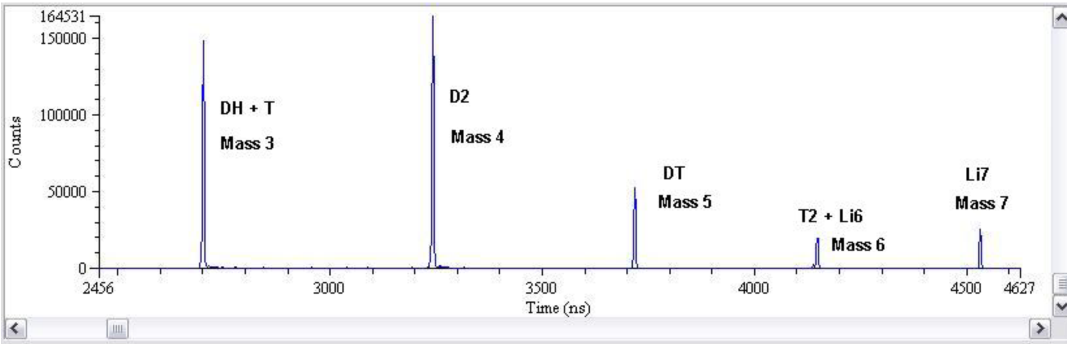

Figure 4: **Mass Spectrum of Heavy Water mass 3 to mass 7.**

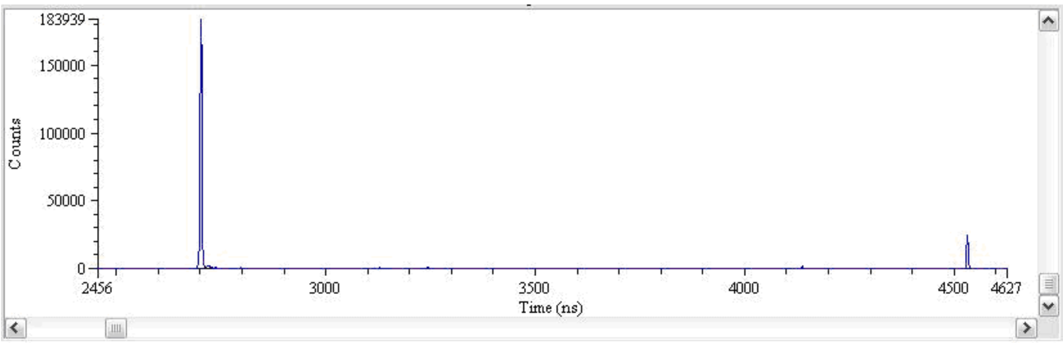

Figure 5: **Mass Spectrum of Normal Water from mass 3 to mass 7.**

As well as the light ions present in bulk in the heavy water there are also traces of heavier metals that are of interest in the heavy water reactor industry. Figure 6 shows the mass spectrum of heavy water from mass 81 to mass 152. This shows the Sr, Cd and Ba isotopes.

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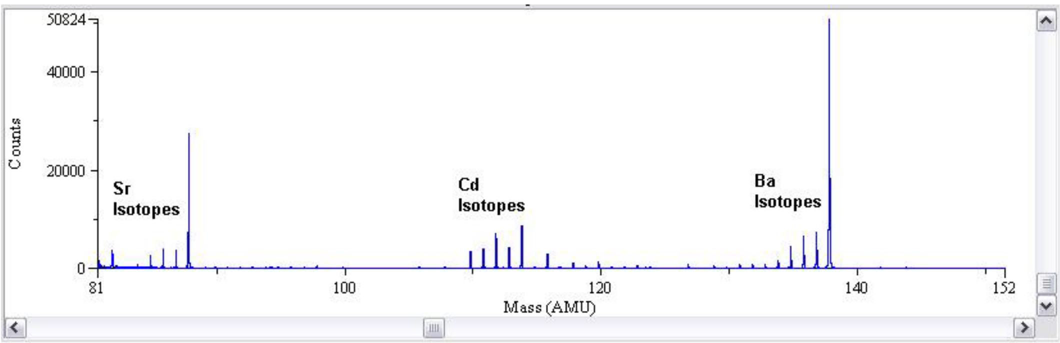

Figure 6: **Mass Spectrum of Heavy Water from mass 81 to mass 152.**

Figure 7 shows the mass spectrum for Ba from mass 132 to mass 140.

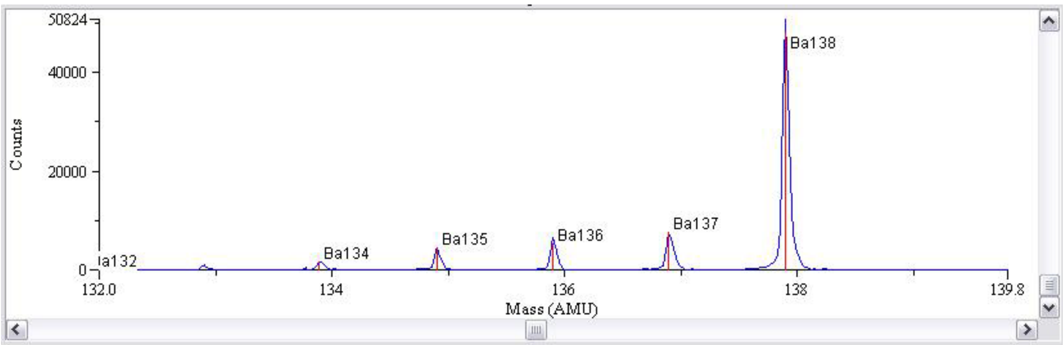

Figure 7: **Mass Spectrum of Heavy Water from mass 132 to mass 140.**

Figure 8 shows the mass spectrum of heavy water from mass 56 to mass 73. This shows the various isotopes of Ni, Cu and Zn. The presence of these in heavy water is of great concern in a reactor due to the thermal reaction cross sections.

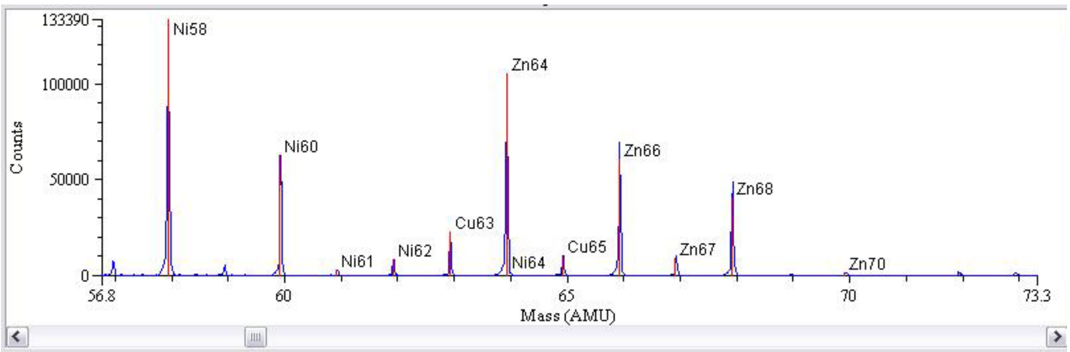

Figure 8: **Mass Spectrum of Heavy Water from mass 56 to mass 73.**

CONCLUSION

The Optimass allows fast simultaneous data acquisition of all elements allowing the measurement of deuterium, tritium and any reactor poisons present in heavy water. Within 20 seconds a sample can be aspirated and the results of all masses of interest can be determined. This fast speed of analysis is crucial in a CANDU reactor as any reactor poisons can be quickly identified. Once identified, standard techniques are then used to remove them.

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