Towards AMS measurements of ^{91,94}Nb and ^{93}Mo produced in fusion environment

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One of the main advantages of nuclear fusion in comparison to fission is that any radioactive waste produced is future fusion reactors is expected to be low-level waste (LLW) at least 100 years after the end of its operation. The activation of the structural material would be caused by the expected high fluences of high-energy neutrons (14.1 MeV) produced by the deuterium-tritium fusion reaction. In order to confirm that these materials will meet the LLW criteria, the simulations of the production of radionuclides must be validated experimentally activating them with much lower neutron fluences from the same reaction. Such fluences are currently available using research fusion reactors and accelerator-based neutron generators. One example is the recent campaigns of irradiation in the Joint European Torus (JET) reactor at the Culham Centre for Fusion Energy [1]. While some of these radionuclides can be experimentally measured by radiometric techniques, such as γ-spectrometry or liquid scintillation counting, for most long-lived radionuclides the expected activities are below the detections limits of these techniques. Three examples are ^{91}Nb, ^{94}Nb and ^{93}Mo, which would be produced in molybdenum-containing materials, like stainless steel 316.

The main challenge for the measurement of these radionuclides by accelerator mass spectrometry (AMS) is the interference caused by their stable isobars: ^{91}Zr in the case of ^{91}Nb; ^{94}Zr and ^{94}Mo in the case of ^{94}Nb; and ^{93}Nb in the case of ^{93}Mo. The Ion-Laser InterAction Mass Spectrometry (ILIAMS) setup of the 3-MV-AMS facility at the University of Vienna, VERA (Vienna Environmental Research Accelerator) has already proven its capabilities to deal with this challenge for several other radionuclides [2]. This setup is based on the selective photodetachment of the anions with photon energies capable of suppressing the stable isobar anion, without doing the same for the radionuclide of interest. Preliminary studies show that laser photodetachment with a 355 nm laser would allow measurements of ^{91,94}Nb when selecting the NbO_3^- anion for injection into the accelerator, suppressing both ZrO_3^- and MoO_3^- anions. On the other hand, NbO_2^- anions get detached by laser light with a wavelength of 637 nm, but do not affect MoO_2^- anions, which makes this setup suitable for ^{93}Mo measurements.

Refs:

[1] Packer, L.W. et al., (2021), "Technological exploitation of the JET neutron environment: progress in ITER materials irradiation and nuclear analysis", Nuclear Fusion 61, 116057

[2] Martschini, M. et al., (2022), "5 years of ion-laser interaction mass spectrometry - status and prospects of isobar suppression in AMS by lasers", Radiocarbon 64, 555-568