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Determination of ^{93}Mo (and ^{94}Nb) in nuclear decommissioning waste from a nuclear reactor

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Molybdenum is an alloying component of structural materials used in nuclear reactors. The activation product of stable ^{92}Mo (14.65% abundance) is ^{93}Mo , which has a long half-life ($(4.0 \pm 0.8) \times 10^3$ years); so it is an important contributor of nuclear power plant wastes (especially dismantling wastes). As it decays by electron capture; its proper detection is very difficult. X-ray spectrometry, LSC and mass spectrometry (ICP-MS) can be used, but chemical separation is needed to separate ^{93}Mo from the matrix and interferences before detection. Although some methods have been reported for its determination, a more thorough isolation is required in case of nuclear decommissioning waste, where activities of ^{60}Co , ^{125}Sb , ^{65}Zn and many other radionuclides are 3-8 orders of magnitude higher, than that of ^{93}Mo . So a newly developed method for this purpose will be presented.

Several metallic samples from a nuclear power plant were analyzed. Each sample was dissolved using aqua regia and HF, and prepared in diluted HF acid for separation.

A combined chromatographic separation procedure was applied to separate Mo from the matrix and interfering radionuclides. The majority of activity was removed using cation exchange chromatography, as the activation products of most metallic components (^{54}Mn , ^{55}Fe , ^{60}Co , ^{59}Ni , ^{63}Ni , ^{65}Zn) were retained on a cation exchange resin as cations. However, Mo as anion (e. g. MoF_7^- , MoOF_5^- , MoO_2F_3^- or $[\text{MoO}_2\text{F}_4]^{2-}$) passes through the cation exchange column and remains in effluent; just like anion complexes of Zr (^{93}Zr) and Nb ($^{93\text{m}}\text{Nb}$, ^{94}Nb) (ZrF_6^{2-} , NbF_6^- , NbOF_5^{2-}), as well as ^{99}Tc (TcO_4^-).

Due to the removal of the main gamma emitters at this stage, ^{94}Nb in the effluent can directly be measured using gamma spectrometry.

Before measurement of ^{93}Mo using LSC, further separation of Mo is required from all other radionuclides, especially from the anions of Zr and Nb. The different affinities of these anions to TEVA resin were utilized to perform a nearly clean isolation of Mo from Zr and Nb; and by this procedure most of interferences can be removed.

For further purification, the separated ^{93}Mo was prepared in a diluted HNO_3 solution, and loaded to an alumina (Al_2O_3) column. After rinsing with diluted HNO_3 , the adsorbed ^{93}Mo was finally eluted with ammonia solution. This solution was concentrated and prepared in water for LSC measurement after adding scintillation cocktail.

The recovery of Mo in the whole procedure was determined by measuring stable Mo in the separated solution and the initial solution using ICP-OES, and found to be more than 70 %. The decontamination factors for the key interfering radionuclides are higher than 10^5 .

An internal solution of ^{93}Mo was prepared from a proton irradiated niobium target, and standardized using X-ray spectrometry using a HPGe detector (to determine the activity of ^{93}Mo due to its X-ray radiation). This solution was used to prepare quench curve of ^{93}Mo for the calibration of the LSC instrument, and quantitative measurement of ^{93}Mo in the separated sample solutions.