Radionuclides of astrophysical interest from Accelerator Waste

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Abstract – An irradiated copper beam dump from the PSI 590-MeV-cyclotron is a source for several exotic radionuclides to be used in a number of nuclear astrophysics related studies. First step for a successful exploitation of this valuable material is the complete analytical characterisation of the nuclide inventory. Results of this analysis as well as the first study of the neutron capture of ^{60}Fe at stellar energies as an application example are presented.

Keywords – long-lived radionuclides, radiochemical separation, nuclear astrophysics, ^{60}Fe, ^{26}Al, ^{44}Ti

I. INTRODUCTION

Long-lived exotic radionuclides such as ^{60}Fe, ^{26}Al or ^{44}Ti are of great interest in several fields of research like basic nuclear physics, astrophysics and/or radioactive ion beam techniques. Some examples for the use of such rare isotopes in the research area of nuclear astrophysics are the application of ^{44}Ti for investigations of core collapse supernovae or studies of several neutron capture reactions on radioactive isotopes like the ^{60}Fe(n,γ)^{61}Fe reaction at stellar energies, one of the key reactions for tracing the history of the Early Solar System. The direct production of these nuclides in sufficient amounts is, in some cases, nearly impossible, in others very time consuming and extremely expensive.

The Paul Scherrer Institute operates the most powerful spallation neutron source (SINQ) in Europe, driven by a high power proton accelerator, the 590-MeV ring cyclotron with a proton beam current up to 1.8 mA. Previous radiochemical analyses showed that beam dumps, shielding and target materials from these facilities contain long-lived radionuclides in such high amounts, that chemical separation for several applications seems to be attractive. It was found that the isotopes ^{60}Fe, ^{26}Al, ^{44}Ti and probably many others can be separated already now in amounts of 10^{14} - 10^{16} atoms [1]. Based on these very prospective results, an initiative called ERAWAST (Exotic Radionuclides from Accelerator waste for Science and Technology) aiming at establishing a user and producer community was started under the leadership of PSI and covers now already about 30 interested parties [2].

II. RADIOCHEMICAL CHARACTERISATION OF AN IRRADIATED COPPER BEAM DUMP

One of the materials that are already now available is a copper beam dump which was irradiated with 590-MeV protons and was dismounted in 1993. It consists of a cylinder with a diameter of 8 cm, which was cut into 7 pieces. Samples were taken from the central and peripheral point of each piece, as well as from additional positions outside the central part to determine the radial radionuclide distribution. With these data set, a full spacious distribution of 13 radionuclides could be obtained. The results are compared with theoretical predictions based on model calculations [3].

After the analysis, the central regions of the most active pieces were drilled out. With this procedure, 500 grams of highly-active copper chips were obtained which can be used to extract exotic radio-isotopes. First results of radiochemical separation in the frame of the ERAWAST project plan are described in [4].

III. FIRST RESULTS

The radiochemical analytics yielded a total amount of about 100 MBq ^{44}Ti, 500 kBq ^{53}Mn, 7 kBq ^{26}Al and 7 kBq ^{60}Fe in the copper chips. First chemical separations were carried out on a laboratory scale for ^{60}Fe, ^{44}Ti and ^{26}Al, an extension to technical scale is foreseen in the near future.

As first application $1.2 \cdot 10^{16}$ atoms of ^{60}Fe were separated by liquid-liquid extraction after dissolution of the copper in HNO_3. The material was then used to produce a target for studying the nuclear reaction ^{60}Fe(n,γ)^{61}Fe. A first successful neutron irradiation experiment started on 29th October 2007 at FZ Karlsruhe, Germany. Data analysis is under way and results will be published soon.

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