On-line production of neutron rich isotopes from Uranium Carbide targets

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INTRODUCTION

The production of intense radioactive isotopes beams has been an interesting field of nuclear physics research during the last twenty years. The production of n-rich nuclei far from the valley of beta stability is possible through the ISOL technique. In the framework of the EURISOL [1] and SPES [2] projects, a collaboration between Laboratori Nazionali di Legnaro (Italy), Institute de Physique Nucleaire of Orsay (France), GANIL (France) and Petersburg Nuclear Physics Institute of Gatchina (Russia) started from 2002 with the aim of producing an efficient Uranium Carbide target that quickly releases the reaction products and survives a long term irradiation. The experiments were performed at the IRIS facility of PNPI Institute [3], using UCx targets with different densities and internal structure, using also various container materials and ionization methods.

The main goal of these studies is to find the best value of the target density that permits both good production efficiency and fast release of the produced nuclides. Special attention is devoted to reliably extract isotopic yields in case of complex decay schemes and to the valuation of release efficiency of some isotopic chains.

YIELD CURVES AND RELEASE EFFICIENCY

A formalism was developed to disantangle the contribution of beta-decay in the target from direct production by fission and to provide more consistent data for the interpretation of release curves. In fact, an important part of the data analysis is the evaluation of the production yields of the species populated in the fission of the UCx target. From the peak areas associated to the isotopes characteristic gamma-transitions it is possible to deduce these yields knowing in details the characteristics of the experimental setup, the radioactive half-lives and the decay branchings ratios. A problem shows up when gamma-lines are fed simultaneously by isomeric states and ground state decays.

The isotope production is calculated during the different stages of the experiment: irradiation of the tape, tape motion to the Ge-detector and gamma-measurement; the beam is considered always on the target that reaches the saturation. The number of decays is calculated, corrected for the system efficiency and the branchings and then compared with the measured quantities (= number of counts). From this comparison we can extract the yield value for the ground state and the isomer separately, if the acquisition time is suitable to observe both (Fig. 1-up).

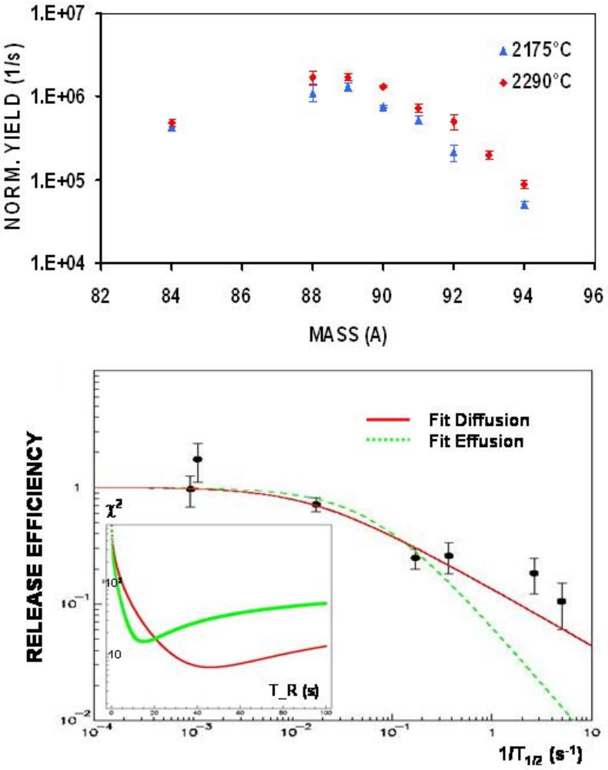

FIG. 1: Rb yield curves (up) for two temperatures of the UCx target and release efficiency curves (down) for the highest temperature supposing only diffusion (red curve) or only effusion (green curve) as release process.

In this way, is possible to obtain a matrix formalism that connect directly the yield vector to the intensity vector, that is the measured quantity.

A relevant characteristic of the targets for the production of radioactive beams is not only the in-target production but mainly the yield available at the measurement point. For this reason the release efficiency is defined as the ratio between the experimental yield and the in-target yield.

Through this efficiency is possible to determine which process reduces the in the target isotopes intensity when they arrive to the experimental point (Fig. 1-down).

For solid targets, as in the present case, different depending on whether the predominant release process is diffusion, desorption or effusion [4]. In first approximation these processes can be regarded as consecutive to easier determine which is the principal process that delay the exit of the isotope.

The most critical point in the in-target yield calculation is to determine the cross section of the isotope produced with the 1GeV proton beam on UCx target. We used the cross sections tabulated by Bernas et al. [5], coming from the study of the fission-residues produced in the spallation reaction ^{238}U+p at 1 AGeV.

^{92}RB GAMMA-BRANCHING MEASUREMENT

A measurement to evaluate the correct gamma-branching of ^{92}Rb was necessary to remove the discontinuity in the Rb chain yield curves. It comes out if the gamma-rays intensities quoted on the Nuclear Data Sheets are used in the calculations. The adopted measurement method is based on the flow conservation due to the fact that Rb ions are delivered only by the mass separator. For the correct measurement of the ^{92}Rb γ-intensities, is necessary to keep the ^{92}Sr current as low as possible. A test of the ^{94}Sr over ^{94}Rb ratio was carried out to determine the better measurements conditions, because the huge difference in the half life of ^{92}Sr and ^{92}Rb prevents this measure for A=92. The new value of the branching is in agreement with the measurements of Olson et al. [6] and can be explained if a large fraction of the γ-ray intensity is missing in the present decay scheme.

A RELEASE MODEL

A model to describe the release of isotopes produced inside the target is carried out tacking into account all the different steps of the process: the release function describes the following of diffusion out of the target grains and than of effusion through the empty space towards the exit hole. These steps have to be modeled on the experimental conditions.

This Release Model considers different ways of isotopes production: directly from fission or from the γ-decay of the isotope's mother, also created via fission. This second way is split into two paths: the mother may decay during the in-grain diffusion or also during the free effusion. The two paths provide different contributions to the release curve. The effect is very sensitive to the mother's half life: if it is long the effect is negligible, if it is comparable with the daughter's half life the effect is maximum (see Figure 2).

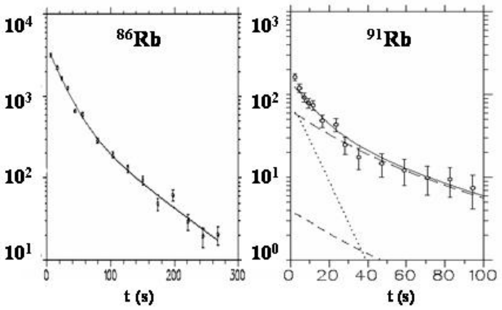

FIG. 2: Release curves of ^{86}Rb (left) and ^{91}Rd (right). For ^{86}Rb no mother effect is necessary to fit the experimental points. For ^{91}Rb is necessary to take into account this effect to have a good fit.

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[4] R. Kirchner, Nucl. Instr. and Meth. **B70** (1992) 186.
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[6] Olson et al., Phys. Rev. **C5** (1972) 20952107