Production of Neutron-rich Surface-ionized Nuclides at PARRNe


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I. INTRODUCTION

In the framework of the EURISOL and SPES projects yields of n–rich isotopes produced by fast neutron induced fission of $^{238}$U were measured at the ISOL set-up PARRNe (Production d’Atomes Radioactifs Riches en Neutrons) at IPN Orsay. The neutrons were generated by a beam of 26 MeV deuterons stopped in a graphite converter. The target was a standard ISOLDE type $^{238}$UC/graphite heated by a tantalum oven to about 2050°C. A surface ionization source was used to ionize selectively elements with low ionization potentials. In order to observe also their most n-rich isotopes, the identification was achieved by a combined measurement of $\beta$, $\gamma$-rays and $\beta$-delayed neutrons. A large variety of radioactive isotopes could be determined quantitatively. Production rates measured for Rb and Cs isotopes are presented here.

II. THE ON–LINE SET–UP

A 1 µA beam of 26 MeV deuterons delivered to the PARRNe line was fully stopped in a 3 mm thick graphite converter to produce a forward peaked flux of fast neutrons. The neutron mean energy was 10 MeV with a FWHM of the energy distribution of 10 MeV [4]. The converter was in direct contact to the target composed of 148 disks of ISOLDE–type $^{238}$UC (50 g/cm$^2$) pellets [5] at about 2050°C. The fission target was connected to a tungsten surface ionizer heated to about 2050°C. This ion source produces most efficiently alkali beams and shows a selectivity in favor of elements with ionization potential lower than about 6 eV (e.g. [6]). The radioactive ion beam extracted from the ion source was sent through an electromagnetic mass separator (mean bending radius of 0.6 m, dispersion of 1370 mm) [7] and collected on a movable metallized mylar tape. This tape allowed to remove after each acquisition the collection point away from the detectors. The detection system could identify simultaneously $\beta$, $\gamma$ and $\beta$-delayed neutrons. It consisted of the Mainz neutron long counter (an array of 49 $^3$He proportional counters embedded into a polyethylene matrix [8]), a 1 mm thick plastic scintillator for $\beta$ detection [9] and a 68% efficiency HP-Ge detector. The COMET–6X module [2] used for the data acquisition encoded in amplitude the signals from all detectors and tagged them with absolute, high resolution (400 ps) time information. Thus coincidences as well as on-line release curves as function of time could be reconstructed (see fig. 1).

III. YIELD MEASUREMENTS

Production of Rb isotopes measured at the PARRNe isotope separator are presented in figure 2. The short-lived Rb isotopes could be clearly identified by their $\gamma$ spectra up to $^{96}$Rb ($T_{1/2} = 114$ ms) while the $^{90}$Rb (50.3 ms) was observed by $\gamma$-rays and $\beta$-delayed neutrons. Under the same target-ion source conditions, productions of Cs isotopes measured at the PARRNe isotope separator are presented in figure 3.

Fig. 1: Release curve of $^{94}$Rb ($T_{1/2} = 2.7$ s).

Fig. 2: Yields in ions/µC of neutron-rich Rb isotopes.
The short-lived Cs isotopes could be clearly identified both by their $\gamma$ and neutron spectra up to $^{146}$Cs ($T_{1/2} = 321$ ms). As $^{147}$Cs ($T_{1/2} = 225$ ms) has no intense $\gamma$-ray, the isotope was only detected by the neutron detector. While looking for elements less efficiently produced (e.g. In), the W ionizer was heated up to 2450°C and the target up to 2200°C. With these conditions, yields of Rb and Cs isotopes increased (squares in Fig. 2).

![Fig. 3: Yields in ions/µC of neutron-rich Cs isotopes](image)

The gain appeared to be more important for the shortest-lived isotopes. It was a factor of 3 for $^{95}$Rb ($T_{1/2} = 378$ ms) and $^{145}$Cs ($T_{1/2} = 594$ ms), and a factor of 6 for $^{147}$Cs ($T_{1/2} = 225$ ms). Furthermore, $^{148}$Cs ($T_{1/2} = 158$ ms) could be observed with $8 \pm 1.6$ ions/µC. These results have been presented at EMIS14 conference [5].

References