Systematic comparison of ISOLDE-SC yields with calculated in-target production rates *

S. Lukić,[#] F. Gevaert, A. Kelić, M. V. Ricciardi, K.-H. Schmidt, O. Yordanov
GSI, Darmstadt, Germany

Within the scope of the EURISOL project [1], the design of a large-scale European secondary-beam facility based on the ISOL (Isotope Separation On Line) method is actually being worked out. One of the tasks defined in the project is devoted to the predictions of the nuclide yields of the future facility.

The efficiency with which specific nuclides are extracted can vary over many orders of magnitude, thus strongly influencing the final yields. The information on the behaviour of the extraction efficiency with isotopic half-lives can help identifying the issues that need most attention in the process of target and ion-source development. The overall extraction efficiencies have been obtained earlier for some nuclides by measuring the extracted yields of stable [2] or radioactive [3] tracers implanted into a target. This method requires a dedicated experimental effort for every nuclide and every target and ion-source system.

We have used the ABRABLA code, benchmarked against recent GSI experimental cross-sections, to calculate the nuclide production rates in ISOLDE targets by proton-induced spallation at 600 MeV. We have compared these results to the published ISOLDE yields obtained with the proton beam from the CERN Synchrocyclotron (SC) [4]. In this way, we have systematically deduced the overall extraction efficiencies for a wide variety of isotopic chains from different target and ion-source systems, and studied their dependence on the isotope half-life. This dependence is found to follow a simple pattern in many different cases. For the shortest-lived isotopes, the extraction efficiency scales with a power function of the isotope half-life. For longer half-lives, the decay losses become negligible, and the extraction efficiency approaches the value valid for the stable isotopes. This behavior can be parameterized using the following function with three parameters that summarize the essential properties of the system in question:

$$\varepsilon\left(t_{1/2}\right) = \frac{\varepsilon_s}{1+\left(\frac{t_{1/2}}{t_0}\right)^{-\alpha}} \qquad (1)$$

The parameters of the efficiency function are:

- The efficiency value ε_s in the limit of long half-lives.
- The exponent α of the power-function behaviour for the short half-lives.
- The value t_0 of the half-life around which the transition from the power-function to the constant behaviour occurs.

The efficiency in the limit of long half-lives reveals losses due to chemical reactions, sticking to the walls, condensation or escapes from the ionizer. The remaining two parameters directly relate to the decay losses and, thus, indicate the speed of the extraction.

As an example, the fit of the function (1) to the francium data is shown in the figure 1.

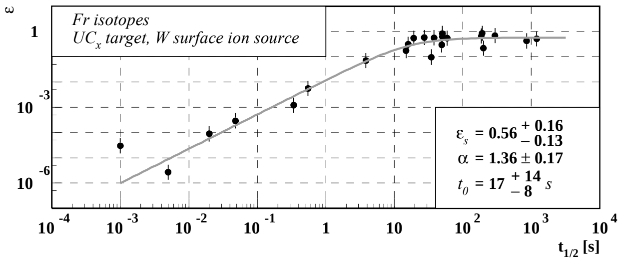

Figure 1: Overall release efficiency for Fr isotopes from a UC_x target with a W-surface ion source plotted in function of the isotopic half-life. The function described by the equation (1) was fitted to the data.

Several examples of fitted parameters for alkali elements are shown in the table 1.

Table 1: fitted parameter values for the alkali elements.

Element	Target	Ion Source	ε_s [%]	α	t_0 [s]
Na	UC_x	W surface	79^{+42}_{-28}	1.26±0.32	$1.2^{+2.4}_{-0.8}$
K	UC_x	W surface	108^{+45}_{-32}	1.33±0.31	22^{+37}_{-14}
Rb	UC_x	W surface	107^{+71}_{-43}	0.45±0.40	$4.6^{+150}_{-4.5}$
Cs	La molten	Ta surface	96^{+30}_{-23}	2.78±0.32	56^{+22}_{-16}
Fr	UCx	W surface	56^{+16}_{-13}	1.36±0.17	17^{+14}_{-8}

This kind of study is, in principle, applicable across the entire table of elements and for all targets and ion-sources. The present study comprises 35 cases of isotopic chains of elements from 4 different chemical groups, extracted from various target – ion-source systems [5].

References

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# s.lukic@gsi.de