A novel approach to medical radioisotope production using inverse kinematics

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A novel approach to produce medically important radionuclides using inverse kinematics has been developed at the Cyclotron Institute at Texas A&M University. A heavy-ion beam is accelerated at an appropriate energy and focused on a light gas target. A foil catcher is positioned after the target to collect the isotopes of interest, typically focused along with the beam direction. Secondary emitted particles such as neutrons from the primary nuclear reaction can be used to irradiate other targets for further radionuclide production. As the quantity of material required to prepare heavy-ion beam is less than that used in the standard solid target approach, material costs are expected to be considerably reduced through this methodology. A detailed discussion about the methodology can be found in [1-3]. A successful test of this concept was performed with the production of the theranostic radionuclide ^{67}Cu ($T_{1/2}$ = 62 h) through the reaction of a ^{70}Zn beam at 15 MeV/nucleon with a hydrogen gas target [1]. The ^{67}Cu radionuclide alongside other coproduced isotopes, was collected after the gas target on an aluminum catcher foil, them their γ-activity was measured off-line. The main radioimpurity in the Al catcher coming from the ^{70}Zn + p reaction was ^{69m}Zn ($T_{1/2}$=13.8 h).

The activities at the end of bombardment (A_{EOB}) as well as the activities considering a beam intensity of 1pnA and an irradiation time of 1h, the so-called 1pnA-1h activity (H_{EOB}) were obtained. The average cross section ⟨σ⟩ and the respective average energy ⟨E⟩ were determined. In addition, the thick target yield in inverse kinematics extracted from the experimental activities and beam current TTY_{inv}^{exp}, and its conversion to forward kinematics TTY_{for}^{exp} were also obtained. Details of the analysis and the results can be found at [3]. Table I presents all these experimental results in comparison with the thick

Table 1. Experimental results for ^{67}Cu and ^{69m}Zn: activities, average cross sections and respective average energies, thick target yield in inverse kinematics and its conversion to forward kinematics. The thick target yield calculated from cross section and stopping power and the integral yield recommended by IEAE [4] are shown for comparison.

	A_{EOB} (kBq)	H_{EOB} $\left(\frac{kBq}{pnA.h}\right)$	$\langle\sigma\rangle$ (mb)	TTY_{inv}^{calc} (GBq/C)	TTY_{inv}^{exp} (GBq/C)	TTY_{for}^{exp} (GBq/C)	$Y(E_{max}) - Y(E_{min})$ (GBq/C)
^{67}Cu	2.16(12)	1.8(5)	7.7(21)	0.0161(16)	0.021(5)	0.38(10)	0.314
^{69m}Zn	2.55(26)	2.2(6)	4.6(13)	0.0214(21)	0.027(7)	0.50(14)	

target yield in inverse kinematics determined from cross section and stopping power TTY_{inv}^{calc} and the integral yield, $Y(E_{max}) - Y(E_{min})$ recommended by IAEA [4]

The results for ^{67}Cu production are in good agreement with experimental cross section from Kastleiner *et al*. [5]. For ^{69m}Zn, the average cross section describes well the experimental values from Levkovskij *et al*. [6]. The TTY_{inv}^{calc} predicted and the TTY_{inv}^{exp} experimentally determined are consistent considering the uncertainties. The experimental TTY converted to forward kinematics, for the ^{67}Cu, are also in good agreement with the integral yields recommended by IAEA [4], $Y(E_{max}) - Y(E_{min})$ as seen in Table I.

A test using the forward-focused neutrons from the primary reaction to irradiate ^{nat}Zn in order to produce ^{67}Cu was also performed. A block of twenty 25.4 × 25.4 mm^2 foils of ^{nat}Zn with 1 mm thickness was placed behind the Al catcher. Although, the tests showed promising results [3], more detailed experimental investigation is needed.

The present successful test indicates the possibility of producing important non-standard radionuclides of high radionuclide purity with the approach of inverse kinematics. The main requirement necessary to achieve the production of activities appropriate for preclinical studies is the availability of high-intensity (particle μA) heavy-ion primary beams.

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