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Radionuclides For Theranostic Applications

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1. Introduction

The use of High Specific Activity Radionuclides HSARNs, obtained by either proton, deuteron or alpha cyclotron irradiation, followed by selective radiochemical separation from the irradiated target in *No Carrier Added* (*NCA*) form, is a powerful analytical tool for plenty of applications in pure and applied sciences and technologies. The main applications of these RNs are in medical radio-diagnostics and metabolic radiotherapy in addition to toxicological, environmental and industrial studies. Nowadays the new challenge in Nuclear Medicine is the so-called theranostic medicine, a relatively novel paradigm that involves specific individual 'dual-purpose' radionuclides or radionuclide pairs with emissions that are suitable for both imaging, therapy and monitoring the response to therapy. The theranostic radionuclides would potentially bring us closer to the age-long dream of personalized medicine [1]. Different radionuclides with the suitable characteristics to be used as theranostics can be produced by bombardment of targets by charged particle beams in No Carrier Added form with very high A_S, with irradiations made with deuteron beams that present some more advantages. Recently there is an increasing interest in the terbium family, due to the four medically relevant radioisotopes ^{149}Tb, ^{152}Tb, ^{155}Tb and ^{161}Tb, which could be employed either in diagnostic or therapy. We present our results of the cross-section determination of nuclear reactions induced by deuterons on ^{nat}Dy targets.

2. Experiment

At the Radiochemistry Laboratory of LASA, a wide range of high specific activity accelerator-produced radionuclides have been produced since the 70-ties in *NCA* form. Presently, nuclear activations are carried out at the cyclotron IBA K=70 of ARRONAX Center in Nantes France, which can deliver proton and alpha beams, with variable energy up to 70 MeV and deuteron beams of energy up to 35 MeV. The gamma and X-ray spectra are measured at Physics Measurements Laboratory in

LASA with several 15 % efficient, 2.3 keV (FWHM) resolution, coaxial 50 cm^3 active volume HPGe detectors relative to 3"x3" NaI(Tl) and a Compton to peak ratio of 30:1 at the 1332 keV photo-peak of ^{60}Co connected to Ortec mod. 918 and 919A MCAs. All detectors are calibrated with reference sources and standard geometries with overall uncertainties of no more than 3 % at 1 σ. To avoid corrections for the different geometry configurations, all samples are measured in the same geometrical assembly as the calibration sources. The quality control tests are carried out for both chemical and radiochemical purities, using electrothermal atomic absorption spectrometry, instrumental neutron activation analysis in conjunction with a liquid scintillation counter and HPGe spectrometry.

3. Results and Discussion

The production of ^{149}Tb, ^{152}Tb, ^{155}Tb and ^{161}Tb by deuteron beams irradiation with particular attention to the ^{155}Tb and ^{161}Tb production with the long-lived interferences has been investigated [2] in the energy range of 12.5 – 32 MeV and the coproduction of terbium and dysprosium contaminants ($^{156,160}Tb$ and $^{155,157,159}Dy$). The experimental cross-sections for the different reactions were determined with the well-known staked foil technique and compared with only one set of data present in the literature [3], showing a generally good agreement. The curves of theoretical calculations with EMPIRE-II, EMPIRE-3.2.2 and TALYS 1.96 run with default options and fail to predict the experimental data in most cases. Also, the Thick Target Yields, obtained as the integration of the thin target yields, and the radionuclidic Purity are calculated for ^{155}Tb and ^{161}Tb radionuclides and compared with protons irradiation production as well. For ^{161}Tb the results obtained with deuterons are better, reaching a RNP at the highest energy and energy loss of about 70 %. For ^{155}Tb better results are obtained for proton irradiation, suggesting to try to can have a larger energy interval for deuterons irradiations or to study the indirect production via the decay of ^{155}Dy in a ^{155}Dy-^{155}Tb generator but taking into account the unavoidable presence of ^{157}Dy with a TTY higher than ^{155}Dy.

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