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Cyclotron Production of Tb-155 from Gd_2O_3 Targets: From Design to Preliminary Results

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Introduction

Terbium-155 ($t_{1/2}$=5.32 days) is one of four medically relevant terbium (Tb) isotopes and has suitable gamma emission for Single Photon Emission Computed Tomography (SPECT) imaging.[1] With identical chemical properties as other Tb isotopes, ^{155}Tb is an element equivalent imaging companion for ^{161}Tb (β^- therapy). ^{155}Tb is also being investigated as the imaging companion to other radionuclides like ^{225}Ac.

Historically, ^{155}Tb has been produced in small quantities via on-line mass separation of high-energy spallation products of heavier elements like Ta.[2] This method is unsuitable for routine production of ^{155}Tb as the cost of production is high for a relatively low yield. Current research efforts have focused on the production of ^{155}Tb from enriched Gd_2O_3 targets via proton irradiation in low energy cyclotrons.[3]

Herein displays the design, manufacture and preliminary irradiation data of natural Gd_2O_3 targets irradiated at TRIUMF's TR13 cyclotron.

Target Design

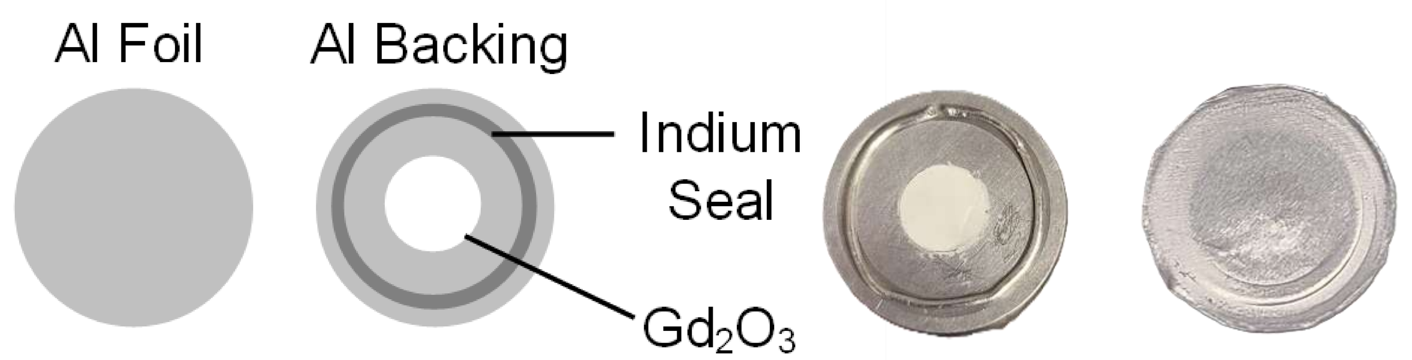

Figure 1: (left) Schematic of Gd_2O_3 target, (right) photographs of a target in assembly and a sealed target

Design Considerations:

- Due to the fragile nature of the Gd_2O_3 target an Al foil cover was added. This cover is sealed to the backing with indium wire
  - To overcome the poor thermal conductivity of the Gd_2O_3 target material, an Al backing was chosen, and the maximum beam current was limited to 20 μA.
    - The thickness of the Al foil cover was optimized using SRIM calculations[4] to degrade the incident proton energy to 10.8 MeV minimize the $^{155}Gd(p,2n)^{154}Tb$ reaction.

Irradiation Results

Table 1: Activity of Terbium isotopes from irradiations at increasing beam currents and times (Activities reported at EOB).

Irradiation Time (min)	Current (μA)	^{155}Tb (MBq)	$^{156}Tb^{m/g}$ (MBq)
10	2	0.204	0.272
10	5	0.368	0.506
10	10	0.860	1.215
10	15	1.945	2.439
10	20	3.129	3.864
30	20	3.858	5.645
60	20	11.813	15.937

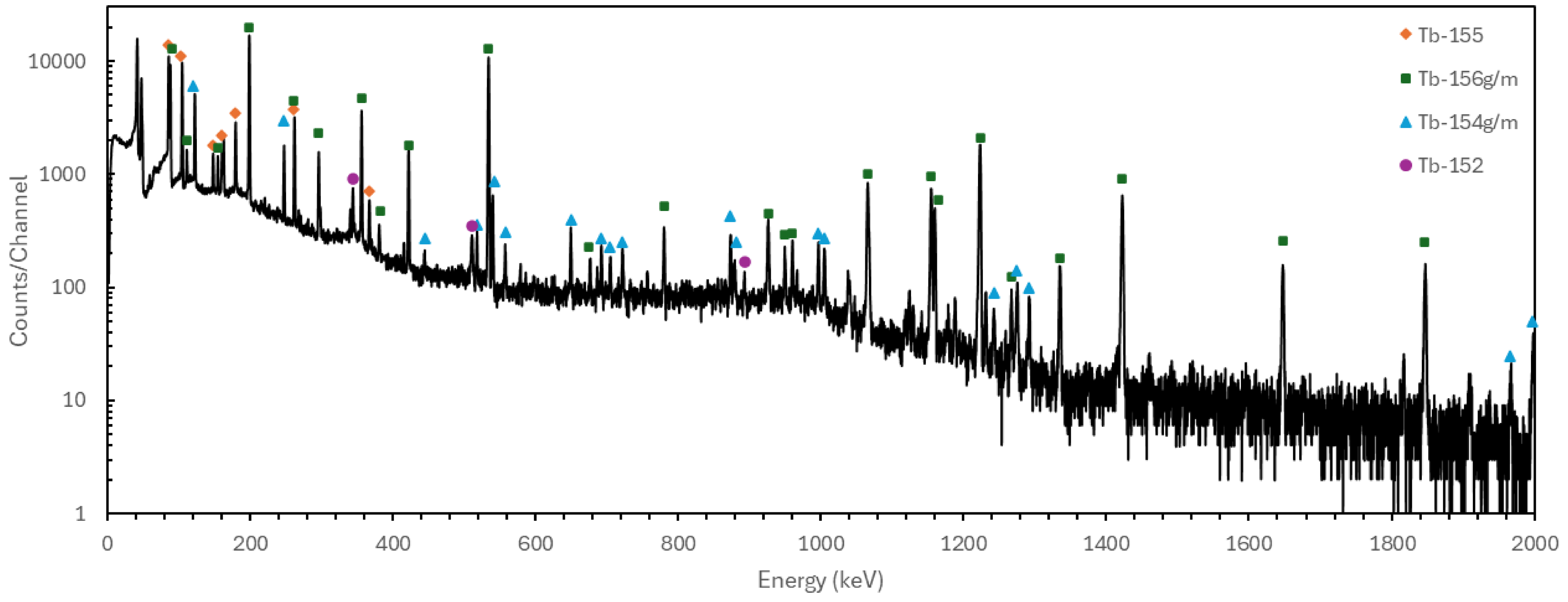

Figure 2: Gamma spectrum of dissolved target solution, recorded on a Canberra HPGe detector, live time 1831 s

Figure 3: Unsealed Gd_2O_3 targets post irradiation (from left to right 5 μA, 10 μA, 15 μA, and 20 μA

Future Works

The next steps towards the routine production of ^{155}Tb for pre-clinical applications include:

- The development of a suitable purification method to isolate Tb from the Gd target material. Modification of an established solid phase extraction method[5] will be attempted first.
- To evaluate purification methods, samples will be assessed with ICP-MS, and gamma spectroscopy.

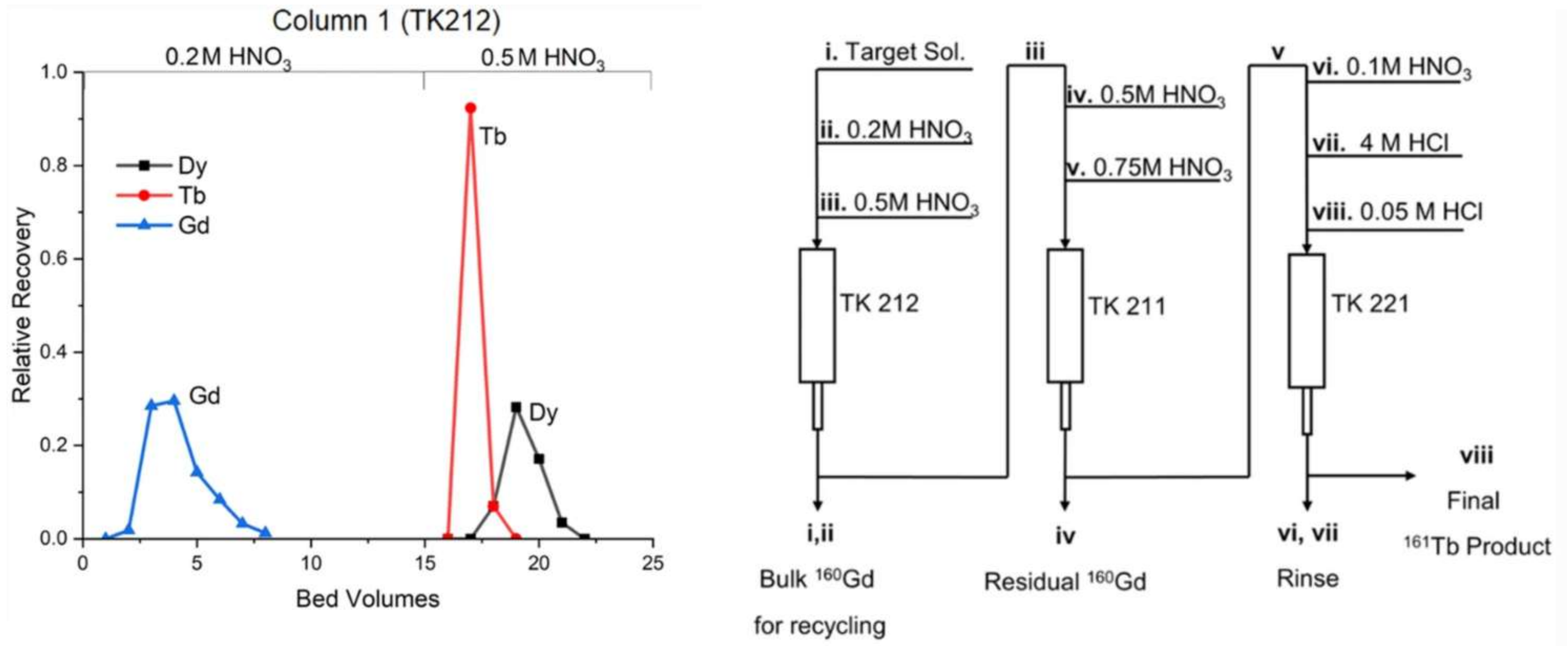

Figure 4: Purification method of ^{161}Tb, with potential to be modified for cyclotron produced ^{155}Tb.[5]

- Once the Tb product has reached suitable chemical and radiochemical purity, chelation study with ligands and bioconjugates will be tested.
- With the process fully established for natural Gd_2O_3 targets Enriched $[^{155}Gd]Gd_2O_3$ targets will be used to produced higher activities of ^{155}Tb with a greater radionuclidic purity.
- The purification method will include a recycling procedure to reclaim $[^{155}Gd]Gd_2O_3$.

Acknowledgements:

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References:

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Discovery, accelerated