

TRIGA Reactor Production and Synergistic Separation of ^{161}Tb from Enriched ^{160}Gd Targets

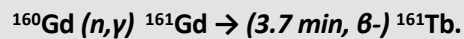


Connor K. Holiski¹, Glenn E. Sjoden¹, Tara E. Mastren¹

¹ Nuclear Engineering Program, Department of Civil and Environmental Engineering, University of Utah, Salt Lake City, Utah

I. Introduction

One radionuclide of interest to nuclear medicine is terbium-161, which decays by beta emission and has similar beta decay properties as ^{177}Lu (FDA approved as LUTATHERA®). In addition to beta emission, ^{161}Tb emits a substantial number of conversion and Auger electrons. [1,2] Auger electrons are of high interest in nuclear medicine because of the advantages over traditional beta therapy for the potential treatment of metastatic and disseminated disease. [3] The Auger electrons emitted from ^{161}Tb have high LET (1-10 keV/ μm), short ranges (0.1-50 μm) in tissue, and have been shown to provide a 2-3-fold increase in dose over ^{177}Lu for distances between 10-100 μm from the location of decay. [4] The production of ^{161}Tb is achieved using nuclear reactors via the indirect method,



One of the challenges with implementing ^{161}Tb in nuclear medicine is separating target and product material to obtain high specific activity. Hundreds of liquid and solid phase systems have been investigated for adjacent lanthanide separations, but most systems fail to achieve selectivity in their separation. One technique for achieving enhanced separation is employing dual extractant systems that display synergism in separation and extraction efficiency.

II. Methods

Enriched ^{160}Gd (10.0 mg) and natural Gd (50.0 mg) targets were irradiated in the CI at Utah's TRIGA reactor at 90 kW for 3 hours. Theoretical yields were calculated employing a 14-group energy flux using a 3D Transport model. Experimental yields were measured via HPGe spectroscopy utilizing characteristic gamma rays for ^{161}Tb . Extraction behavior of Tb^{3+} and Gd^{3+} in liquid-liquid systems was evaluated using extractants (β -diketones and neutral) alone and in combination at 0.05M in 1,2-dichloroethane. The extraction for terbium was evaluated using radiotracer ^{160}Tb , while gadolinium extraction was evaluated using UV-VIS methods and Arsenazo III dye. Extraction was studied as a function of pH and extractant concentrations.



Figure 1 – This figure shows the University of Utah's TRIGA reactor at 90 kW for the enriched irradiation.

III. Results

Extraction with combined neutral and β -diketones extractants synergistically increased extraction across all studied pH values. The β -diketone HP showed greater increase in extraction efficiency with > 95% from pH 1.5 – 3.0, whereas HTTA only achieved > 95% at pH 2.25 – 3.0. Preliminary separation factors give 1.35 for the CMPO/HP system and 1.52 for the DBDECMP/HP system both at pH 1.50. Experiments are underway to determine optimal ligand concentration and pH for maximum separation of ^{161}Tb from bulk Gd targets. Preliminary conversion of liquid-liquid systems to extraction chromatographic resins show that synergism is present in both systems.

Table 1 – This table shows the experimental and theoretical yields with the corresponding percent error for natural and enriched gadolinium targets.

| Sample | Theoretical Yield | Actual Yield | Percent Error |
|-----------------|----------------------|----------------------|---------------|
| Natural Target | 65.00 μCi | 11.62 μCi | 82.12% |
| Enriched Target | 59.00 μCi | 56.89 μCi | 3.576% |

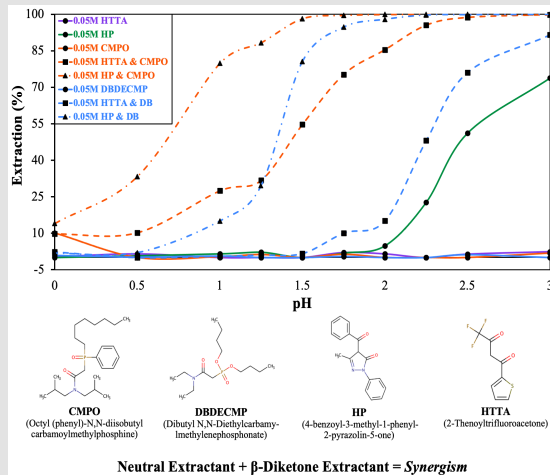


Figure 2 – This figure shows the extraction percentage of Tb^{3+} (stable and ^{160}Tb as a radiotracer) as a function of pH from a nitric acid medium with various extractants dissolved in 1,2-Dichloroethane.

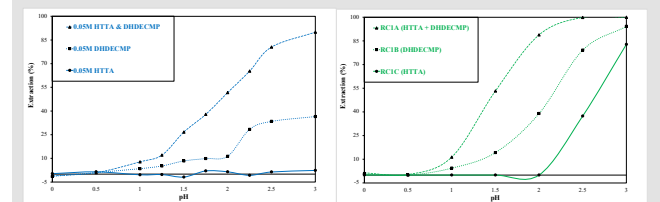


Figure 3 – This figure shows the extraction percentage of Tb^{3+} (stable and ^{160}Tb as a radiotracer) for novel Extraction Chromatographic (EXC) Resins (right) and Liquid-Liquid System (left), Extraction as a function of pH from a nitric acid medium with mixtures of HTTA (2-Thenoyltrifluoroacetone) and DBDECMP (Diethyl N,N-Diethylcarbamylmethylene-phosphonate) in EXC resins (solid phase).

IV. Conclusions

The dual ligand systems studied demonstrate synergistic extraction of Tb and Gd from nitric acid solutions ranging in pH from 1-3. Experiments are currently underway to determine optimum conditions (pH, ligand concentration) for the enhanced separation of Tb from Gd. Furthermore, conversion to a solid phase extraction chromatographic system is being explored as these systems further enhance separation factor and significantly minimize mixed solvent waste.[5] These novel solid phase systems are being studied using both Tb and Gd for thermodynamics, loading capacities, and kinetics.

V. References

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VI. Acknowledgement

This research is supported by the U.S. Department of Energy Isotope Program, managed by the Office of Science for Isotope R&D and Production. This work was also supported in part by Department of Energy Isotope Program's Grant DE-SC0022550, the Horizon-broadening Isotope Production Pipeline Opportunities (HIPPO) program.

