Preparation and Evaluation of a SnO_2-Based $^{44}Ti/^{44}Sc$ Generator for Medical Applications

Christine E. Schmidt,[1,2] Jennifer A. Shusterman,[3,4] Melissa A. Deri[1,2]

[1]Ph.D. Program in Chemistry, The Graduate Center of the City University of New York, New York, NY 10016
[2]Department of Chemistry, Lehman College, CUNY, Bronx, NY 10468
[3]Department of Chemistry, Hunter College, CUNY, New York, NY 10065
[4]Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore, CA, 94550

Introduction

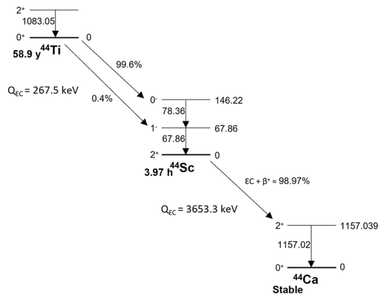

Figure 1. ^{44}Ti decay scheme.

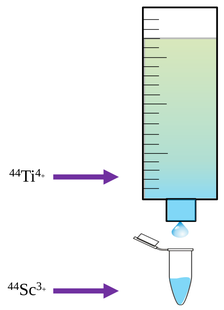

Figure 2. Typical column chromatography setup.

- ^{44}Sc is a favorable radionuclide for positron emission tomography due to its relatively short half-life ($t_{1/2}$ = 3.97 h) and high positron branching ratio (94.3%).
- $^{44}Ti/^{44}Sc$ generators could provide a source of ^{44}Sc for medical applications without the need for an on-site cyclotron by separating the ^{44}Sc from its ^{44}Ti parent nuclide bound to a chromatography column.
- This work focuses on the synthesis and utilization of tin dioxide (SnO_2), a robust inorganic-based resin, as the column matrix for a $^{44}Ti/^{44}Sc$ generator.

Synthesis and Characterization of SnO_2

Figure 3. Synthesized SnO_2.

- SnO_2 was synthesized by slowly digesting metallic Sn with hot concentrated HNO_3 [4].
- **Figure 3:** SnO_2 calcined at 650°C after 2 hours.
- **Figure 4:** FT-IR peaks at 605 cm^{-1} and 467 cm^{-1} indicate Sn-O and O-Sn-O vibrational stretching, respectively.
- **Figure 5:** Powder XRD pattern assigned to the (110), (101), (200), and (211) planes of the tetragonal phase with 2θ value of SnO_2.

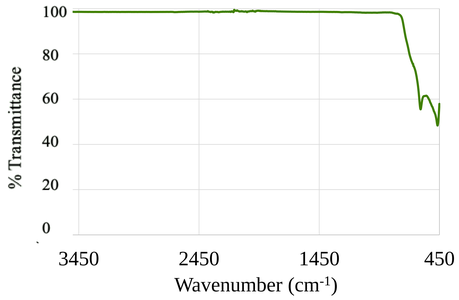

Figure 4. FT-IR spectrum of synthesized SnO_2.

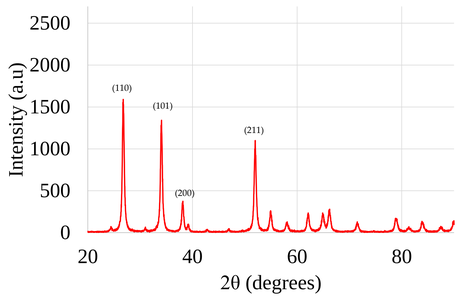

Figure 5. XRD pattern of synthesized SnO_2.

Batch Experiments Results

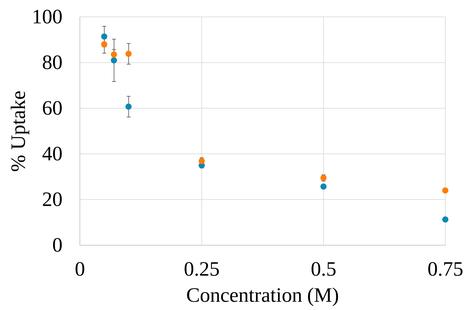

Figure 6. Percent uptake of ^{44}Ti at 5 Hours in HCl and HNO_3.

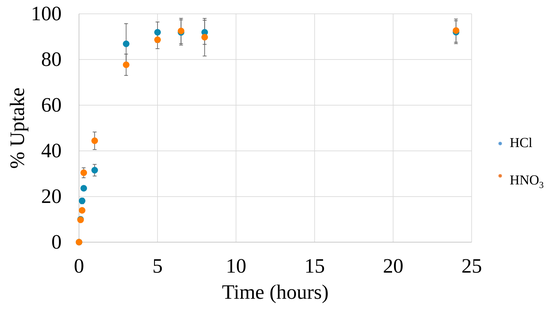

Figure 7. Percent uptake of ^{44}Ti overtime in 0.05 M HCl and HNO_3.

- ^{44}Ti was detected directly via characteristic gamma emissions present at 67.87 keV (93.0 %) and 78.32 keV (96.4 %) using a HPGe detector.
- **Figure 6:** Preliminary batch study results showed relatively high ^{44}Ti retention to the resin at lower acid concentrations (0.05 M HCl and 0.05 M HNO_3) and increased contact time (up to 5-hours).
- **Figure 7:** Equilibrium was established between 5-6.5 hours.

Column Experiments Results

Figure 8. $^{44}Ti/^{44}Sc$ generator setup.

- **Goal:** Retain ^{44}Ti on the resin and elute pure ^{44}Sc.
- **Figures 9 and 10:** Column studies with increased acid concentrations (0.05-12 M) were performed to determine the acid concentration with the highest amount of ^{44}Sc elution.
- Concentrations between 0.05-1 M showed less than 45% of the total amount of ^{44}Sc eluted off the columns.
- Acid concentrations >9 M caused more than 1% ^{44}Ti breakthrough.

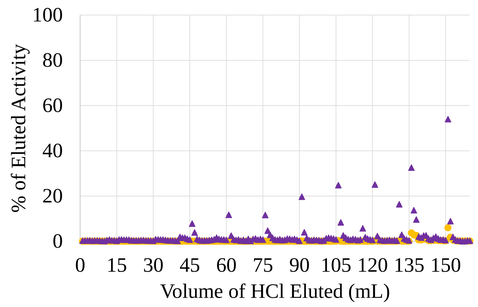

Figure 9. Percent of $^{44}Ti/^{44}Sc$ eluted activity with increasing HCl concentrations from 0.05-12 M.

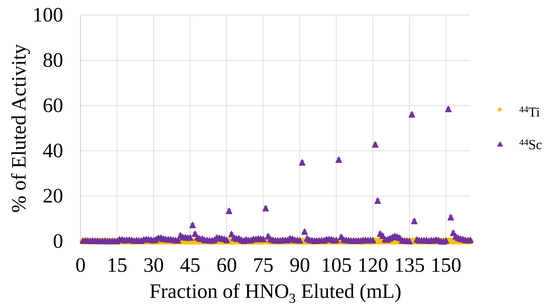

Figure 10. Percent of $^{44}Ti/^{44}Sc$ eluted activity with increasing HNO_3 concentrations from 0.05-12 M.

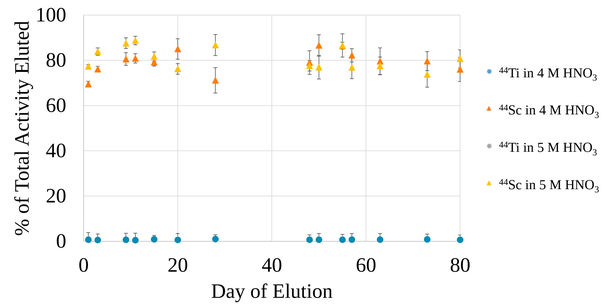

Figure 11. Percent of total $^{44}Ti/^{44}Sc$ eluted activity per day of elution in 4 M and 5 M HNO_3.

- **Figure 11:** Percent of total activity eluted off 4 and 5 M HNO_3 columns over 80 days.
- Less than 1% of ^{44}Ti breakthrough has been seen for both acid concentrations.
- Note in **Figure 11** that the ^{44}Ti measurements for both acids concentrations overlap almost entirely.

Conclusions and Future Work

- Over the course of 5 months, the SnO_2-based $^{44}Ti/^{44}Sc$ generator showed promising results as an efficient separation method for $^{44}Ti/^{44}Sc$.
- ^{44}Sc elution and ^{44}Ti breakthrough will continue to be monitored at the selected optimal acid concentrations to evaluate the system for longevity.
- Future work includes an up-scaled generator system for a long-term generator study with a higher ^{44}Ti activity load. Radiolabeling of the ^{44}Sc eluted from the generator will also be investigated.

Acknowledgements

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References

(1)Filosofov, D. V.; Loktionova, N. S.; Rösch, F. A $^{44}Ti/^{44}Sc$ Radionuclide Generator for Potential Application of ^{44}Sc-Based PET-Radiopharmaceuticals. *Radiochim. Acta* **2010**, *98* (3), 149–156.

(2) Radchenko, V.; Meyer, C. A. L.; Engle, J. W.; Naranjo, C. M.; Unc, G. A.; Mastren, T.; Brugh, M.; Birnbaum, E. R.; John, K. D.; Nortier, F. M.; Fassbender, M. E. Separation of ^{44}Ti from Proton Irradiated Scandium by Using Solid-Phase Extraction Chromatography and Design of $^{44}Ti/^{44}Sc$ Generator System. *J. Chromatogr. A* **2016**, *1477*, 39–46.

(3) Larenkov, A. A.; Makichyan, A. G.; Iatsenko, V. N. Separation Of ^{44}Sc From ^{44}Ti in the Context of a Generator System for Radiopharmaceutical Purposes with the Example of [^{44}Sc]Sc-PSMA-617 and [^{44}Sc]Sc-PSMA-I&tT Synthesis. *Molecules* **2021**, *26* (21).

(4) Das, S. S.; Chattopadhyay, S.; Alam, M. M.; Barua, L.; Das, M. K. Preparation and Evaluation of SnO_2-Based $^{68}Ge/^{68}Ga$ Generator Made from ^{68}Ge Produced through NatZn(α,Xn) Reaction. *Appl. Radiat. Isot.* **2013**, *79*, 42–47.