Production and Purification of ^{47}Sc from ^{nat}V Targets

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Introduction

An example of a clinically used theranostic pair is $^{68}Ga/^{177}Lu$. The term "theranostic" agent stems from the use of a therapeutic agent and a diagnostic agent used in conjunction in medicine. While $^{68}Ga/^{177}Lu$ have shown to be clinically important as a theranostic strategy, there is a drawback to using this pair of radionuclides. The two radionuclides have differing chemistries, so this can pose several challenges in attempting to develop imaging and therapeutic agents with identical properties. A solution to these challenges would be to develop an elementally matched theranostic pair. This will result in identical complexation chemistry, identical *in vitro* binding, and identical *in vivo* pharmacokinetics. An elementally matched theranostic pair would also allow scientists and physicians to image for treatment assessment, determine dosimetry of radiopharmaceuticals, therapy, and follow-up assessment. Three isotopes of scandium (^{43}Sc, ^{44}Sc, and ^{47}Sc) have the decay properties for potential use in medicine as a theranostic pair compared to $^{68}Ga/^{177}Lu$ (decay scheme below[1]).

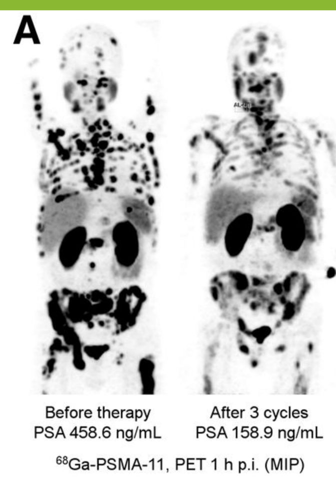


Figure 1: PET imaging using ^{68}Ga[1]

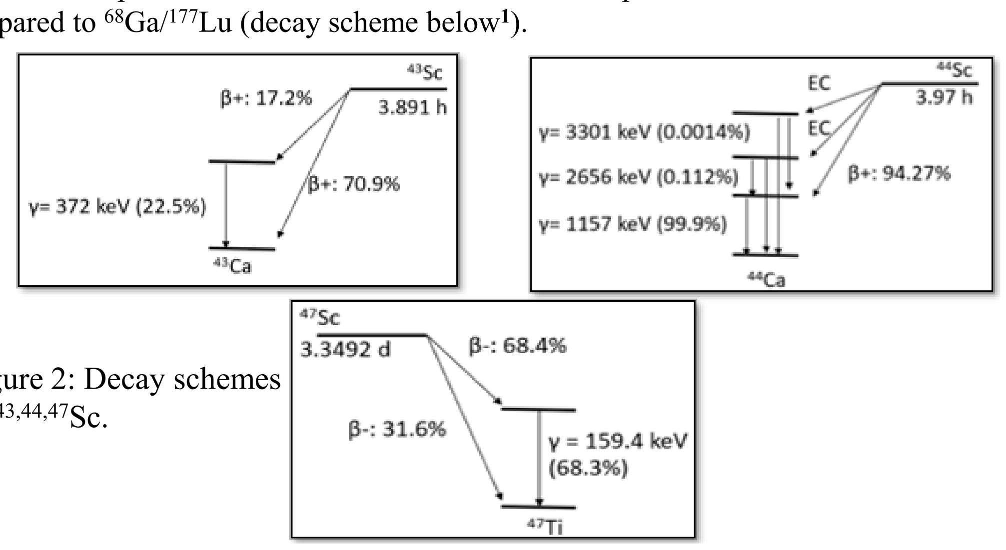


Figure 2: Decay schemes of $^{43,44,47}Sc$.

- Availability for high radionuclide purity scandium isotopes are limited due to lack of robust production techniques.
- Our goal is to develop a technique to produce high purity radioscandium isotopes from proton irradiation of ^{nat}V foil targets.

Production

UAB's TR24 Cyclotron

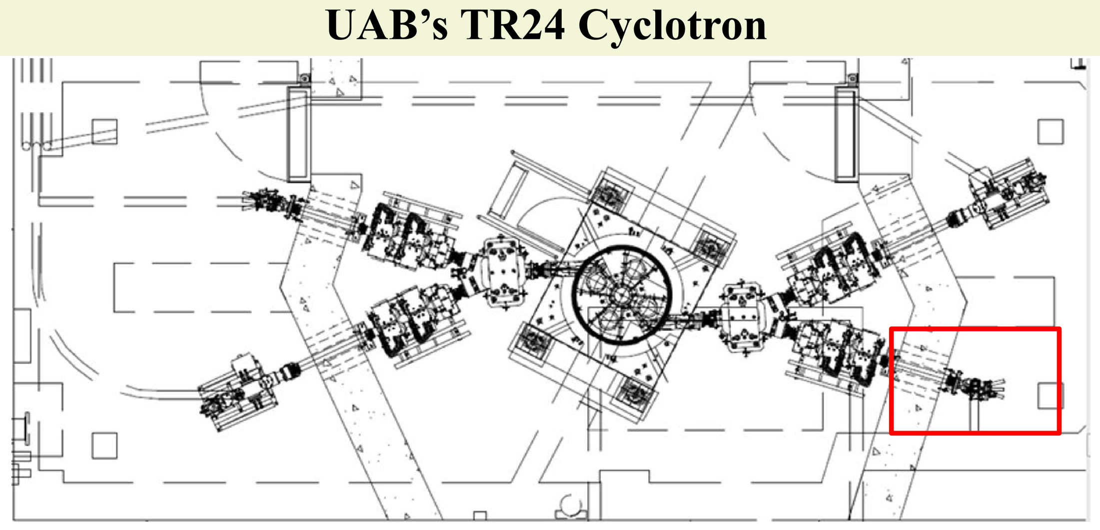


Figure 3: Schematic of UAB's TR24 cyclotron.

Production of ^{47}Sc from Vanadium Targets

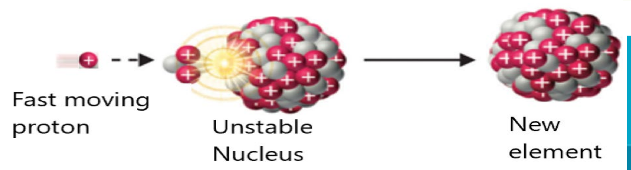


Figure 4: Proton irradiation

Table 1: Products from ^{nat}V

Isotope	Nuclear reaction	Half-life	γ
^{47}Sc	$^{51}V(p,p+\alpha)^{47}Sc$	3.3 days	159(68.3%)
^{49}Cr	$^{50}V(p,2n)^{49}Cr$	42.3 minutes	91(53.2%) 153(30.3%)
^{51}Cr	$^{51}V(p,n)^{51}Cr$	27.7 days	320.1(9.9%)

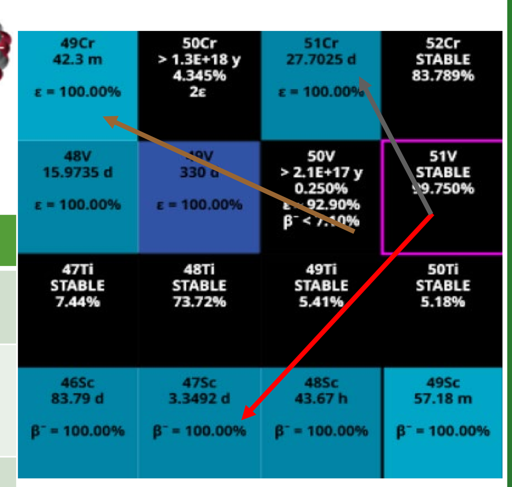


Figure 5:Nuclear reactions that occur during this production method.

Cross-sections for $^{51}V(p,p+\alpha)^{47}Sc$ and $^{51}V(p,n)^{51}Cr$

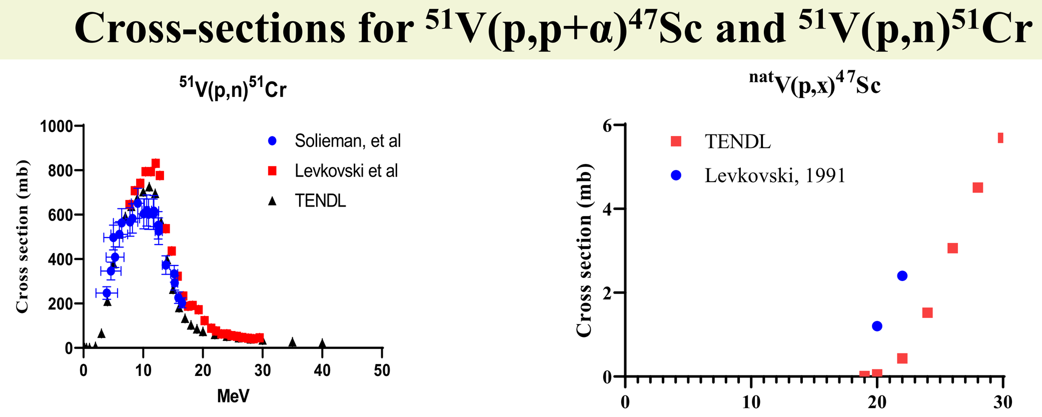


Figure 5: Cross sections for ^{47}Sc and ^{51}Cr on ^{51}V[2,3,4]

Purification

Target

- 0.254 mm thick foil
- 10 mm diameter disc
- 24 MeV for $^{51}V(p,p+\alpha)^{47}Sc$
- 40μA
- 4 h bombardment
- 2 mm tantalum target holder

Isotopic Abundance of Vanadium Foil

- ^{50}V: 0.25%
- ^{51}V: 99.75%

Dissolution Process

- Step 1: Target removed and dissolved in 10 mL of 7 M HNO_3
- Step 2: Dried down at 160 °C until completely dry
- Step 3: 10 mL of 8 M HCl added to reconstitute

Column Equilibration

- Step 1: Add 1.31 grams of AG MP-50 resin[5]
- Step 2: Add 20 mL of 10% 1 M ammonium acetate
- Step 3: Add 20 mL of MilliQ water
- Step 4: Add 20 mL of 8 M HCl

Separation

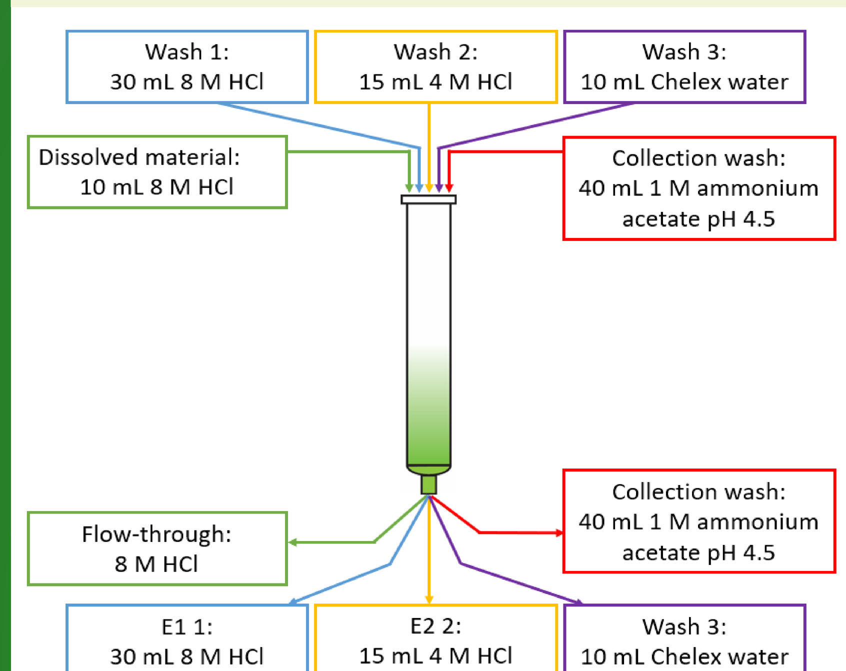


Figure 6: Step by step separation process

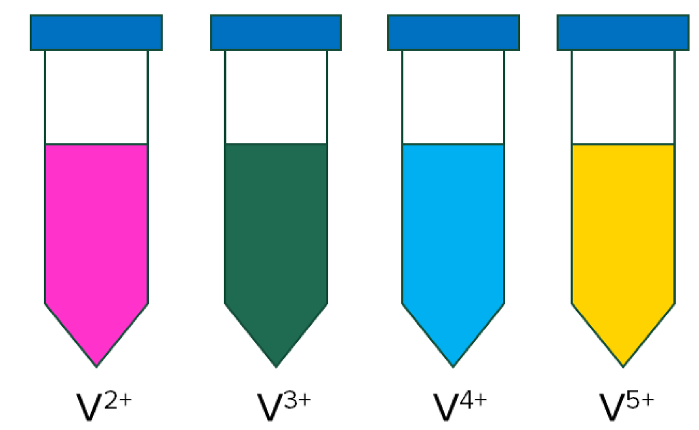


Figure 7: Different oxidation states of vanadium

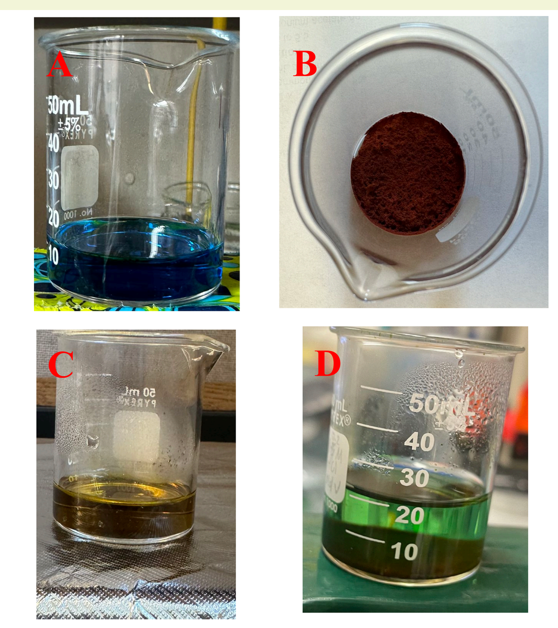


Figure 8: A, 7 M HNO_3. B, dried ^{Nat}V. C, heated 8 M HCl. D, cooled 8 M HCl

Separation Results

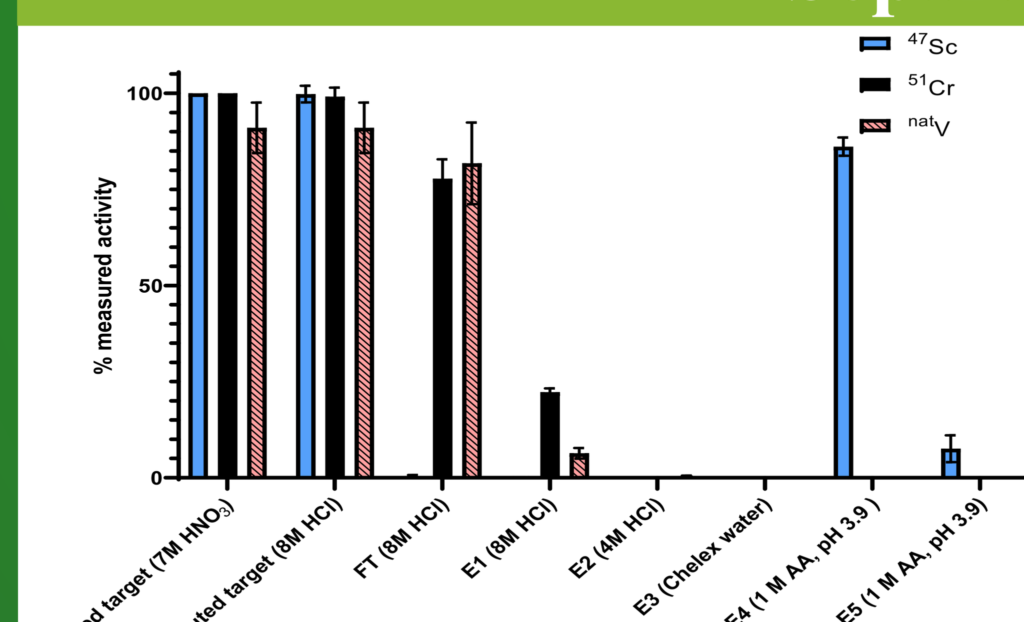


Figure 9: Separation profile

Activity corrected to end of bombardment for the collected ^{47}Sc: E4				
Radionuclide	^{46}Sc	^{47}Sc	^{48}Sc	Total radioscandium
Activity (μCi)	0.36	746.5	1.99	748.8
Percentage	0.05	99.7	0.26	100

Figure 11: Chart detailing the radionuclidic purity of radioscandium produced.

Average activity yields at EOB for 0.254 mm target at 24 MeV, 40 μA protons for 4 hours:

- ***^{47}Sc: 827.1 ± 82.6 μCi***
- ***^{51}Cr: 4.77 ± 0.36 mCi***

% Recovery with Respect to Dissolved Target	
Step	*^{47}Sc*
Reconstituted	99.5
FT	0.6
E1	7.08
E2	3.5
E3	0.09
E4	86.9
E5	7.5

Figure 10: Chart detailing the numerical values from the separation

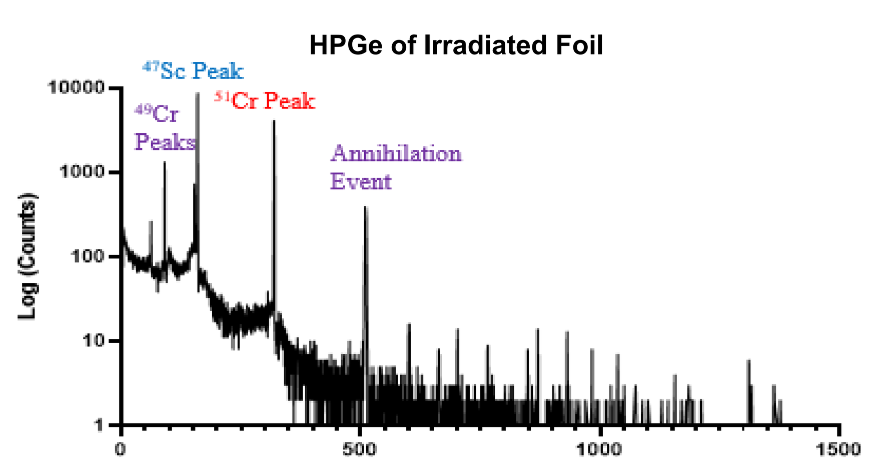


Figure 12: High Purity Germanium data from the irradiated foil

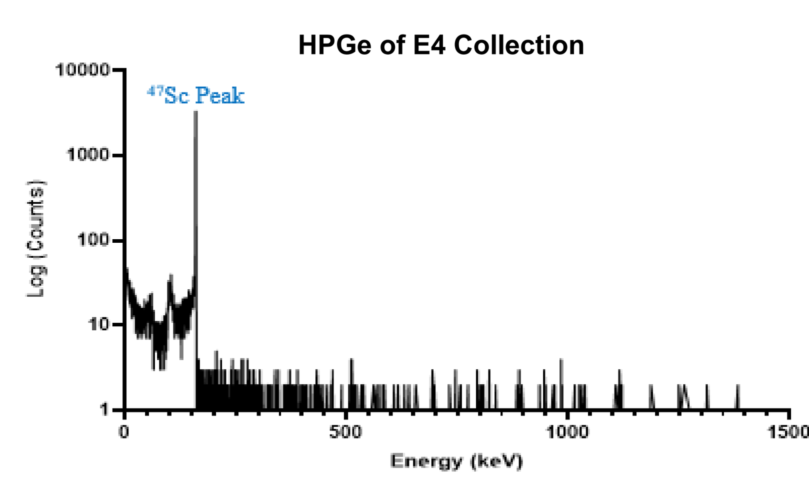


Figure 13: High Purity Germanium data from the pure ^{47}Sc

Radiolabeling

Studies were conducted to determine the apparent molar activity (AMA) of the purified ^{47}Sc

First, ^{47}Sc was evaporated down to dryness and was then brought up in 100μL of 0.1 M HCl. A 5 mg/mL stock of DOTA (1,4,7,10 Tetraazacyclodecane-1,4,7,10-tetraacetic acid) was made and set aside for serial dilutions for different concentrations of DOTA. Samples were made by adding 80-100 μCi of ^{47}Sc in each vial of 0.25 M ammonium acetate pH 4 and the carrying concentration of DOTA (performed in triplicates). These samples were then heated and vortexed at 95°C at 800 rpm for 30 minutes. After the 30 minutes time point, the samples were then analyzed by utilizing a SG-iTLC developed in 1 M citrate buffer to determine labeling.

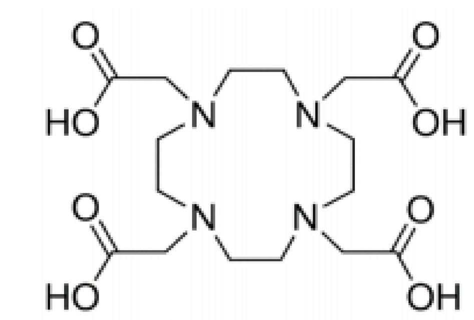
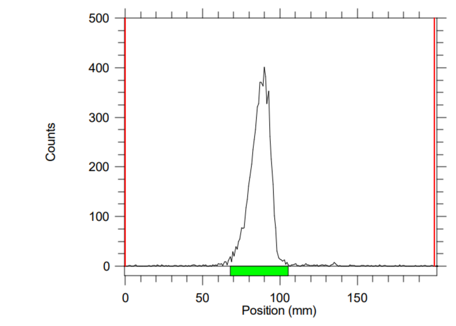
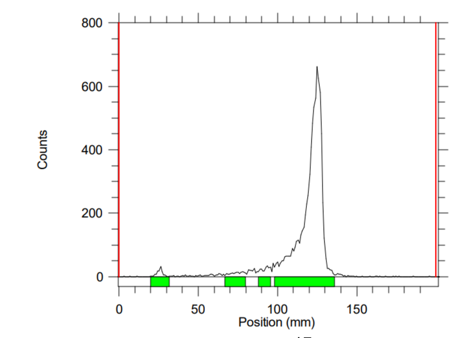


Figure 14: structure of DOTA



Labeled [^{47}Sc] Sc-DOTA

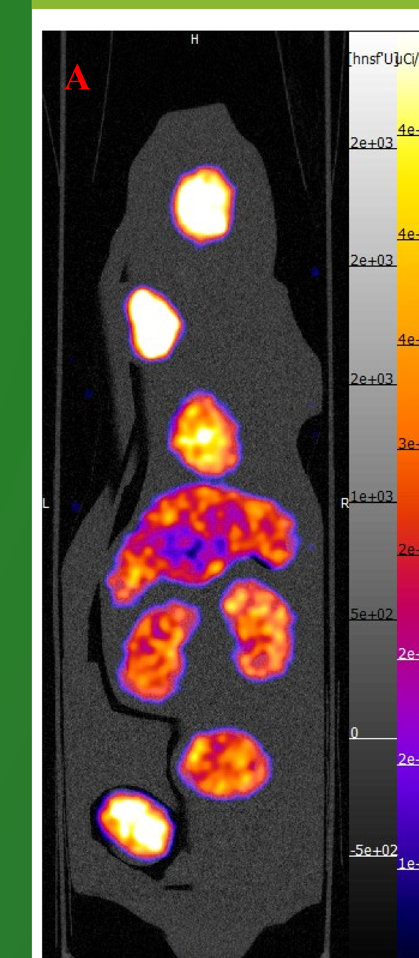
Apparent Molar Activity (AMA): 205.39±3.5 mCi/μmol for [^{47}Sc] Sc-DOTA



Free ^{47}Sc

Figure 15: iTLC data

SPECT Imaging



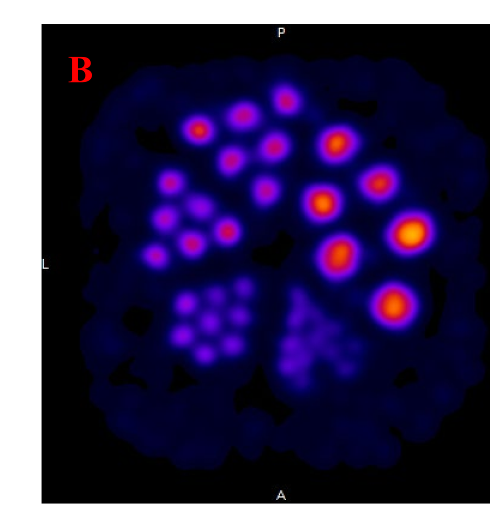


Figure 16: A, SPECT image using mouse phantom. B, SPECT image using a Derenzo phantom.

Preliminary Single-Photon Emission Computed Tomography (SPECT) images using phantoms (Figure 14) were conducted to investigate the imaging properties and quality of the produced ^{47}Sc.

Conclusions

Production of high purity ^{47}Sc from proton bombardment of ^{nat}V foils have been shown to be feasible and provide high recovery when separated, and preliminary studies conducted determined the AMA of recovered ^{47}Sc by radiolabeling to DOTA showed promise for further use of this radionuclide.

Acknowledgements

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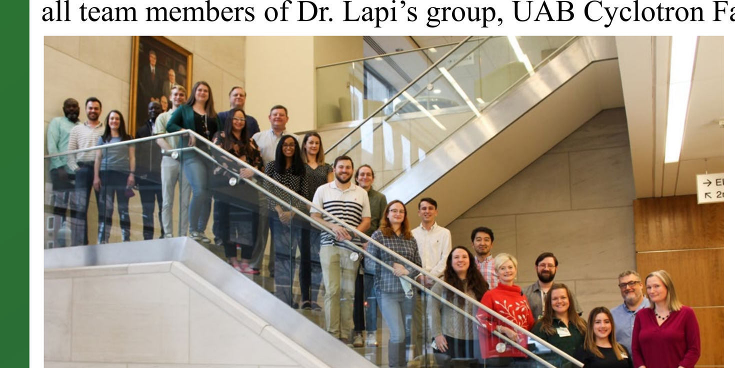

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