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. 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]).

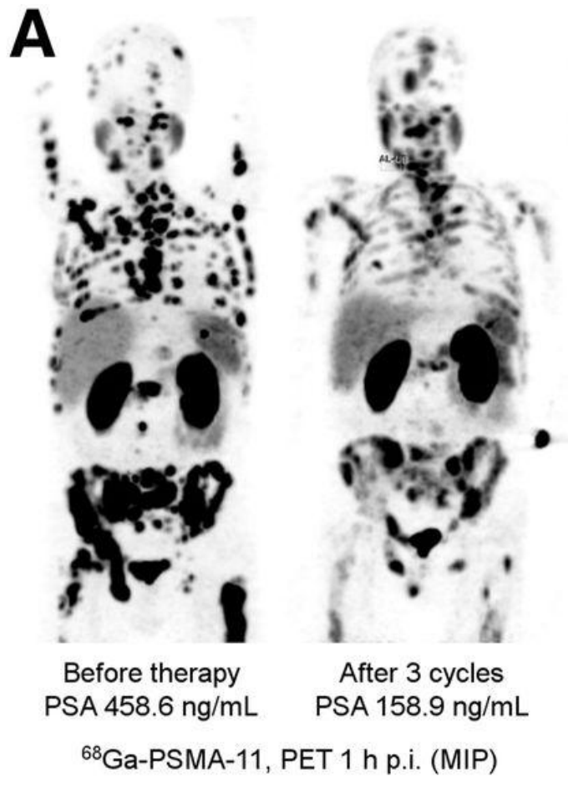
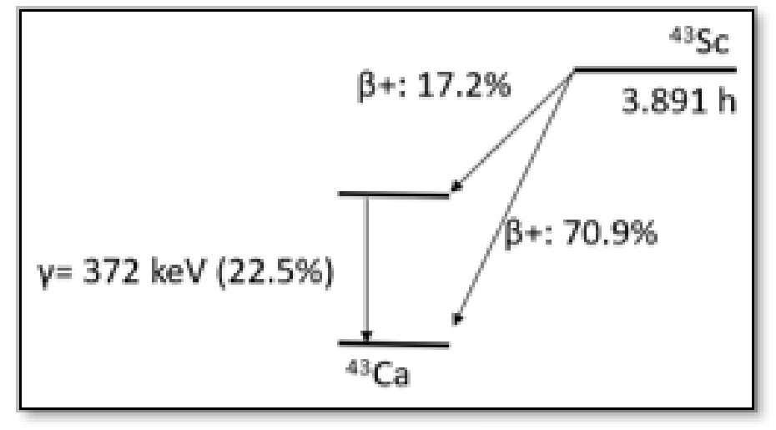
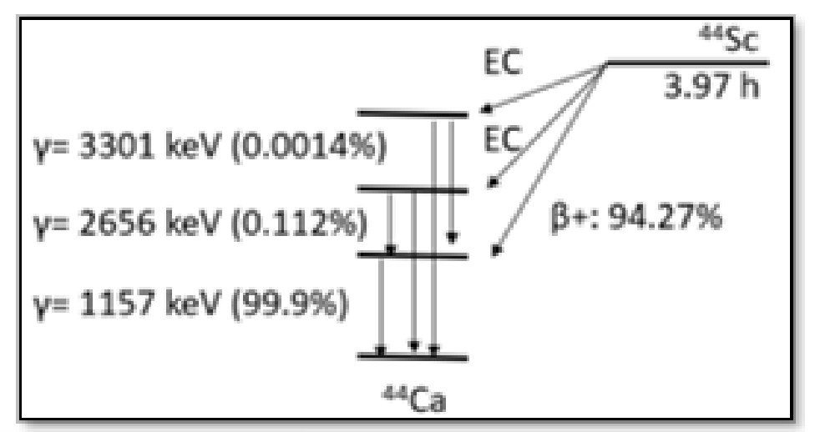
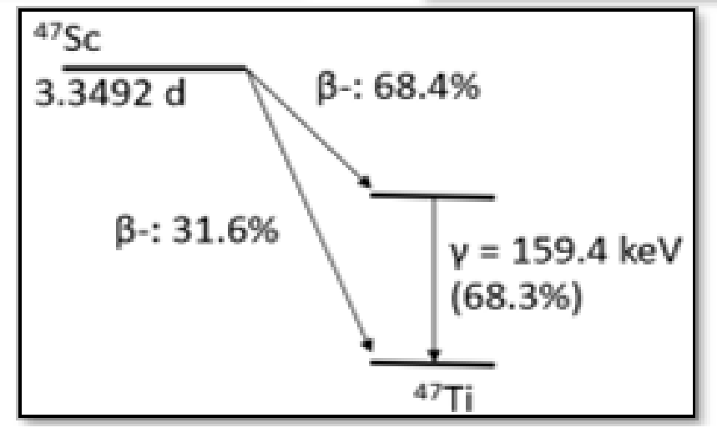


Figure 1: PET imaging using ^{68}Ga



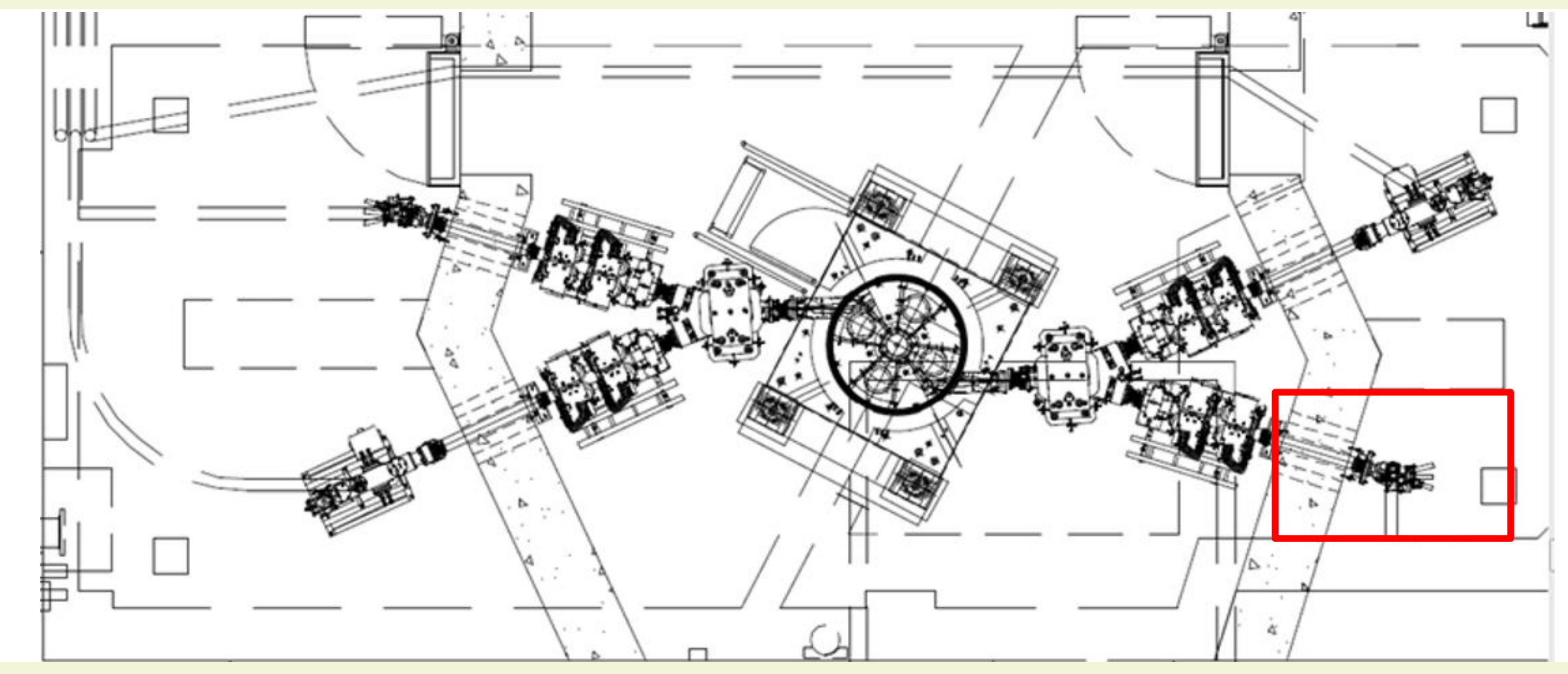




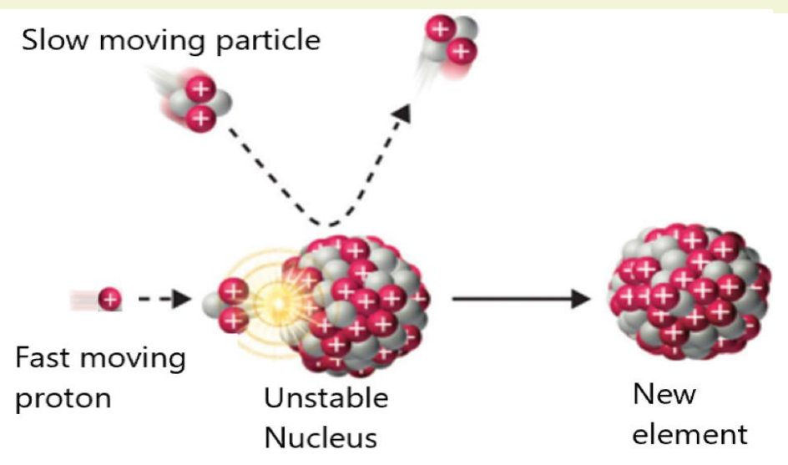
- Availability for high radionuclide purity scandium isotopes are limited due to lack of robust production techniques.
- Our goal is to develop a technique to produce high purity radioscandium isotopes from proton irradiation of ^{nat}V foil targets.

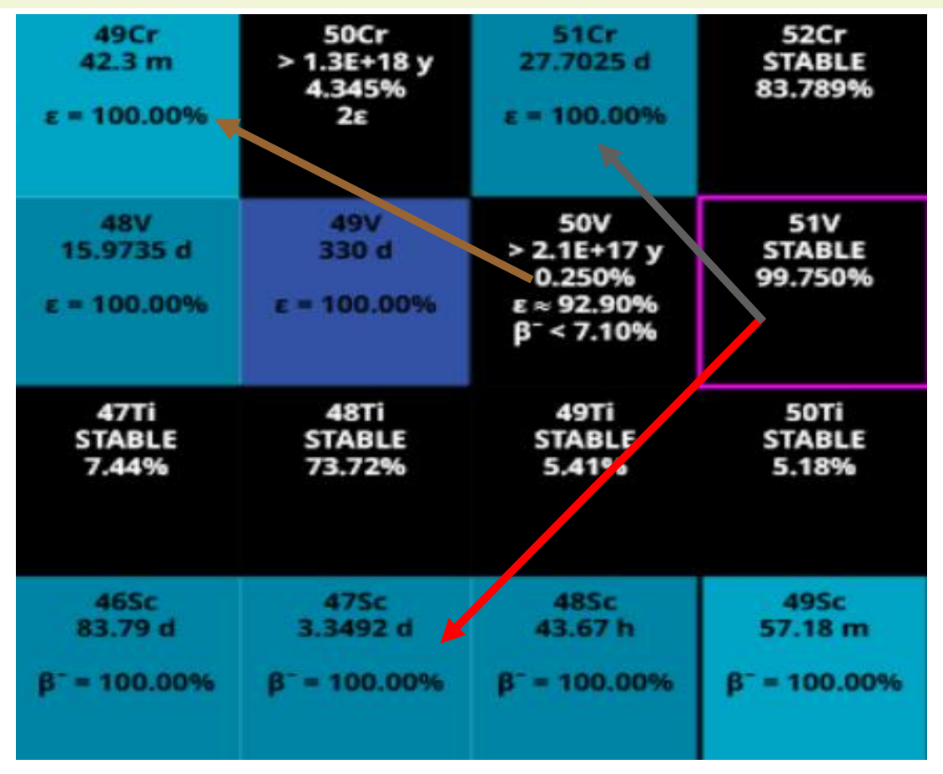
Production

UAB's TR24 Cyclotron



Production of ^{47}Sc from Vanadium Targets





Isotopes of ^{nat}V
- ^{51}V: 99.75%
- ^{50}V: 0.25%

Figure 2: Nuclear reactions that occur during this production method.

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

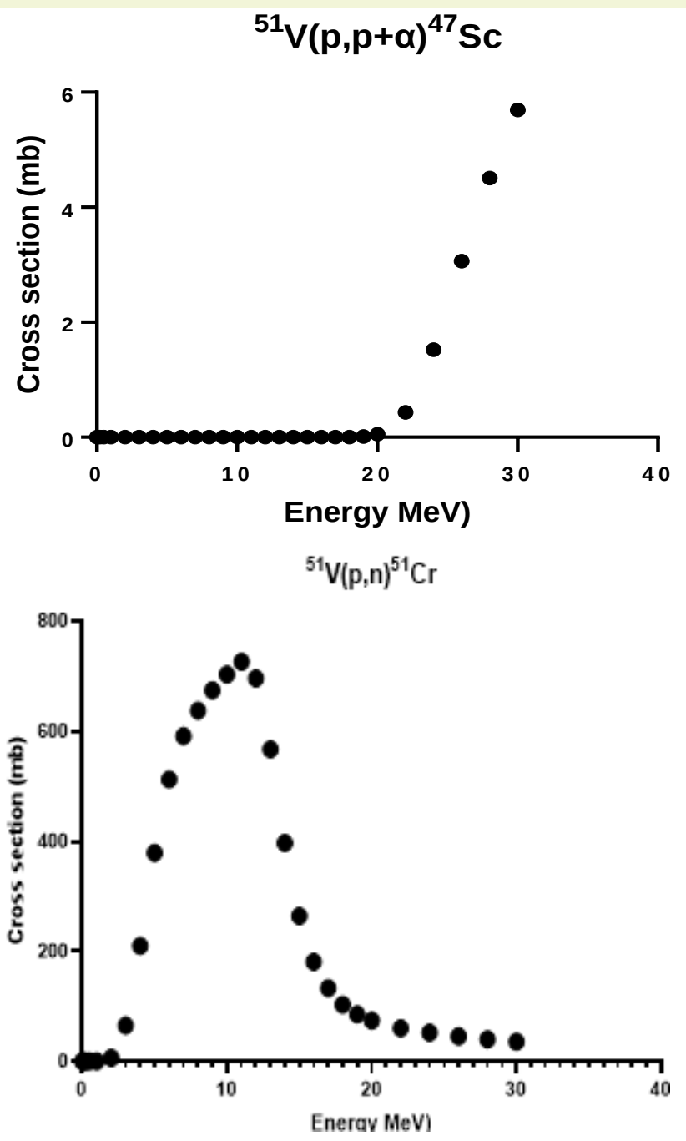


Table 1: Products from ^{nat}V

Isotope	Nuclear reaction	Half-life	γ
^{47}Sc	^{51}V(p,p+α)^{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 3: Cross sections for ^{47}Sc and ^{51}Cr on ^{51}V provided by TENDL.[2]

Purification

Target

- 0.254 mm thick foil
- 10 mm diameter disc
- 24 MeV for ^{51}V(p,p+α)^{47}Sc
- 30μA
- 1 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[3]

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

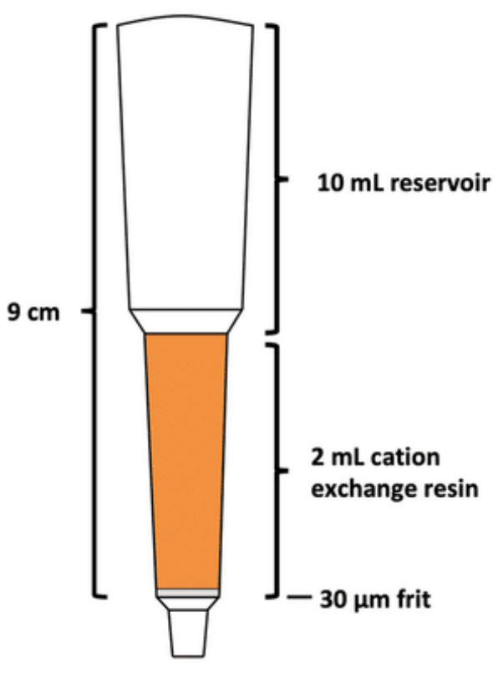


Figure 4: Diagram of column

FT
- Dissolved target was added
- Elution of V and ^{49,51}Cr

Wash
- 20 mL of 8 M HCl added
- Elution of V and ^{49,51}Cr

E1
- 15 mL of 4 M HCl added
- Elution of ^{49,51}Cr

Wash
- 10 mL of MilliQ water
- Ensure all ^{49,51}Cr is removed

E2
- 35 mL of 1 M ammonium acetate added
- Elution of ^{47}Sc

Figure 5: Step by step separation process

Separation Results

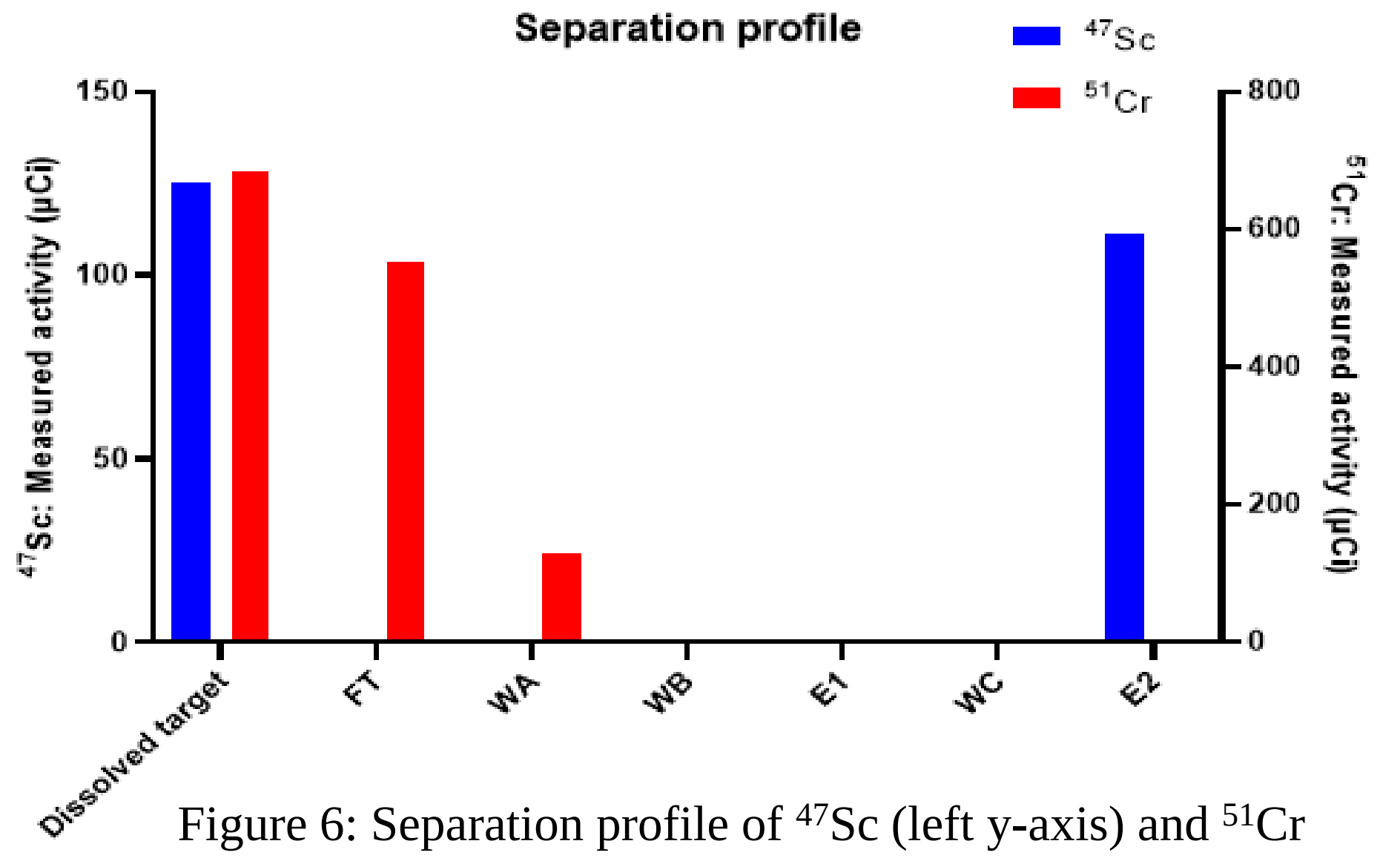


Figure 6: Separation profile of ^{47}Sc (left y-axis) and ^{51}Cr (right y-axis)

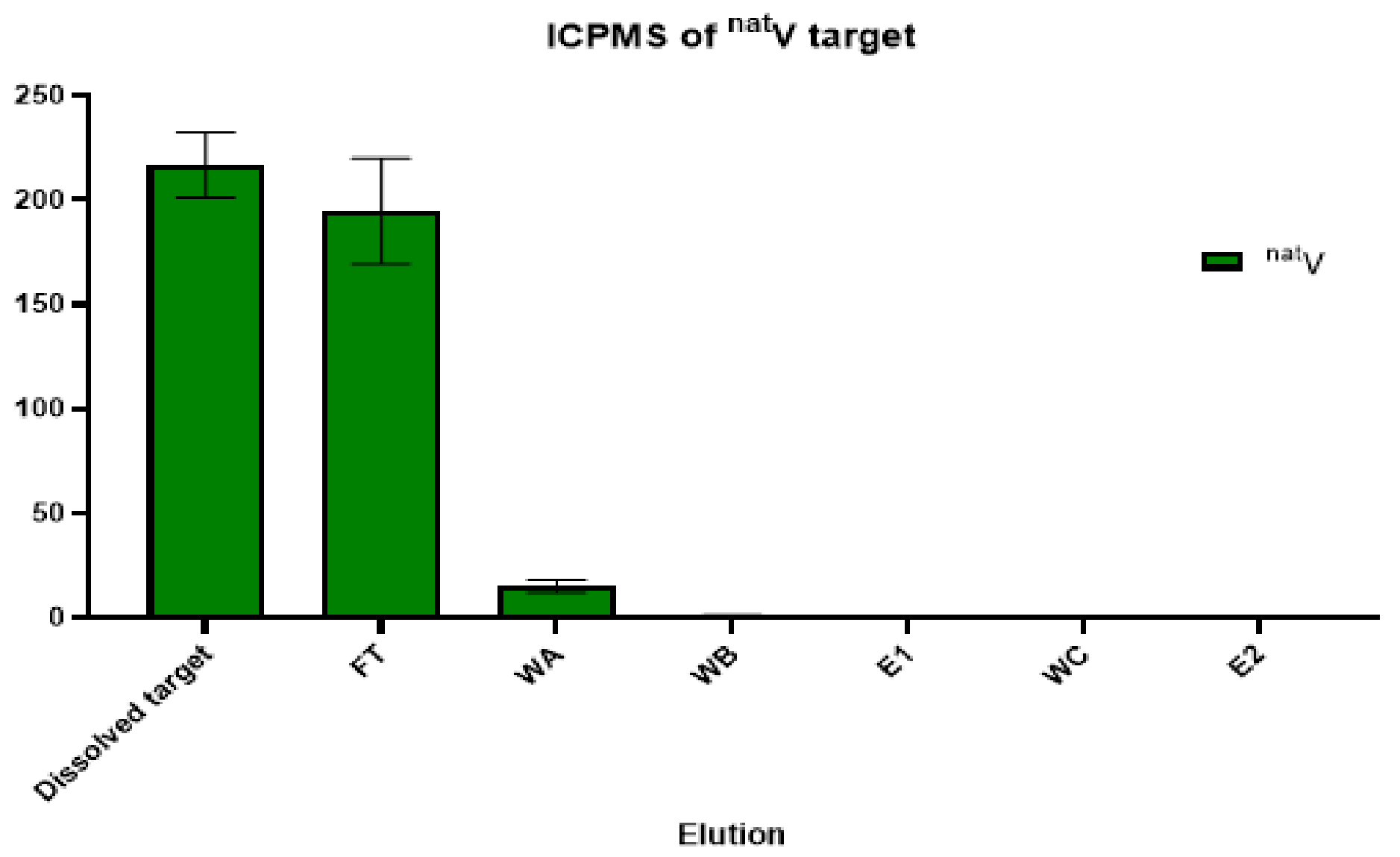


Figure 7: Inductively coupled plasma mass spectroscopy results for trace metal analysis

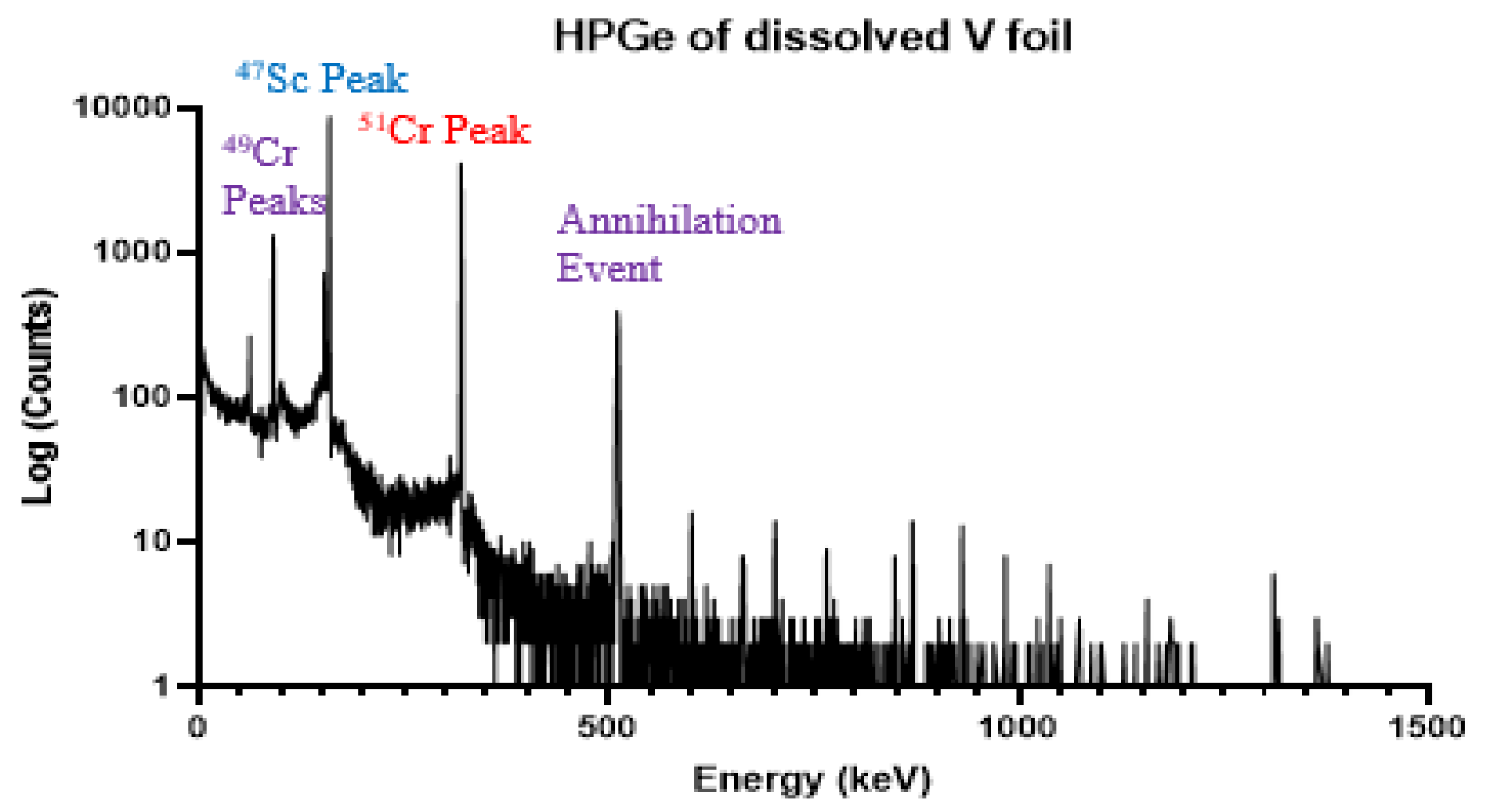


Figure 8: High Purity Germanium data from the dissolved foil

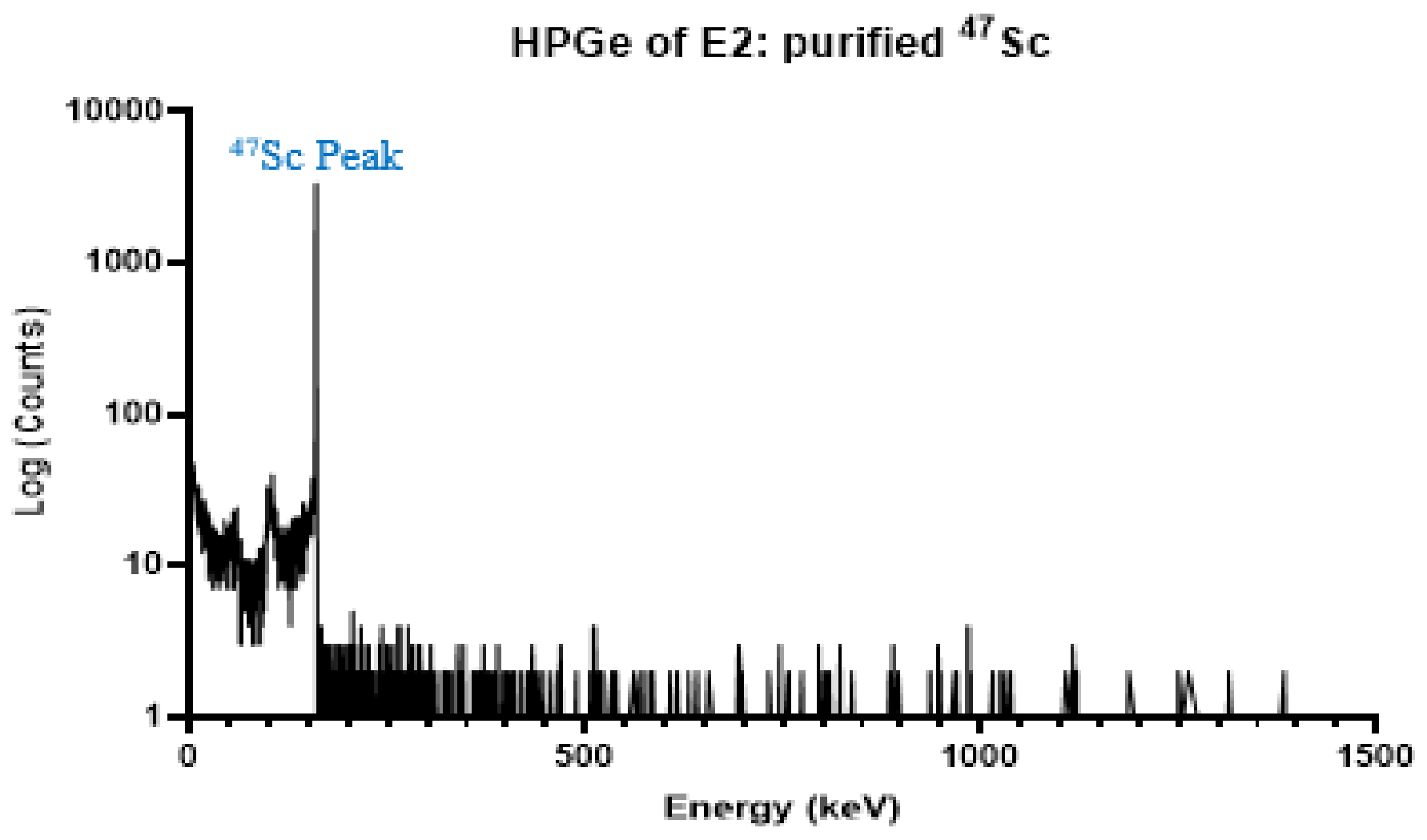


Figure 9: High Purity Germanium data from the pure ^{47}Sc

	Starting Amount	FT	WA	WB	E1	WC	E2
^{47}Sc	125.2 μCi	0 μCi	0.527 μCi	0.129 μCi	0.118 μCi	0.074 μCi	111.2 μCi
^{51}Cr	684.4 μCi	552.3 μCi	129.4 μCi	1.201 μCi	0.090 μCi	0 μCi	0 μCi

Figure 10: Chart detailing the numerical values from the separation

Isotope	^{47}Sc	^{51}Cr
Starting Amount	125.2 μCi	684.4 μCi
Amount Recovered	112.1 μCi	683.0 μCi
Percent Recovery	**89.5%**	**99.8%**

Figure 11: Final recovery percentages

References

[1] Loveless, Christopher Shaun, "Production of Medical Radioisotopes using Titanium Accelerator Targets" (2020). *Arts & Sciences Electronic Theses and Dissertations*. 2328. https://openscholarship.wustl.edu/art_sci_etds/2328
[2] A.J. Koning, D. Rochman, J. Sublet, N. Dzysiuk, M. Fleming and S. van der Marck, "TENDL: Complete Nuclear Data Library for Innovative Nuclear Science and Technology", Nuclear Data Sheets 155 (2019) 1
[3] Meulen, N. V. der. Ion Exchange Behaviour of 42 Selected Elements on AG MP-50 Cation Exchange Resin in Nitric Acid and Citric Acid Mixtures. Thesis. Master of Science. University of Stellenbosch. Stellenbosch, South Africa. January 2003. Doi: 10.1.1.973.3935

Radiolabeling

Preliminary studies were conducted to prove the utility of the purified ^{47}Sc

- Evaporate ^{47}Sc down to dryness and brought up in 100μL of 0.1 M HCl
- 1 mg/mL stock of DOTA (1,4,7,10-Tetraazacyclodecane-1,4,7,10-tetraacetic acid)
- In 0.25 M ammonium acetate pH 4
- 5 μCi of ^{47}Sc in each vial
- Heated and vortexed at 95°C at 800 rpm for 30 minutes
- SG-iTLC developed in 1 M citrate buffer

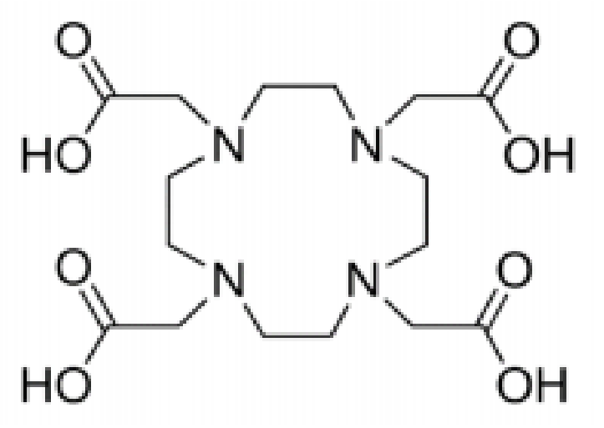


Figure 9: structure of DOTA

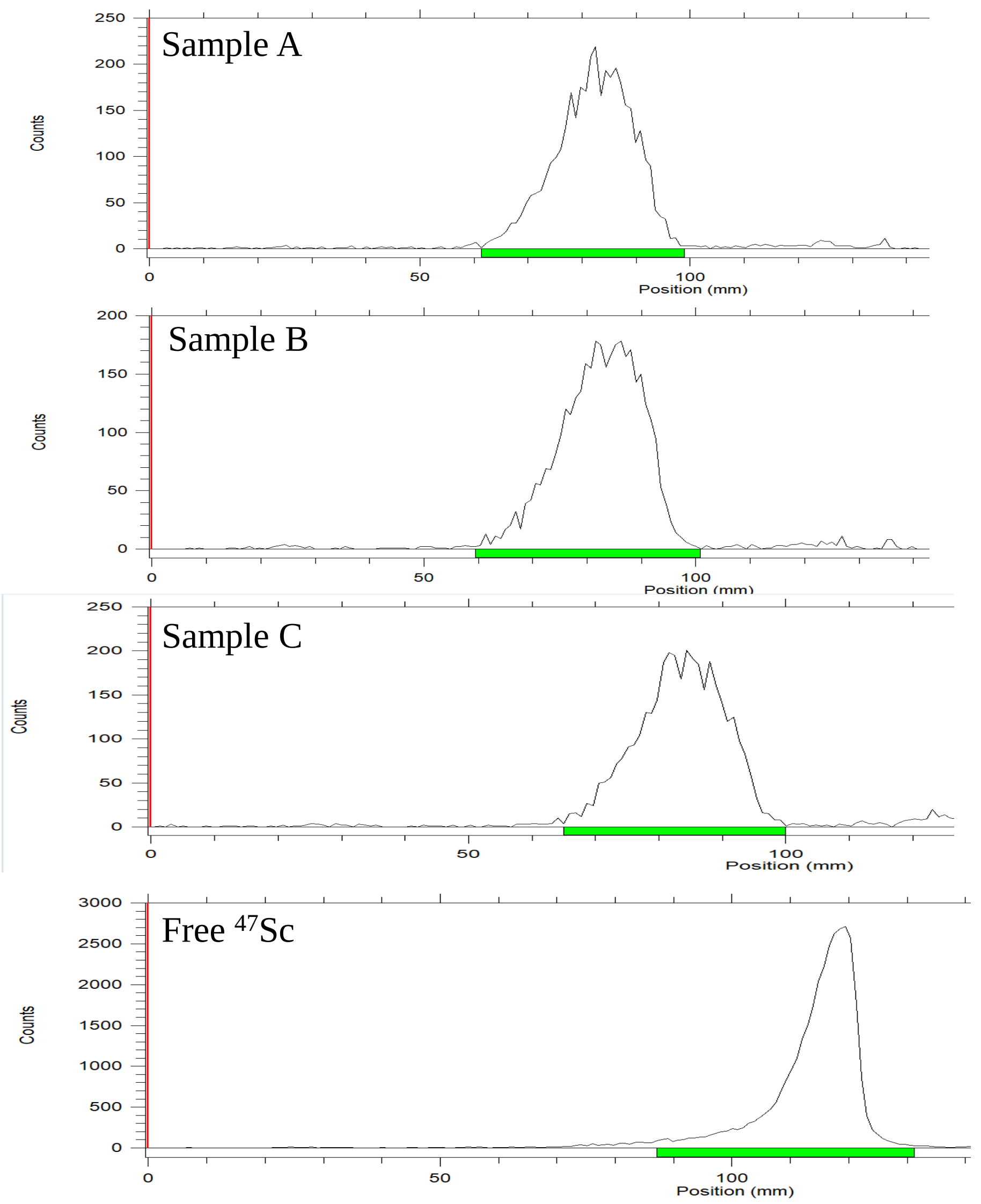


Figure 12: iTLC data

Sample Identity	Rf Value	% Labeled	% Free ^{47}Sc
A	0.83	≥ 99.9%	0%
B	0.83	≥ 99.9%	0%
C	0.83	≥ 99.9%	0%
Free ^{47}Sc	1	0%	≥ 99.9%

Figure 13: Radiolabeling results

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.
- Preliminary studies conducted to validate utility of recovered ^{47}Sc by radiolabeling to DOTA showed promise for further use of this radionuclide.

Acknowledgements

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