Production of ^{44}Ti via the ^{45}Sc($p, 2n$)^{44}Ti reaction for ^{44}Ti/^{44g}Sc generator development

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^{44g}Sc is a promising radionuclide for PET imaging applications. Its direct production via the ^{44}Ca(p, n)$^{44m, g}$Sc and ^{44}Ca($d, 2n$)$^{44m, g}$Sc reactions were investigated by several groups.[1–4] Owing to the short half-life of ^{44g}Sc ($T_{1/2}$ = 3.9 h), daily irradiations close to the site where it is used are required to maintain a constant supply of ^{44g}Sc. An alternative approach to obtain ^{44g}Sc is the production by the ^{44}Ti ($T_{1/2}$ = 59.1 y)/^{44g}Sc generator.[5] In this work, we investigated the production of ^{44}Ti via the ^{45}Sc($p, 2n$)^{44}Ti reaction to develop the ^{44}Ti/^{44g}Sc generator.

A metallic ^{45}Sc (99.99%) disk target with a diameter and thickness of 10 mm and 0.90 g/cm^2, respectively, was placed in an irradiation chamber with helium gas and water cooling.[6] The target was irradiated for 1.25 h with a 0.25-μA proton beam from the RIKEN AVF cyclotron. The incoming and outgoing proton beam energies were 30 MeV and 15 MeV, respectively.

Large amounts of ^{44m}Sc ($T_{1/2}$ = 58.6 h) and ^{44g}Sc were also produced in the ^{45}Sc(p, x)$^{44m, g}$Sc reactions. The short-lived ^{44g}Sc fully decays in several days. Thus, the activities of ^{44m}Sc and ^{44}Ti at the end of bombardment (EOB) were determined by fitting the decay curve of the 1157-keV gamma line of ^{44g}Sc after radioactive equilibrium. The yields of ^{44}Ti and ^{44m}Sc with the beam energy range of 30–15 MeV were calculated based on the cross-section data reported by L. Daraban.[7] The calculated results agree well with the experimental results. In addition, ^{46}Sc ($T_{1/2}$ = 83.8 d) was co-produced via the secondary-neutron-induced reaction of ^{45}Sc(n, γ)^{46}Sc. The activity of ^{46}Sc was determined by the 889-keV and 1121-keV gamma lines after 76 days of cooling. The results from the two gamma lines agree well with each other and are listed in Table 1.

Table 1. Activities of ^{44}Ti, $^{44m, 46}$Sc at EOB.

Nuclide	γ-ray energy (keV)	Calc. yield (Bq/μAh)	Activity at EOB (Bq)	
			Calc.	Exp.
^{44}Ti	1157	3338	1043	1114 ± 55
^{44m}Sc	1157	1.3×10^8	4.2×10^7	$4.1\times10^7 \pm 2.5\times10^5$
^{46}Sc	889 1121		-	454 ± 15 459 ± 15

^{44}Ti was separated from the target with ZR resin. Firstly, the irradiated ^{45}Sc target (0.71 g) was dissolved in 20 mL of 6 M HCl and heated to dryness. Subsequently, the residue was dissolved in 5 mL of 6 M HCl and fed into a column filled with conditioned ZR resin (100–150 μm, 5 mm *i.d.* × 5 mm). Scandium passed through the column while titanium was adsorbed on the resin. Finally, ^{44}Ti was eluted with 6 mL of 3 M HCl/0.325 M H_2O_2 solution.[8] The Ti/Sc separation factor was determined by the activity ratio of ^{44}Ti and ^{46}Sc before and after separation. The recovery yield of ^{44}Ti was 95%, and the Ti/Sc separation factor was $>10^3$ in this scheme. The gamma-ray spectrum of ^{44}Ti after the chemical separation is shown in Fig. 1. Small amounts of long-lived ^{56}Co ($T_{1/2}$ = 77.3 d) and ^{54}Mn ($T_{1/2}$ = 312.3 d) found in the irradiated target were successfully removed by the chemical separation. Only gamma lines from ^{44}Ti and its daughter, ^{44g}Sc, were identified in the gamma-ray spectrum. The radionnuclidic purity of ^{44}Ti after chemical separation was evaluated to be >99%.

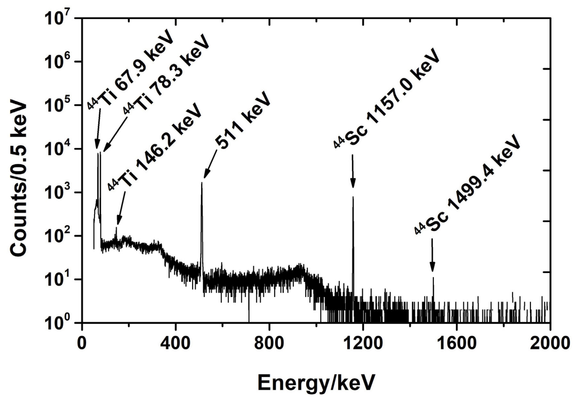

Fig. 1. Gamma-ray spectrum of ^{44}Ti after separation.

By assuming experimental conditions (incident beam energy: 30 MeV; beam intensity: 10 μA; target thickness: 0.9 g/cm^2; irradiation time: 10 d), 8 MBq of ^{44}Ti can be produced at the EOB.

In the future, we will develop a prototype of the ^{44}Ti/^{44g}Sc generator with long-term stability, high yield of ^{44g}Sc, and no ^{44}Ti breakthrough.

References

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