Experimental and theoretical cross section study for production of medically important radioisotopes ^{52}Mn, ^{51}Cr and ^{46,47}Sc

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The production of ^{52}Mn, ^{51}Cr, ^{46}Sc and ^{47}Sc radioisotopes of considerable interest for the application in nuclear medicine for PET imaging, cancer treatment, monoclonal antibodies and radio-immunotherapy[1,2], as shown in Table I, were investigated by alpha bombardment of natural Vanadium target up to E_α= 25 MeV/u and currents of about 50 nA.

Table I. The significant applications for the studied radioisotopes.

Radioisotope	Applications
^{52}Mn	PET scanning.
^{51}Cr	Cell labeling and dosimetry.
^{46}Sc	Regional blood flow studies, PET imaging.
^{47}Sc	Cancer treatment/diagnostics, monoclonal antibodies, radio-immunotherapy.

The experimental excitation function and yield for the reaction shown in Table II were measured using the stacked foil irradiation technique followed by HPGe γ-ray analysis and then compared with earlier measured and published values when possible.

Two irradiation processes were carried out using an Aluminum target holder that acts as Faraday

Table II. The contributing reactions and the decay data of the investigated radioisotopes [3].

Nuclide	Half life	Principal contributing reactions	Q-value MeV	E_γ keV	$I\gamma$ %
^{54}Mn	312.2 d	^{51}V(α,n)	-2.31	834.8	99.9
^{52}Mn	5.71 d	^{51}V(α,3n)	-23.42	1434.1	98.2
^{51}Cr	27.7 d	^{51}V(α,p3n)	-29.85	320.2	9.83
^{48}V	16.2 d	^{51}V(α,α3n)	-31.94	944.3	7.75
^{48}Sc	43.66 h	*^{51}V(a,a2pn)*	-58.61	1037.5	97.5
^{47}Sc	3.42 d	^{51}V(α,2α)	-10.32	159.4	68.0
^{46}Sc	83.86 d	^{51}V(α,2αn)	-20.96	889.2	99.9

cup to measure the beam intensity. The alpha particles beam extracted from the K500 superconducting cyclotron have been used to irradiate a multi-target stack made of the targets shown in Table III.

Table III. The used specifications and roles of the used targets.

Target	Purity %	Thickness (μm)	Number of used foils	Role
^{nat}V	99.8+	80	21	Target for medical radioisotope production
^{nat}Ti	99.6+	25	10	Monitoring and degrading
^{nat}Al	99.99	50, 59, 100	23	Monitoring and degrading

Different monitor reactions such as: $^{27}Al(p,x)^{22,24}Na$, $^{nat}Cu(p,x)^{62,63,65}Zn$, $^{nat}Ti(\alpha,x)^{51}Cr$, $^{nat}Al(\alpha,x)^{22,24}Na$, and $^{nat}Cu(\alpha,x)^{66,67}Ga,^{65}Zn$ [4,5] were studied by inserting the monitor foils in different positions along the stack to determine the beam current. The chosen irradiation geometry allows the beam to pass through every foil. The secondary effect of the background neutrons on each target was checked by foils placed in the stack far beyond the range of the fully stopped proton beam.

The radioactivity of the residual nuclei in the activated foils was measured using one HPGe γ-ray detector (70% relative efficiency). Each foil was recounted after different cooling times to avoid disturbance by overlapping γ-lines from undesired sources and in order to accurately evaluate cross-sections for cumulative formation of the corresponding longer-lived daughter radionuclide. The detector-source distance was kept large enough to keep the dead time below 5% and to assure the same geometry. From the decay rates of the radioactive products and the measured beam current, the cross sections for the nuclear reactions were determined using the well-known activation formula [6]. Figure 1 show two excitation functions from the measured cross-sections.

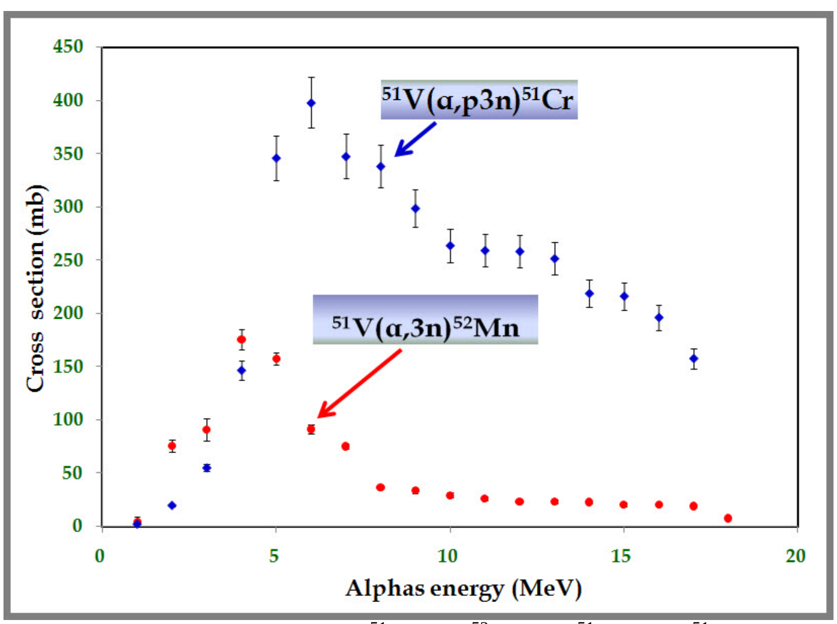

FIG. 1. Excitation function of the $^{51}V(\alpha,3n)^{52}Mn$ and $^{51}V(\alpha,p3n)^{51}Cr$ reactions.

A consistency check of all experimental data was carried out using nuclear model calculations via two different codes. The first is EMPIRE II [7], which is accounting for the major nuclear reaction mechanisms, including the Optical Model (OM), the Multi-step Compound, Exciton Model, full featured Hauser-Feshbach Model, with a comprehensive parameter library mainly covering nuclear mass, OM data, discrete levels and decay schemes. The second code is TALYS [8] which is a software package which provides a simulation of nuclear reactions that takes in consideration a huge database for nuclear structure and model parameters, mostly based on the IAEA reference input parameter library.

We are finalysing the data analysis and the constructed excitation functions will be compared with the available previously published data to be able to derive reproducible and recommended cross section values for the different reactions.

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