# Excitation Functions for 3He-induced Reactions on Silver

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## VI. 5 Excitation Functions for $^{3}$He-induced Reactions on Silver

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Indium-111 which decays by electron capture ($T_{1/2}$ = 2.83 d) has several advantages for *in vivo* applications. The gamma-ray energies, 171 and 245 keV, are in optimum range of detectable energy for commercially available detecting devices. The cross sections for the $^{109}$Ag($\alpha$,2n)$^{111}$In$^{1-3)}$, $^{111}$Cd(p,n)$^{111}$In$^{4)}$ and $^{110}$Cd(d,n)$^{111}$In$^{5)}$ have been measured in detail as a function of energy of bombarding particle. However, those for the reactions of silver with $^{3}$He have not yet determined completely.

In order to elucidate the reactions of silver with $^{3}$He, in the present study, the excitation functions for the $^{109}$Ag($^{3}$He,3n)$^{109}$In plus $^{107}$Ag($^{3}$He,n)$^{109}$In, $^{109}$Ag($^{3}$He,2n)$^{110}$In and $^{109}$Ag($^{3}$He,n)$^{111}$In reactions as well as for the $^{107}$Ag($^{3}$He,$\alpha$n)$^{105}$Ag and $^{107}$Ag($^{3}$He,$\alpha$)$^{106m}$Ag plus $^{109}$Ag($^{3}$He,$\alpha$2n)$^{106m}$Ag reactions have been determined by bombarding doubly ionized $^{3}$He particles on natural silver targets. Further, the thick target yields for the $^{109}$In, $^{110}$In and $^{111}$In were calculated on the basis of the excitation functions.

### EXPERIMENTAL

The cross-sections were experimentally determined by means of the activation method. Stacks of natural silver foils were exposed to external $^{3}$He$^{2+}$ beam generated from an AVF cyclotron at the Cyclotron and Radioisotope Center, Tohoku University. The silver foils weighed out accurately were placed between aluminium foils of known thickness. The $^{3}$He$^{2+}$ energy at the midpoint of each target thickness was calculated from range-energy tables.$^{6)}$

After bombardment, the stack was allowed to stand for about 10 h in order to eliminate short half-life radioactivities. The $\gamma$-ray spectrum of each foil was measured with a Ge(Li) detector connected to a TN-4000 data processing system. Radioactivity measurements were carried out at time intervals suitable for radionuclide identification. The number of counts in the relevant photopeak area was corrected by means of the counting efficiency of the detector and the $\gamma$-ray branching ratio. The counting efficiencies were determined with a $^{152}$Eu standard source, and the $\gamma$-ray branching ratios were taken from the decay scheme data.$^{7)}$

Losses of the radioisotopes into the aluminium foil due to recoil were examined in a similar manner as above. The overall error for the cross-section was estimated to be less than 8 %. It is mainly due to errors in the counting statistics, detector efficiencies, decay scheme data, and thickness and area of the foil.

## RESULTS AND DISCUSSION

The $\gamma$-ray spectrum of each silver foil was very complicated even after the radioisotopes with half-lives of less than an hour had already decayed. Hence, the following $\gamma$-ray photopeaks were chosen in order to determine acculately the absolute production yields of $^{109}$In, $^{110}$In, $^{111}$In, $^{105}$Ag and $^{106m}$Ag; 203 keV for $^{109}$In, 885 and 937 keV for $^{110}$In, 171 and 245 keV for $^{111}$In, 280 and 345 keV for $^{105}$Ag, and 1046 keV for $^{106m}$Ag.

The excitation function curves for the $^{109}$Ag($^{3}$He,3n)$^{109}$In plus $^{107}$Ag($^{3}$He,n)$^{109}$In, $^{109}$Ag($^{3}$He,2n)$^{110}$In, and $^{109}$Ag($^{3}$He,n)$^{111}$In reactions are shown in Fig. 1 together with those for the $^{107}$Ag($^{3}$He,$\alpha$n)$^{105}$Ag, and $^{107}$Ag($^{3}$He,$\alpha$)$^{106m}$Ag plus $^{109}$Ag($^{3}$He,$\alpha$2n)$^{106m}$Ag reaction. The cross-sections for the $^{107}$Ag($^{3}$He,n)$^{109}$In and $^{107}$Ag($^{3}$He,$\alpha$)$^{106m}$Ag reactions, especially in the lower energy region, contribute to those for the $^{109}$Ag($^{3}$He,3n)$^{109}$In and $^{109}$Ag($^{3}$He,$\alpha$2n)$^{106m}$Ag reactions, respectively.

The thick target yields of $^{109}$In, $^{110}$In and $^{111}$In were obtained by integration of the corresponding yield curves. The yield of $^{111}$In is found ro be 1.7 $\mu$Ci/$\mu$A.h by irradiating 40 MeV $^{3}$He$^{2+}$, while those of $^{109}$In and $^{110}$In are 240 and 2800 $\mu$Ci/$\mu$A.h, respectively.

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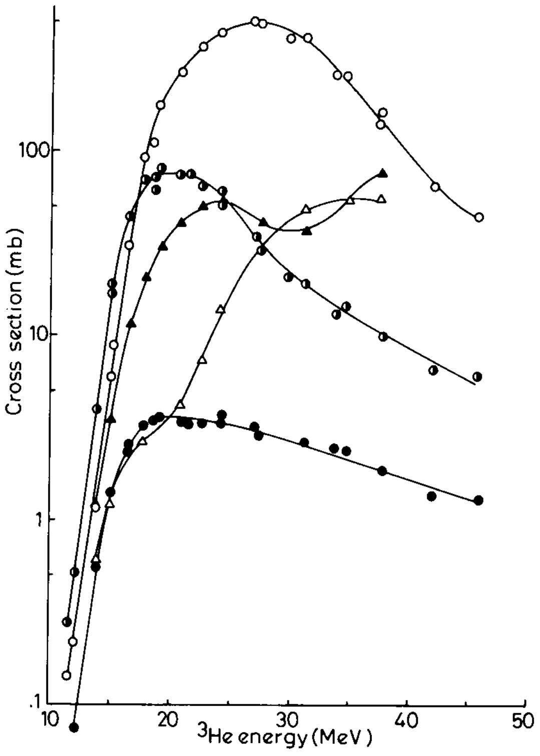

Fig. 1. The excitation functions for the Ag + $^{3}$He reactions.

○: $^{109}$Ag($^{3}$He,3n)$^{109}$In + $^{107}$Ag($^{3}$He,n)$^{109}$In

◑: $^{109}$Ag($^{3}$He,2n)$^{110}$In

●: $^{109}$Ag($^{3}$He,n)$^{111}$In

▲: $^{107}$Ag($^{3}$He, n)$^{105}$Ag

△: $^{107}$Ag($^{3}$He, )$^{106m}$Ag + $^{109}$Ag($^{3}$He, 2n)$^{106m}$Ag