学位論文内容の要旨

（Abstract of thesis）

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学 位 論 文 題 名 （Title of thesis）

Production cross sections of medical radioisotopes ^{52g}Mn and ^{198g}Au via charged-particle-induced reactions

（荷電粒子入射反応による医療用放射性同位体 ^{52g}Mn 及び ^{198g}Au の生成反応断面積）

We studied the production cross sections (excitation functions) of medical radioisotopes ^{52g}Mn and ^{198g}Au via charged-particle-induced reactions in this thesis.

The ground state of the ^{52g}Mn radioisotope has a half-life of $T_{1/2}$ = 5.6 days and decays via electron capture (70.6%) and positron emission processes (29.4%, $<E_{\beta^+}>$ = 242 keV). The positrons emitted from the decay of ^{52g}Mn can be used for Positron Emission Tomography (PET). The direct reactions to produce ^{52g}Mn are charged-particle-induced reactions on chromium and vanadium. The indirect route is through the internal transition of ^{52m}Mn co-produced simultaneously in the reactions. In this study, we focused on the alpha-particle-induced reaction on ^{nat}V. Eleven experimental cross-section data of the ^{nat}V(α,x)^{52g}Mn reactions were found in the experimental nuclear reaction database (EXFOR library). However, their data are largely scattered. Therefore, we measured the excitation functions of the alpha-particle-induced reactions on ^{nat}V up to 50 MeV, with a particular focus on the ^{52g}Mn production.

The radionuclide ^{198g}Au has a half-life of 2.6941 d and is a beta emitter (β^-: 100%, $<E_{\beta^-}>$ = 312.5 keV). ^{198g}Au is widely used for therapy in nuclear medicine. The neutron capture reaction on the monoisotopic element ^{197}Au in a reactor can produce a large amount of ^{198g}Au. However, the route can obtain only the low specific activity of ^{198g}Au because the separation of ^{198g}Au from the Au target is difficult. The high specific activity ^{198g}Au is expected to be produced using charged-particle-induced reactions on platinum. In this study, we focused on the proton-induced reaction on the ^{nat}Pt target. Four previous experimental studies for isotope production by proton-induced reactions on platinum were found in our literature survey. The previous experimental cross-section data have large uncertainties and show discrepancies among them. More reliable and accurate data are required. Therefore, we measured the excitation functions of the proton-induced reactions on ^{nat}Pt up to 30 MeV, with a particular focus on the ^{198g}Au production.

The measured data are compared with previous experimental data and the calculations using the theoretical model code TALYS (TENDL-2019 library).

Two experiments were performed at the AVF cyclotron of the RIKEN RI Beam Factory using

stacked-foil activation techniques and gamma-ray spectrometry.

The targets for the experiments consisted of pure metallic foils. The first target (#1) consisted of ^{nat}V (25-μm thick, 99% purity), ^{nat}Ti (5-μm thick, 99.6% purity), and ^{27}Al (5-μm thick, 99.9% purity). The second target (#2) consisted of ^{nat}Pt (20-μm thick, 99.95% purity), and ^{nat}Ti (5-μm thick, 99.6% purity). The ^{nat}Ti foils were used for the ^{nat}Ti(α,x)^{51}Cr (#1) and ^{nat}Ti(p,x)^{48}V (#2) monitor reactions, respectively. The ^{27}Al foils were inserted to separate the recoiled reaction products from ^{nat}V and ^{nat}Ti foils. The target thicknesses were derived using measured sizes and weights of the foils. The foils were then cut into a size of 8×8 mm (#1) and 10×10 mm (#2) to fit target holders that served as Faraday cups. Eleven sets of V-Al-Ti-Ti-Al (#1) and twenty-five sets of Pt-Pt-Ti-Ti (#2) foils were stacked in the target holders.

The stacked target was irradiated with a 50.6±0.2 (#1) alpha-particle beam and 30.1±0.1 MeV (#2) proton beam for 30 min, respectively. The primary beam energies were measured by the time-of-flight method. Energy degradations in the stacked target were calculated using stopping powers derived from the SRIM code. The average beam intensities measured by the Faraday cup were 194 (#1) and 101 nA (#2), respectively.

The gamma-ray spectra of each irradiated foil were measured after different colling times without chemical separation by a high-resolution HPGe detector and analyzed by the dedicated software. The distance between the detector and the foils was arranged to keep the dead time less than 5%.

The measured beam parameters and target thicknesses were assessed using the ^{nat}Ti(α,x)^{51}Cr and ^{nat}Ti(p,x)^{48}V monitor reactions. The derived excitation functions of the monitor reactions were found to be in good agreement with the IAEA recommended values. The measured beam parameters and target thicknesses were used without any correction to determine the cross sections.

In the first experiment (#1), we measured the excitation functions of the alpha-particle-induced reactions on ^{nat}V up to 50 MeV. The production cross sections of ^{52g}Mn and co-produced ^{54}Mn, ^{51}Cr, ^{48}V, and $^{47, 46g}$Sc were determined. The derived excitation function of the ^{nat}V(α,x)^{52g}Mn reaction is compared with the literature data and TENDL-2019 values. Among the eleven previous studies, only the data by Levkovski (1991) are consistent with our result. The physical yield of ^{52g}Mn was deduced from the measured cross sections and found to be larger than the experimental data of Dmitriev et al. (1969).

In the second experiment (#2), activation cross sections of the proton-induced reactions on ^{nat}Pt were measured up to 30 MeV. The excitation functions for eleven radioisotopes $^{198, 196, 196m2, 195, 194, 193, 192, 191}$Au, ^{191}Pt, and $^{192, 190}$Ir were determined. Our measured excitation functions show smooth curves. The previous studies are in acceptable agreement with ours within uncertainty. The TENDL-2019 values are slightly different from our result.

Our measured cross sections are less scattered and more reliable than most of literature data. The reliable cross sections can enhance and improve nuclear reaction databases. The results can also contribute to optimization of the production of ^{52g}Mn and ^{198g}Au for medical use and development of theoretical model calculation codes.