Activation cross sections of deuteron-induced reactions on natural chromium up to 24 MeV

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^{52g}Mn ($T_{1/2}$ = 5.591 d) that decays by electron capture and positron emission can be used in positron emission tomography (PET).[1] ^{51}Cr ($T_{1/2}$ = 27.8 d) that decays by the same mode was used to label red blood cells as a tracer in the measurement of the mass and volume of living systems.[2] These medical radionuclides can be produced via charged-particle-induced reactions on neighbor elements. We focused on the deuteron-induced reaction on natural chromium. Experimental literature data regarding the cross sections of the reaction are inconsistent,[3–5] and therefore, we performed the experiment to measure the production cross sections of ^{52g}Mn and ^{51}Cr. In addition, the cross sections of the by-products ^{48}V and ^{52m,54}Mn were determined.

We adopted the well-established stacked-foil activation technique followed by high-resolution gamma-ray spectrometry to determine excitation functions. The target comprised nickel-chromium (NiCr) alloy (99.9% purity, Goodfellow Co., Ltd., UK), ^{nat}Ti (99.6% purity, Nilaco Corp., Japan), and ^{27}Al (>99% purity, Nilaco Corp., Japan) foils. The ^{nat}Ti foil was used for the ^{nat}Ti$(d,x)^{48}$V monitor reaction to assess the beam parameters. The ^{27}Al foil was interleaved to collect recoiled products. The average thickness of each foil was derived from their measured weight and size. We analyzed the elemental ratio of the NiCr alloy foil by a scanning electron microscope with an energy dispersive X-ray spectrometer (Hitachi TM4000 Plus II). The measured mass ratios were Cr 21.5%, Ni 76.7%, and Mn 1.7%, respectively. All foils were then cut into squares of 8 × 8 mm^2 to fit the size of a target holder that served as a Faraday cup. Thirteen sets of NiCr-NiCr-Al-Ti-Ti-Al foils were stacked as the target.

The stacked target was irradiated for 15 min by a 24-MeV deuteron beam from the AVF cyclotron at RIKEN. The average intensity and primary energy of the beam were measured to be 105 nA and 24.0 ± 0.1 MeV. Energy degradation in the stacked target was calculated using stopping powers obtained by the SRIM code.[6] Gamma-ray spectrometry was performed using a high-purity germanium detector (ORTEC GEM30P4-70) and analyzed by the analysis software (SEIKO EG&G Gamma Studio). Only gamma spectra from each second NiCr alloy and Ti foil were measured assuming that recoiled nuclides from the second foils were compensated by those from the first.

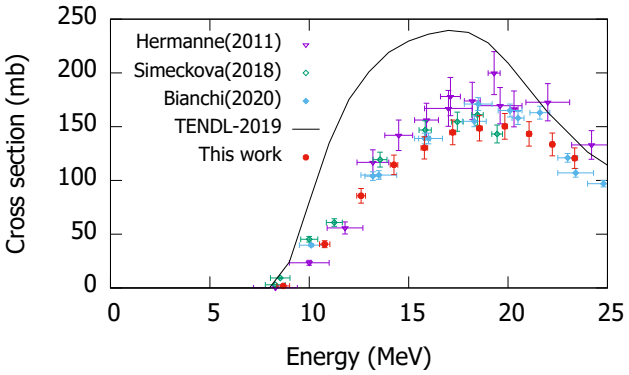

Fig. 1. Cross sections of the ^{nat}Cr$(d,x)^{52g}$Mn reaction with previous data[3–5] and the TENDL-2019 values.[8]

During 1 h–32 d cooling, NiCr alloy foils were measured 7 times to assess the radionuclides with different half-lives. The measurement distances were 3–50 cm. The dead time was kept below 5.2%.

The cross sections of the ^{nat}Ti$(d,x)^{48}$V monitor reaction were derived and compared with the recommended values of IAEA.[7] The comparison results indicated that, the beam intensity was corrected by −1.1% within the uncertainty (5%). The other parameters were adopted without any correction.

We derived the cross sections using the measurement of the 935.544-keV gamma line (I_γ = 94.5%) emitted with the decay of ^{52g}Mn. A short-lived metastable isomer ^{52m}Mn ($T_{1/2}$ = 21.1 min) decayed to the ground state ^{52g}Mn by isomeric transition with a branching ratio of 1.78%. Thus, we determined the cumulative cross section of ^{52g}Mn. We compare our data with the previous studies[3–5] and the TENDL-2019 values[8] in Fig. 1; our data are less scattered and in agreement with the recently published data.[4,5] The theoretical values of TENDL-2019 obviously overestimate the experimental data.

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