Production of 169Yb by the proton-induced reaction on 169Tm

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Activation cross sections of the 169Tm(p,n)169Yb reaction were measured using the MGC-20E cyclotron at Institute for Nuclear Research (ATOMKI), Hungary. The stacked-foil activation technique and the high-resolution gamma-ray spectrometry were adopted to derive the cross sections. The preliminary cross sections were compared with experimental data studied earlier and with theoretical model calculation.

# **1. Introduction**

The radionuclide 169Yb (T1/2 = 32.018 d) decays with emissions of Auger electrons and X-rays. These properties of 169Yb are appropriate for brachytherapy [1]. For such practical use, the best reaction for its production should be selected among all possible reactions. One of them is the neutron capture reaction on 168Yb, of which the isotopic ratio is only 0.123%. Another route is a reaction using charged particles, such as proton, deuteron and alpha particles. We have systematically investigated the production reactions of 169Yb with a focus on the charged-particle induced reactions. The experiments on deuteron- [2] and alpha-induced reactions on 169Tm, and alpha-induced reactions on natEr [3] have already been performed. Therefore, we carried out an experiment of the proton-induced reaction on 169Tm. In this paper, we report the preliminary result of this experiment.

# **2. Experimental**

The experiment was performed using the MGC-20E cyclotron at Institute for Nuclear Research (ATOMKI), Hungary. The stacked-foil activation technique and the high-resolution gamma-ray spectrometry were adopted to derive cross sections.

The target consisted of metallic foils of 169Tm (99.0% purity) and natTi (99.6% purity). The sizes and weights of the foils were measured for determining the average thicknesses of the Tm and Ti foils. The thicknesses were found to be 21.0 and 9.1 mg/cm2, respectively. The foils were cut into small pieces of 6×6 mm2 and stacked into a target holder, which was also served as a Faraday cup. The target was irradiated for 30 min with an 18 MeV proton beam. Energy degradation in the target was calculated using the SRIM code [4]. The average beam intensity was 210 nA, which was measured by the Faraday cup. Gamma rays emitted from each irradiated foil were measured by a HPGe detector without chemical separation. Nuclear data required to derive cross sections were obtained from NuDat 2.7 [5] and QCalc [6] and summarized in Table 1.

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| Table 1. Reaction and decay data for 169Yb production |
| Nuclide | Half-life | Decay mode (%) | E (keV) | I (%) | Contributing reaction | Q-value (MeV) |
| 169Yb | 32.018 d | EC (100) | 177.21 | 22.28(11) | 169Tm(p,n) | -1.7 |

# **3. Results**

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| Fig. 1. Excitation function of the 169Tm(p,n)169Yb reaction with the previous data [7–9] and the TENDL-2017 data [10]. |

 The 177.21-keV gamma rays (I = 22.28%) emitted with the 169Yb decay (T1/2 = 32.018 d) were measured after a cooling time of about 4 days. The cross sections of the 169Tm(p,n)169Yb reaction were derived from the measurements and the nuclear data in Table 1. The preliminary result is shown in Fig. 1 in comparison with the previous experimental data [7–9] and the TENDL-2017 data [10]. The peak amplitude of the data of Birattari et al. (1973) [7] is almost consistent with our result. However, the data of Spahn et al. (2005) [8] shows two times larger amplitude than ours. The peak of the TENDL-2017 data show the similar amplitude with ours, however smaller width and lower energy position than ours.

# **4. Summary**

We measured activation cross sections of the 169Tm(p,n)169Yb reaction up to 18 MeV. The experiment was performed using the cyclotron at ATOMKI. The well-established methods, the stacked-foil activation method and the gamma-ray spectrometry, were adopted. The preliminary result of the cross sections was compared with previous experimental data and theoretical model calculation. The further analysis is being performed.

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