Production cross-section of the ^{99m}Tc medical isotope by using the $^{nat}Mo(p, 2n)$ reaction

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Introduction

The radioisotope ^{99m}Tc is widely used in nuclear medicine for diagnostics and imaging like, single photon emission computed tomography (SPECT), for bone and brain scans, myocardial perfusion imaging (MPI), and many more studies around the globe. The relatively short half-life of ^{99m}Tc (6.01 h) and its biological half-life of 1 day allows us to use large quantities while keeping effective radiation dose to the patients very low. The medical isotope ^{99m}Tc is directly produced from the $^{238}U(p, f)$, $^{98}Mo(n, \gamma)^{99}Mo$ and $^{100}Mo(p, 2n)$ reactions. The ^{99m}Tc isotope can also be produced using the $^{100}Mo(n, 2n)^{99}Mo$ reaction [1], as the ^{99}Mo decays into the final product ^{99m}Tc. The production from the $^{238}U(p, f)$ reaction is not a very good option due to the cost, safety, licensing, radioactive waste production and the half-life of 6.01 h only permits to produce ^{99m}Tc from the $^{100}Mo(p, 2n)$ reaction for its instant use. Therefore, as far as medical purposes are concerned, ^{99m}Tc can easily be produced directly by using proton accelerator within small transit radius. Enormous amount of work has been done using the enriched ^{100}Mo target. However, the cross-section data using the ^{nat}Mo target are scarce [2–4]. A general disagreement can also be seen from the compilation of the $^{nat}Mo(p, 2n)$ reaction data. Taking the above points as the sole motivation, we have measured the $^{nat}Mo(p, 2n)^{99m}Tc$ reaction cross-section at 10 MeV proton energy.

Experimental Methodology

The present experiment was carried out by using the activation technique followed by off-line $\gamma - ray$ spectroscopy at BARC-TIFR Pelletron facility in Mumbai, India. High purity ($\approx 99.98\%$) natural molybdenum foil of thickness 0.1 mm wrapped with 0.025 mm thick aluminum foil was used as the target. The wrapped target foil was kept inside the 6 meter irradiation port on the main beam line of the Pelletron. The irradiation was carried out with a 10 MeV proton beam having a constant 180 nA current to build up sufficient activity. The proton flux during the irradiation was calculated from the charge collected on a Faraday cup [5]. In order to reduce the radioactive dose before recording the $\gamma - ray$ spectra, the irradiated sample was allowed to cool for an appropriate time. The sample was counted by using a pre-calibrated 80 cm^3 HPGe detector coupled to a PC based 4096 channel analyzer. The HPGe detector was calibrated with a standard ^{152}Eu source. The resolution of the detector system during counting was measured as 1.82 keV at 1332 keV of ^{60}Co. The counting of the sample was repeated over a period of time following the decay half-life of the reaction product.

Data Analysis

The production cross-section for the ^{99m}Tc was measured using the proton induced reaction of ^{nat}Mo at 10 MeV. The mid-point energy for the target foil was calculated by SRIM

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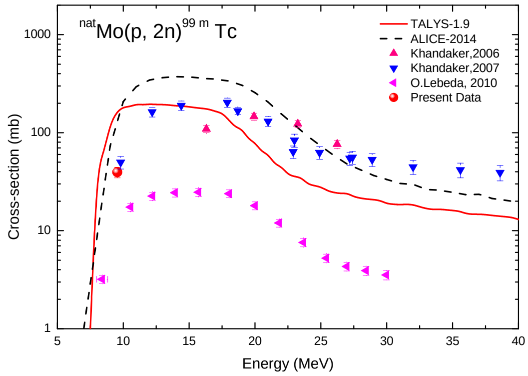

FIG. 1: Comparison of measured data with the literature data [2–4] and theoretical calculations using TALYS-1.9 [6] and ALICE-2014 [7] model codes.

code and was found to be 9.55 ± 0.45 MeV. The reaction residue ^{99}Tc has the ground state with a half-life of 2.0×10^5 years as well as the metastable state with a half-life of 6.0067 hours. The decaying nucleus ^{99m}Tc was identified by the prominent γ-line of 140.5 (89.06%) keV. The photo-peak counts from the 140.5 keV γ-line was used to calculate the reaction cross-section by using the following expression,

$$\sigma_R = \frac{C_{obs}(C_L/L_T)\lambda(e^{\lambda T_c})}{N_0 \epsilon I_\gamma \phi K(1-e^{-\lambda T_i})(1-e^{-\lambda T_{LT}})} \quad (1)$$

where all the symbols have their usual meanings. Since the used target was of a finite thickness, therefore, the self absorption correction factor $K = [1 - exp(-\mu d)]/(\mu d)$ was used for calculating the absorption of γ-rays in the target thickness d with the absorption coefficient μ.

Result and Discussion

In the present work, the $^{nat}Mo(p,2n)^{99m}Tc$ reaction cross-section was measured at 9.55 ± 0.45 MeV proton energy. The reaction cross-section was measured as 39.42 ± 4.2 mb and is plotted together with the literature data [2–4] in Fig. 1. The measured data was found to be in good agreement with the literature data from Khandaker et al., [2]. A large discrepancy between the data from Khandaker et al., [2, 3] and Lebeda et al., [4] can also be seen from the Fig. 1. The TALYS-1.9 [6] and the ALICE-2014 [7] model codes were used for the comparison of the measured and the literature data [2–4]. Both the codes can successfully reproduce the light particles induced nuclear reaction cross-section data for particle energies up to 200 MeV. For the present calculations, the Fermi gas level density model was used in both the codes taking all the other parameters as default. The level density parameter was chosen as 9 as default in the ALICE-2014 code. Both the TALYS-1.9 [6] and the ALICE-2014 [7] model codes were found to produce the trend the the cross-section data up to an acceptable degree. However, the TALYS-1.9 [6] and ALICE-2014 [7] model codes show a peak shift towards the lower proton energies.

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