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Benchmark experiment for the cross section of the ^{100}Mo(p,2n)^{99m}Tc and ^{100}Mo(p,pn)^{99}Mo reactions

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ABSTRACT

As nuclear medicine community has shown an increasing interest in accelerator produced ^{99m}Tc radionuclide, the possible alternative direct production routes for producing ^{99m}Tc were investigated intensively. One of these accelerator production routes is based on the ^{100}Mo(p,2n)^{99m}Tc reaction. The cross section of this nuclear reaction was studied by several laboratories earlier but the available data-sets are not in good agreement. For large scale accelerator production of ^{99m}Tc based on the ^{100}Mo(p,2n)^{99m}Tc reaction, a well-defined excitation function is required to optimise the production process effectively. One of our recent publications pointed out that most of the available experimental excitation functions for the ^{100}Mo(p,2n)^{99m}Tc reaction have the same general shape while their amplitudes are different. To confirm the proper amplitude of the excitation function, results of three independent experiments were presented (Takács et al., 2015). In this work we present results of a thick target count rate measurement of the E_γ = 140.5 keV gamma-line from molybdenum irradiated by E_p = 17.9 MeV proton beam, as an integral benchmark experiment, to prove the cross section data reported for the ^{100}Mo(p,2n)^{99m}Tc and ^{100}Mo(p,pn)^{99}Mo reactions in Takács et al. (2015).

1. Introduction

As an alternative to reactor produced ^{99}Mo/^{99m}Tc generator technology, the direct production of ^{99m}Tc on cyclotrons is considered. The possible reactions and their cross sections, the achievable production yields, specific activity and purity problems were discussed, refer to some selected publications [2–6]. Cross sections of proton induced nuclear reactions on natural and enriched molybdenum have been studied extensively. Several experimental and evaluated data-sets and evaluation are published for the activation cross sections of different reactions regarding the production of ^{99m}Tc and ^{99}Mo radionuclides. Studies on measuring the cross sections of the ^{100}Mo(p,2n)^{99m}Tc and ^{100}Mo(p,pn)^{99}Mo reactions as a function of the bombarding proton energy were carried out by many research groups with conflicting results regarding the amplitude of the reported data [1,7–23] by using both natural Mo and enriched ^{100}Mo targets. Selected data-sets of the available cross sections for the ^{100}Mo(p,2n)^{99m}Tc reaction are collected in Fig. 1 and for the ^{100}Mo(p,pn)^{99}Mo reaction in Fig. 2. In these figures Levkovskij's data (1991) [8] are renormalized by a factor of 0.82 to be consistent with the latest ^{nat}Mo(p,x)^{96g}Tc monitor cross section by Takács (2003) [24] Fig. 1 clearly shows the amplitude differences among the available data-sets, and corrections (reevaluation) are attempted in both Figs. 1 and 2.

In our recent work [1] three independent experiments were performed with the aim to determine the amplitude of the excitation function of the ^{100}Mo(p,2n)^{99m}Tc reaction. Three experiments were carried out at E_p = 16, 36.4, and 38 MeV bombarding proton energies. New experimental cross section data were provided on a Mo target with natural isotopic composition, to clarify the existing discrepancies among the available data-sets. Determination of the cross section of the ^{100}Mo(p,2n)^{99m}Tc reaction does not require a ^{100}Mo enriched target material, since only two reactions contribute to direct production of ^{99m}Tc, the ^{100}Mo(p,2n)^{99m}Tc main reaction and the ^{98}Mo(p,γ)^{99m}Tc reaction with negligible contribution. As it was pointed out, the three new data-sets measured in independent experiments have a very good overall agreement among each other both in shape and in amplitude. The excitation functions of the ^{100}Mo(p,x)^{99}Mo and ^{100}Mo(p,2n)^{99m}Tc reactions were determined experimentally by using analytically derived equations in the data evaluation, avoiding various approximations

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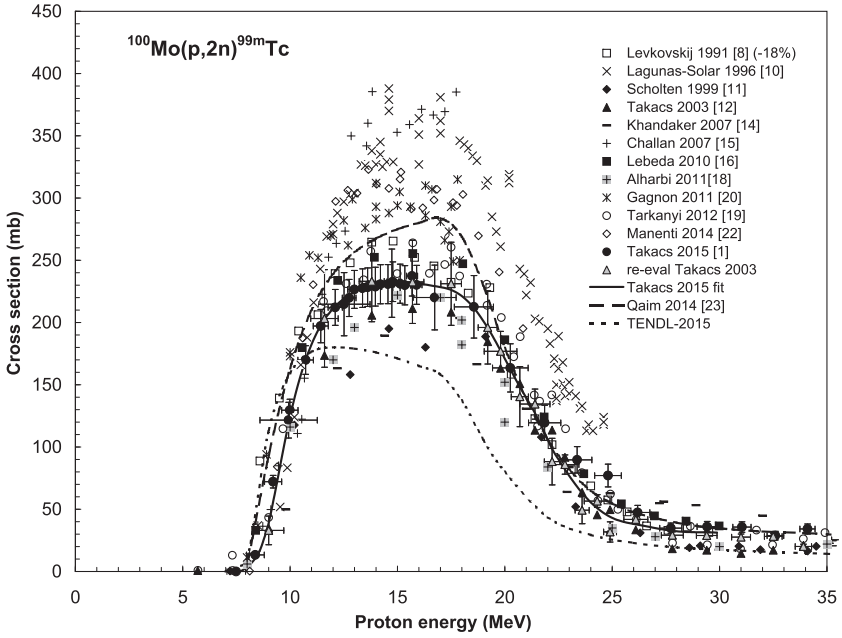

Fig. 1. Available experimental and evaluated cross section data for the ^{100}Mo(p,2n)^{99m}Tc reaction.

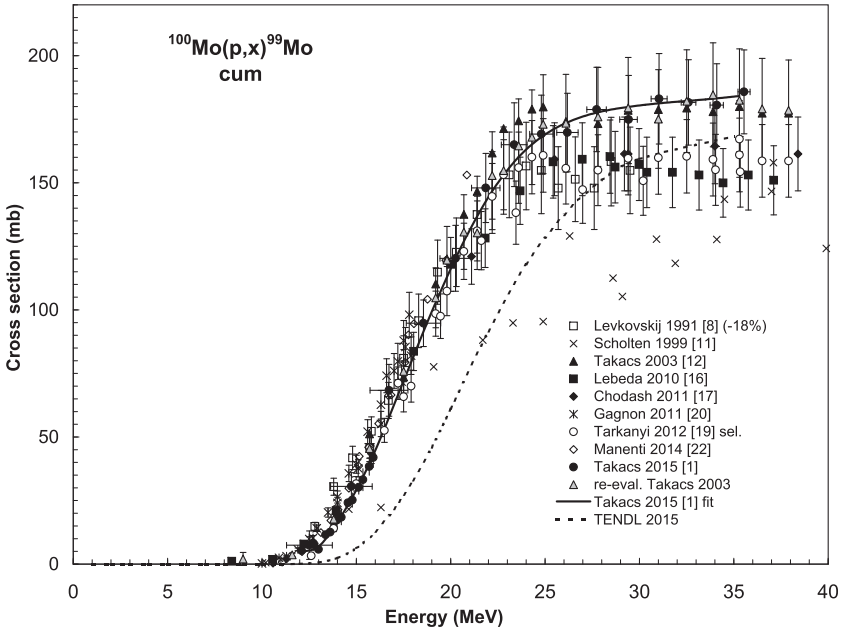

Fig. 2. Selected experimental and evaluated cumulative cross section data (including production by decay of the short lived ^{99}Nb) for the ^{100}Mo(p,x)^{99}Mo reaction.

in the data analysis. The good agreement among the results of the three independent irradiations proves that the main discrepancy among the earlier published experimental cross section data for the ^{100}Mo(p,2n)^{99m}Tc reaction could originate from large uncertainty of the used outdated decay data and probably from the applied data deduction methods.

The aim of this work was to give a further confirmation of the results presented in our recent paper [1] on cross section data of the ^{100}Mo(p,2n)^{99m}Tc and ^{100}Mo(p,pn)^{99}Mo reactions by measuring thick target count rates of the reactions and comparing them with values calculated by using the cross section data presented in [1].

2. Count rate determination

A simple experiment was performed in which the intensity of the E_γ = 140.5 keV gamma-line originating from decay of ^{99m}Tc and ^{99}Mo isotopes was measured. These radionuclides are produced in the ^{100}Mo(p,2n)^{99m}Tc and ^{100}Mo(p,pn)^{99}Mo reactions. A 1 mm thick Mo target with natural isotopic composition was irradiated with an E_p = 17.9 MeV proton beam and the activity of the produced ^{99m}Tc and ^{99}Mo was measured through the common E_γ = 140.5 keV gamma-line. The standard activation method and high resolution HPGe-gamma-spectrometry were used for determining the activity of the irradiated sample. Since the E_γ = 140.5 keV gamma-line can