Measurement of excitation functions for proton induced reactions on ^{nat}Mo for medical isotopes synthesis

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Introduction

Proton-induced reactions play an important role in a variety of domains including medical isotope synthesis, study of isotopic structures, nuclear characteristics and nuclear reactions [1]. Among various established medical isotopes, ^{99m}Tc is particularly significant because it is used in over 30 radiopharmaceuticals, making consistent production and supply necessary for diagnosis and nuclear therapy. With significant breakthroughs in theranostics, the need for ^{99m}Tc continues to rise. An investigation by Takehito Hayakawa and colleagues has identified ^{96g}Tc and ^{95g}Tc as potential replacements, notably these radioisotopes could be viable substitutions. Their findings indicate that these isotopes may be realistic alternatives to ^{99m}Tc, ensuring a more reliable supply chain for medical treatments [2]. This investigation into alternate isotopes emphasizes the continuing need for innovation in isotope manufacturing to support important medical applications. In present work, the cross sections of ^{100}Mo(p,x)^{99m}Tc, ^{nat}Mo(p,x)^{99}Mo, ^{nat}Mo(p,x)$^{96g+m}$Tc and ^{nat}Mo(p,x)$^{95g+m}$Tc reactions were measured along with detailed uncertainty analysis.

Experimental Details

The Experiment was performed using BARC-TIFR Pelletron Linac Facility in Mumbai. Each natural Mo target was stacked with Cu monitor and the irradiation details of each stack of Cu-Mo foils is specified in table 1. The proton beam degradation along the stack was calculated by using SRIM code [3].

Three HPGe detectors were used to count the γ-ray activity of the irradiated samples, the first two detectors with relative efficiency of 30% and the third with 33%. All samples were mounted at 10 cm from the end cap of detector to avoid summing effect. The HPGe detectors were calibrated using standard ^{152}Eu source.

Table 1: Irradiation Details

Energy (MeV)	Mean Current (nA)	Irradiation Time (hrs)
21.8	100	1.15
20.0	92	1.00
18.8	99	1.08
18.0	62	1.10
16.7	111	0.90
16.0	58	1.50
14.0	62	2.12
12.7	97	1.70

Analysis

The detector efficiency was calculated using:

$$\epsilon_s = \frac{C}{A_0 I_\gamma \, \Delta t e^{-\lambda t}}$$

where C is the photo-peak counts of various peaks, A_0 is the initial activity, I_γ is branching ratio, Δt is the counting time, λ is the decay constant of the ^{152}Eu source, t is the time difference between date of production and date of counting of source.

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Cross section (σ) is calculated using the formula:

$$\sigma = \frac{C\lambda}{N_t a \epsilon N_p I_\gamma T}$$

where C is number of counts of each characteristic γ-ray, λ is decay constant, N_t is the number of atoms per unit area, a is abundance, ϵ is the detector efficiency, N_p is the number of protons incident per second on the target, I_γ is gamma ray intensity and T is timing factor.

Results

The measured cross-sections for the production of ^{99m}Tc, ^{99}Mo, $^{96g+m}$Tc, and $^{95g+m}$Tc, spanning the energy range from 12.7±0.05 to 21.8±0.05 MeV MeV have been measured. These results illustrated in Figure 1 to Figure 4 along with their uncertainties, exhibit a good alignment with the data available in the EXFOR database [4] from various authors.

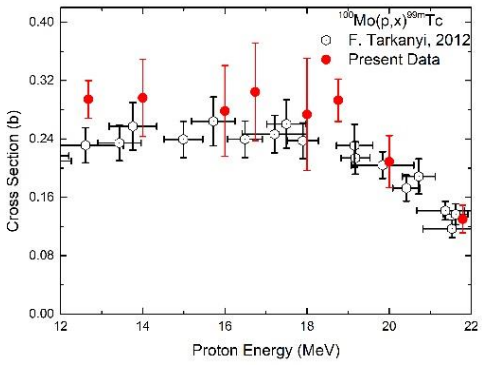

Figure 1. Cross Sections of ^{100}Mo(p,x)^{99m}Tc

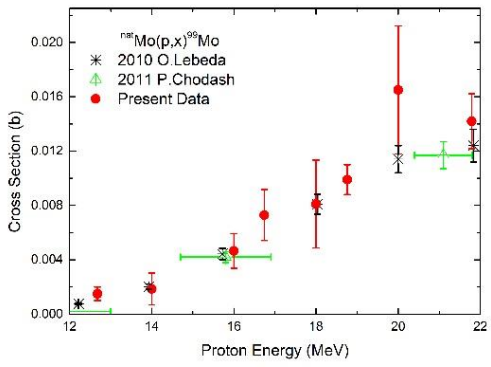

Figure 2. Cross Sections of ^{nat}Mo(p,x)^{99}Mo

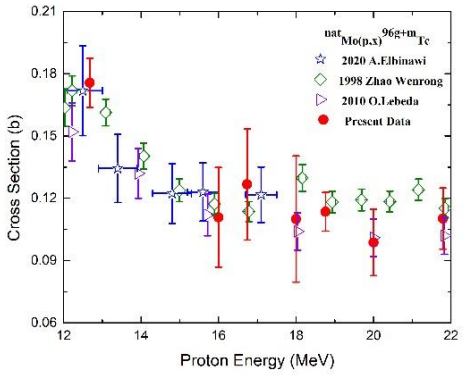

Figure 3. Cross Sections of ^{nat}Mo(p,x)$^{96g+m}$Tc

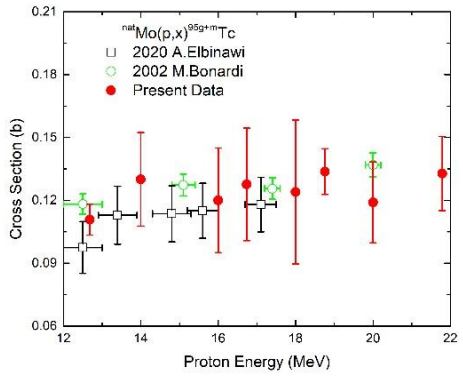

Figure 4. Cross Sections of ^{nat}Mo(p,x)$^{95g+m}$Tc

Acknowledgements:

We gratefully acknowledge the support from BARC-TIFR Pelletron-Linac facility staff and target lab staff. This work is supported by the Department of Atomic Energy, Government of India, under Project Number RTI4002. One of the authors (R.P.) acknowledged the financial support received from the Institutions of Eminence (IoE) BHU (Grant No. 6031-B) and SERB (sanction order no. EEQ/2022/000545).

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