Excitation function for proton induced reactions on natural Mo for the production of medical isotopes

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Introduction

Proton-induced reactions find extensive utility across diverse domains, encompassing the production of crucial medical isotopes, exploration of isotopic structure and nuclear properties, investigation into nuclear reactions, and their pivotal role in advanced medical imaging techniques such as PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computed Tomography) scans [1], production of radioisotopes for radiography, thickness measurement and level gauging. In theranostics, radiopharmaceuticals like ^{99m}Tc, ^{99}Mo plays a vital role in both diagnostic imaging and medical treatment. In this work, the cross sections of ^{nat}Mo(p,x)^{93m}Tc and ^{nat}Mo(p,x)^{93g}Tc were also measured along with detailed uncertainty analysis and correlation coefficients [2].

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.

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Table 1: Irradiation Details

Energy (MeV)	Current (nA)	Irradiation Time (hrs)
21.79±0.05	8	1.15
20.00±0.05	10	1.00
18.76±0.05	10	1.08
18.00±0.05	8	1.10
16.74±0.05	10	0.90
16.00±0.05	8	1.50
14.00±0.05	7	2.12
12.68±0.05	10	1.70

Analysis

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.

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.

Results

The measured cross-sections for the production of 99mTc, 99Mo, 93mTc, and 93gTc, spanning the energy range from 12.68±0.05 to 21.79±0.05 MeV MeV, have been examined. These results, illustrated in Figure 1 to Figure 4, exhibit a good alignment with the data available in the EXFOR database [4]. The correlation coefficients for $^{nat}Mo(p,x)\,^{93m}Tc$ are displayed at all energies in Table 2:

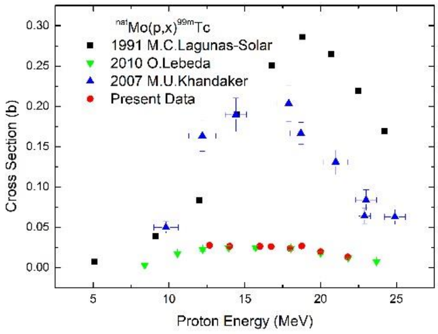

Figure 1. Cross Sections of $^{nat}Mo(p,x)^{99m}Tc$

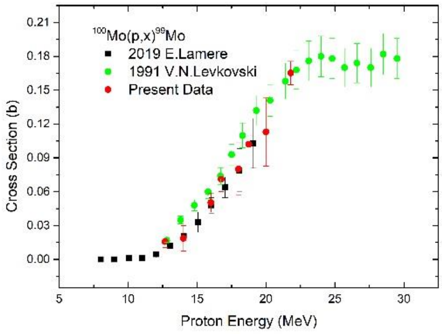

Figure 2. Cross Sections of $^{100}Mo(p,x)^{99}Mo$

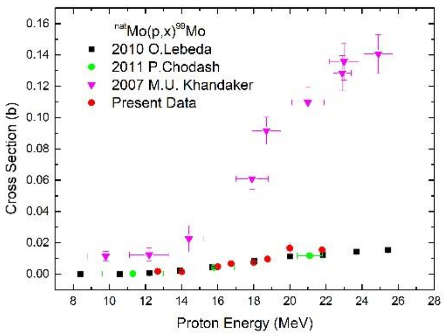

Figure 3. Cross Sections of $^{nat}Mo(p,x)^{99}Mo$

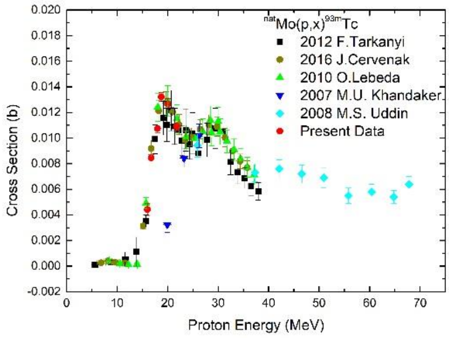

Figure 4. Cross Sections of $^{nat}Mo(p,x)^{93m}Tc$

Table 2: Cross sections and correlations for $^{nat}Mo(p,x)\,^{93m}Tc$

E_p (MeV)	σ (b)	Correlation Coefficients					
21.79	0.0109(3)	1					
20.00	0.0127(4)	0.70	1				
18.76	0.0132(4)	0.66	0.96	1			
18.00	0.0107(3)	0.68	0.96	0.94	1		
16.74	0.0084(2)	0.56	0.96	0.94	0.97	1	
16.00	0.0043(2)	0.68	0.96	0.94	0.97	0.94	1

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