Experimental Cross-section Measurement of $^{nat}Nb(p,n)^{93m}Mo$ reaction up to 20 MeV energy

[1]B. Lawriniang*, [1]R.Ghosh, [1]S. Badwar, [2]V Vansola, [1]B. Jyrwa, [3]H. Naik, [4]Y Naik

[1]Physics Department, North eastern hill University, Meghalaya 793022 INDIA

[2]Department of Physics, Faculty of Science, M. S. University of Baroda, Vadodara-390020, INDIA

[3]Radiochemistry Division, Bhabha Atomic Research Center, Trombay, Mumbai 400085 INDIA.

[4]Product Development Division, Bhabha Atomic Research Center, Trombay, Mumbai 400085 INDIA

* *email: biolaw12@yahoo.com*

Introduction

The mono-isotopic element Niobium is a rare, shiny, malleable, ductile grey white metal with high strength, high melting point (2470°C), high resistance to corrosion and a low neutron absorption cross-section. Niobium is used as an alloy to strengthen steel, but its main application is found in nuclear reactors as structural material due to its physical and chemical properties. Therefore, the cross-section data of Niobium is important for the design of a nuclear reactor.

The knowledge on the excitation function of proton-induced nuclear reactions are important for several fields especially for studies of the material behaviours by the charged particle irradiation. Also, since niobium is a mono-isotopic element, its experimental cross-section data is useful for verification of nuclear reaction theory.

Experimental Details and Data Analysis

In the present work, proton induced experiment on Niobium stacked foil activation technique combined with off-line γ-ray spectrometry has been performed, using an HPGe detector, at Pellatron facility, Tata Institute of Fundamental Research (TIFR), Mumbai. The reaction cross-section for the $^{nat}Nb(p,n)^{93m}Mo$ nuclear process were measured over the energy range from threshold up to 18.63 MeV. A high purity mono-isotopic Niobium foil was used as the target for the irradiation, where the copper foils were also inserted in between in the stack to follow the energy degradation along the stack. In the calculation for reaction cross-section, the proton flux is determined via a monitor reaction $^{nat}Cu(p,x)^{62}Zn$ with known cross-section taken from IAEA database [1]. A stack of five Niobium foils separated by Copper foils arranged in the order Al-Nb-Cu-Nb-Cu-Nb-Cu-Nb-Cu-Nb-Cu (thickness Nb≈91μm, Cu≈103.45 μm, Al≈108μm) was irradiated with proton energy of 20 MeV for 30 minutes at beam current of 50 nA The incident proton beam decreases as it passes through the stack, this loss of proton beam energy was calculated using the SRIM code 2013 [2] taking the incident proton energy as 20 MeV, which reaches the first Niobium foil with energy of 18.63 MeV due to energy loss in the Aluminium foil.

After irradiation, the activity measurement of the radio-nuclides ^{93m}Mo and ^{62}Zn were done using a pre-calibrated HPGe detector, coupled to a Multi Channel Analyser (MCA), after a cooling time of about 6-7 hours. The ^{93m}Mo radionuclide has a metastable state of 6.85 hours half-life and was identified by the γ-lines of 263.062 keV (56.7%), 684.07 keV (99.7%) and 1477.1 keV (99.1%), which were actually detected to determine the reaction cross-section. The efficiency of the detector was calibrated using the 152Eu standard source of known strength. The detection efficiency of the detector, the γ-ray intensity and the half-lives of the radioisotope are all taken into account for the calculation of the $^{nat}Nb(p,n)^{93m}Mo$ Cross-section.

The decay and spectrometric characteristics of the investigated isotopes and the Q-value of the $^{nat}Nb(p,n)^{93m}Mo$ were taken from NuDat [3] and the Q-Value calculator of NNDC [4], respectively.

Results and Discussion

The $^{nat}Nb(p,n)^{93m}Mo$ reaction cross-section have been determined in this work, where the data are presented in Table 1 and the excitation function in fig 1. The results were compared with the existed literature data from EXFOR [5] as well as with the theoretical calculation by nuclear code TALYS1.6 [6] without any parameter adjustment. The experimental data were found to follow the same trend as the theoretical prediction by nuclear code TALYS but with the magnitude slightly lower than the theoretical values. The present measured data fits well with the data reported by M. A. Avila Rodrigues [7] and F. Ditroi [8] in the whole energy range from threshold value up to 18.63 MeV and also with those by V. N. Levkovski [9] for proton energy above 10 MeV.

Table 1: Reaction Cross-section for $^{nat}Nb(p,n)^{93m}Mo$

Proton Energy (MeV)	Q-value (MeV)	Reaction Cross-section (mb)	
		Experimental	TALYS
8.60	1.2	6.58±0.60	12.04
12.54		21.03±1.99	35.43
15.79		12.92±1.23	19.00
18.63		5.49±0.54	14.53

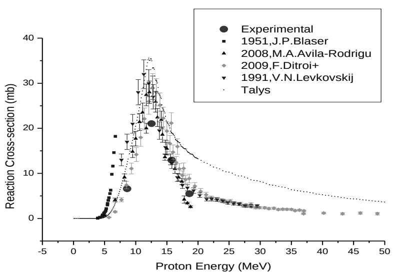

Fig 1: Excitation function of $^{nat}Nb(p,n)^{93m}Mo$

Conclusion

The $^{nat}Nb(p,n)^{93m}Mo$ reaction cross-section determined at the four proton energies are compared with the literature data compiled in EXFOR database are found to be in general agreement. However, theoretically calculated values based on TALYS code with default parameters are higher the experimental data of present work and literature data. Thus the present data helps in streamlining the literature data and validating the theoretical model.

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