Isomeric population ratios in some nuclei produced in proton and alpha induced reactions on ^{93}Nb.

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Introduction

The study of isomeric cross section ratio in the formation of isomeric pairs in nuclear reactions give important information about the nuclear reaction mechanism, particularly the energy and angular momentum transfer during the reaction process as well as the progress of the nuclear reactions. Keeping this in view we have studied the isomeric population ratios for the isomeric pairs ^{93m,g}Mo, ^{96m,g}Tc, ^{95m,g}Tc, ^{94m,g}Tc, ^{93m,g}Tc produced in (p,n), (α,n), (α,2n), (α,3n), (α,4n) reactions respectively on ^{93}Nb target over the energies from threshold up to 40 MeV. The measurement of isomeric cross section ratios for the production of isomeric pairs ^{96m,g}Tc and ^{95m,g}Tc are also done over the same energy range. The dependence of isomeric cross section ratio on the incident energy, spin state of the isomeric pairs, energy difference between the pairs, existence of intermediate energy levels are studied. The details of the measurement and analysis is discussed in the following sections.

Experiment and Analysis

Experiments have been carried out at the Variable Energy Cyclotron Center (VECC), Kolkata, India, employing stacked foil activation technique. Two stacks of ^{93}Nb samples of thickness $\approx$ 5 mg/cm^2 pasted on Al-holders, were prepared as target stacks. One stack was irradiated with 12 MeV proton beam and the other with 40 MeV alpha beam for about $\approx$ 12 hours each. The beam current $\approx$ 100 nA in both the cases. The energy incident on each sample was calculated by taking into account of the energy loss of the incident beam in the sample thickness, Al-backing and interposed degrading foils. The activity induced in each sample were followed using a pre-calibrated 100 cc HPGe detector coupled to the ORTEC's PC based multichannal analyzer at the Inter University Consortium for DAE facilities, Kolkata Center. From the observed activities the cross sections for the production of isomeric and ground states were measured for the isomer ^{93m}Mo up to 12 MeV and ^{95m,g}Tc and ^{96m,g}Tc up to 40 MeV and the isomeric cross section ratios were determined accordingly. The data are plotted in Fig. 1.

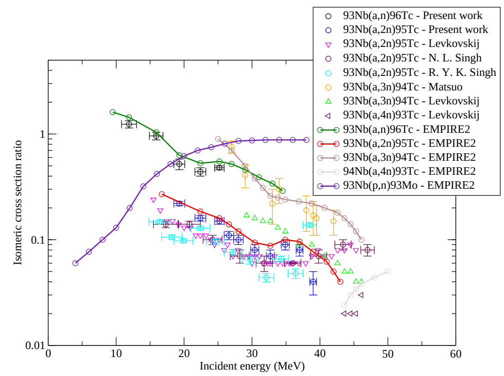

FIG. 1: Isomeric cross section ratio for the isomeric pairs ^{96m,g}Tc, ^{95m,g}Tc, ^{94m,g}Tc, ^{93m,g}Tc and ^{93m,g}Mo.

Theoretical analysis

Theoretical analysis of the data has been performed using the nuclear reaction code EMPIRE-II [1]. This code makes use of the Hauser- Feshbach (HF) model [2] for the statistical part of the nuclear reaction and the NVWY model [3] based on MSD-MSC (Multi

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Step Direct - Multi Step Compound) approach and the exciton model [4] are used for the PE emission part. HF takes into account spin and parity of each level in the decay of the compound nucleus. This helps and determining the relative population of each levels. The ratio for the population of each isomeric pair at various incident energies were determined. The isomeric cross section ratios thus calculated for the production of isomeric pairs ^{93m,g}Mo, ^{96m,g}Tc, ^{95m,g}Tc, ^{94m,g}Tc, $^{93m,g}Tc$ at various incident energies are also shown in Fig. 1 along with available with literature data [5, 6, 7, 8].

1. Result and Discussion

From Fig. 1 it can be seen that the isomeric cross section ratios varies with incident energy. However the nature of the variation is different for different isotopes. Qaim et al [9], reported that the isomeric cross section ratio primarily depends on spins of the states. However the observed isomeric cross section ratio is not a mere function of energy but depends on many other parameters. The detailed parameter set related to the isomeric and ground states are tabulated in Tab. 1. In general it can be seen that the isomeric cross section ratio increases with incident energy in the cases were the isomeric spin is larger than the ground state spin. Where as in the case of pairs with spin of the isomer state lesser than that of ground state the isomeric cross section ratio shows decreasing trend with the incident energy. This may be justified the population of higher angular momentum states increases with incident energy, disregarding the states whether isomeric or ground states. The variation of isomeric cross section ratio critically depends upon the spin and energy differences and also on the existence of intermediate states between the ground state and isomeric states. The general trend of the variation with incident energy is found to be discontinued after a certain energy and some reversing trend is observed in cases with low emission channels like (p,n), (α,n) and (α,2n). This may be due to the fact that at larger incident energies the emission of pre-equilibrium particles take place which carry relatively larger angular momentum suppression the population of states with higher spin. Similar trend is also observed in the case of isomeric pairs produced in irradiation of proton on ^{89}Y [10].

1 Spins of the relevant states of the isomeric nuclides of interest

Nuclide	Ground state(g)			Isomer state(m)	
—	$J\pi$	$T_{1/2}$	E(MeV)	$J\pi$	$T_{1/2}$
^{93}Mo	$5/2^+$	stable	2.42484	$21/2^+$	6.85h
^{96}Tc	7^+	4.28d	0.0342	4^+	51.5m
^{95}Tc	$9/2^+$	20h	0.0389	$1/2^-$	61d
^{94}Tc	7^+	293m	0.075	2^+	52m
^{93}Tc	$9/2^+$	2.75h	0.3926	$1/2^-$	43.5m

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