Study of the various factors affecting the isomeric cross section ratios (ICR) in proton induced nuclear reactions on ^{90}Zr

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1. Introduction

Nuclear isomers continue to make key contributions to the development and understanding of nuclear structure physics [1,2]. The study of isomeric cross section ratio (ICR) of nuclear reaction is a significant tool for testing nuclear models. The understanding of their occurrence and degree of stability promises additional nuclear structure insights, with the potential for novel applications. The isomeric cross-section ratio (ICR) for a pair of isomeric states is known to depend strongly on the spins of the isomers concerned, as well as on the spins of the higher lying levels populating the isomers. The spin distribution finally changes as a result of particle emission followed by gamma deexcitation leading to the formation of the residual nucleus. Thus removal of a substantial amount of angular momentum from the excited composite system will have a strong impact on the yields of isomers having an appreciable amount of spin difference. The excitation functions and and ICR have been an object of theoretical estimations with several computer codes. Qaim et al [1], Satheesh et al [2] have shown that the (ICR) is primarily governed by the spins of the two levels involved, rather than their separation and excitation energies. Keeping this in view we have studied the various factors affecting the ICR in proton induced nuclear reactions on ^{90}Zr, over the energies from threshold up to 40 MeV for proton induced reactions.

2. Theoretical analysis

Theoretical calculations of cross sections carried out using computer codes, TALYS 1.6 [3]. In TALYS 1.6 statistical treatment of the compound nucleus is based on the Hauser - Feshbach model along with the width fluctuation correction model of Moldauer and incorporates modern nuclear models for the optical model, level densities, direct reactions, compound reactions, pre-equilibrium reactions, fission reactions, and a large nuclear structure database. In the present work the emphasis was on the calculation of the ICR. Because such calculations are strongly dependent on the input level scheme of the product nucleus, we have chosen those parameters very carefully. The energies, spins, parities, and branching ratios of the discrete levels were selected from the Nuclear Data Sheets [4]. Another important consideration in calculating the isomeric cross sections is the spin distribution of the level density.

3. Results and analysis

Almost all the experimentally measured values and the theoretically calculated values of excitation functions of compound nuclear exactly fits to each other. But some of the theoretically calculated compound nucleus reaction excitation functions are far apart from the experimentally measured values and instead of forming a long tail they falls rapidly in almost all reactions. The comparisons of the excitation functions is done using nearly comparable energy range of the projectile, assigning for the energy size of the theoretically calculated values in such a way that it corresponds to the experimentally used energy ranges. The calculated compound reaction cross-section values starts from the value 1.64 at the incident energy of the projectile of the order of 10 MeV and starts increasing for increasing value of energy of projectile. Experimental cross section of compound nucleus formation also starts at the same point in the graph and follow the

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same track. The calculated value of compound excitation function exactly fit with the experimentally measured values. The Fig.2 which shows that the isomeric cross ratio remains constant independent of the energy of the projectile.This constant value is equal to 1. The analysis indicates that the isomeric cross section ratio has its manifestation on the relative level difference between the isomeric state and ground state and also at the spin of the states. At relatively larger energies the system preferred higher spin states rather than the excitation energy available for the system is indicated by relative population of the above nuclei. It is found that isomeric cross section ratio critically depends on the spins of ground state and isomeric state and also on the incident energy of the projectile. In the case where isomeric spin is greater than the ground state spin the isomeric cross section ratio increases steadily up to certain energy and thereafter it got constant value. In the case of nuclei with isomeric spin lesser than that of ground state the isomeric cross section ratio initially increase with incident energy and thereafter it decreases up to certain energy and it remains almost constant on further increase of incident energy. The isomeric cross section ratio is found to depend strictly on spin states of ground and isomeric states and also the decay mode of isomeric state It was observed that at low energies the state with lower spin states are populated irrespective of whether it is ground state or isomeric state. As the energy increases the probability of populating the higher spin states increases and proceeds to an equilibration between the two. But, the probability of pre-equilibrium emission changes the pattern to some extent by carrying away a larger angular momentum leaving the residual nucleus in the lower spin states. One another fact is that the isomeric cross section ratio does not depend significantly on the energy difference between the states. It is worth nothing that the maximum value of isomeric cross section ratio is larger for the cases with smaller energy difference and the other way around. In general we could not find any strict relationship of isomeric cross section ratio with the relative half lives of the pair of states. The details will be presented.

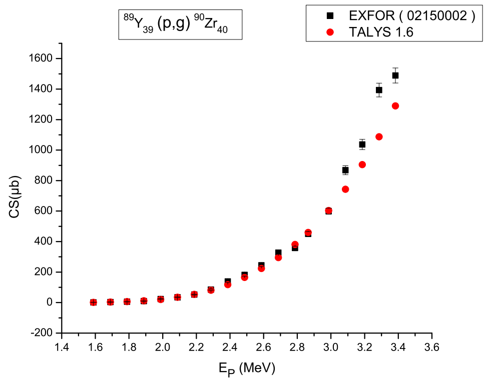

FIG. 1: Comparison between theoretical and experimental excitation function for the reaction ^{89}Y(p,γ)^{90}Zr

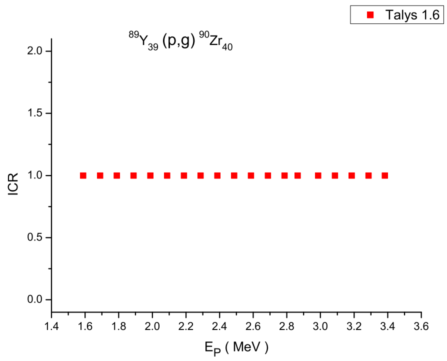

FIG. 2: ICR for ^{89}Y(p,γ)^{90}Zr

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