Isomeric cross section ratio for ^{89,90}Zr produced through various reaction channels.

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Introduction

Experimental and theoretical studies on the isomeric cross-section ratios as a function of incident particle energy lead to useful information on the spin as well as on the level structure of the product nucleus. Qaim et al [1], Satheesh et al [2] have shown that the isomeric cross section ratio (ICR) is primarily governed by the spins of the two levels involved, rather than their separation and excitation energies. It is expected that the ICR may have some reflection on the entrance channel as well as the emission channels, where the contribution of spin transfer is important.

Keeping this in view we have studied the ICR for the isomeric pairs ^{89g,m}Zr and ^{90g,m}Zr produced in ^{86}Sr(α,n)^{89}Zr, ^{87}Sr(α,2n)^{89}Zr, ^{88}Sr(α,3n)^{89}Zr, ^{89}Y(p,n)^{89}Zr, ^{89}Zr(n,n)^{89}Zr, ^{90}Y(p,2n)^{89}Zr, ^{90}Zr(n,2n)(^{89}Zr, ^{90}Y(p,γ)^{90}Zr, ^{86}Srα,γ)^{90}Zr, ^{87}Sr(α,n)^{90}Zr, ^{88}Sr(α,2n)^{90}Zr, ^{89}Zr(n,γ)^{90}Zr, ^{90}Zr(n,n)^{90}Zr and ^{90}Y(p,n)^{90}Zr reactions respectively over the energies from threshold up to 40 MeV for both proton and alpha induced reactions. Experimentally measured cross sections for the reactions ^{89}Y(p,n)^{89g,m}Zr over the energy range ∼ 5 - 15 MeV, have been used as the standard reference for evaluating cross sections for other cases.

1. Experiment and Analysis

Experiment has been performed at the Variable Energy Cyclotron Center (VECC), Kolkata, India, employing stacked foil activation technique. The Yttrium samples of thickness ∼ 3.32 mg/cm^2, were prepared by centrifugal method on Alumium backing. A proton beam of 15 MeV was used for the irradiation of the stack. The energy degradation in the sample thickness and degraders are taken into account. The activity induced in each samples were followd using a precalibrated 100 cc HPGe detector coupled with a data acquistion system. Various standard sources of known stregths were used to determined the geometry dependent efficiency of the detector at various gamma energies. The experimental value if ICR were measured for ^{89}Y(p,n)^{89g,m}Zr reactions using the measured cross sections for the production of ^{89g} and ^{89m} as mentioned above. Theoretical calculations of cross sections were carried out using EMPIRE 3.1 [3], which makes use of the Hauser-Feshbach and the exciton model formalisms. Further- more, it combines several other modern features described below. In these calculations the standard library of input parameters was used which includes the nuclear masses, optical model para- meters, ground state deformations, discrete levels and decay schemes, level densities, moments of inertia (MOMFIT) and gamma-ray strength functions. The direct contribution was determined via the coupled channel calculation using the built in ECIS03 code. The particle transmission coefficients were generated via the spherical optical model using the computer code (ECIS03) and the default set of global parameters: for neutrons and protons from Koning and Delaroche and for alpha particles from McFadden and Satchler. In the calculation the Multi-Step Direct, Multi-Step Compound, Hauser-Feshbach model with width fluctuation correction (HRTW), the DEGAS and PCROSS

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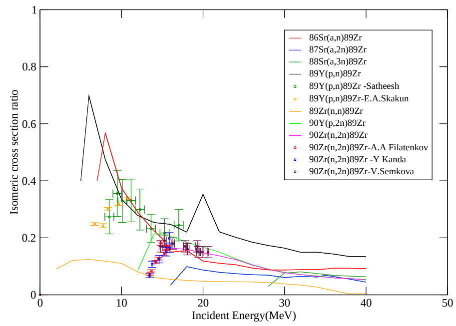

FIG. 1: Experimentally measured and theoretically calculated isomeric cross section ratio for the ^{89}Zr produced through various reactions channels.

codes were used. These codes conserve the particle flux by dividing the absorption cross section of the optical model between the different types of reaction mechanisms. For the level densities, the HF-BCS microscopic structure was used.

2. Results and discussion

The ICR thus calculated for the production of ^{89}Zr and ^{90}Zr nuclei produced through various reaction channels are determined at various incident energies and are plotted in Fig. 1 along with the available experimental data. The analysis indicate that the ICR has reflection on the spins of the states. Relevant data on ground state, isomeric state and intermediate state, such as energy, spin and parity and half lives for the above nuclei are tabulated in table. 1. Apart from the relative spins of the states the ICR critically depends on entrance channel as well as the emission channel, where the angular momentum transfer is important. Pre-equilibrium emission play a major role in isomeric cross section for lesser particle emission channel as it carries away larger angular momentum.

3. Conclusion.

The ICR is found to depend strongly on the relative spins of the isomeric and ground state, energy difference between the levels, presence of intermediate states and some dependence on decay modes as well as on the onset of PE emission. The ICR shows smooth behavior when decays through electron capture.

TABLE I: Spins of the relevant states of the isomeric nuclides of interest

Nuclide	Ground state		Isomeric state			Intermediate state		
	J_π	$T_{1/2}$	MeV	J_π	$T_{1/2}$	MeV	J_π	$T_{1/2}$
^{89}Zr	$9/2^+$	78.41h	0.5878	$1/2^-$	4.16m			
^{90}Zr	0^+	stable	2.3187	5^-	809.2ms	2.19	2^+	93fs

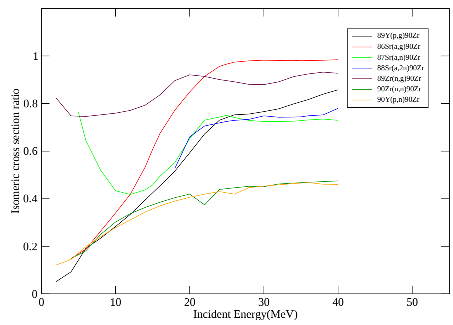

FIG. 2: Experimentally measured and theoretically calculated isomeric cross section ratio for the ^{90}Zr produced through various reactions channels.

References

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