Production of the isomeric pairs ^{119g,m}Te and ^{121g,m}Te in proton induced nuclear reactions.

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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. Keeping this in view we have studied the ICR for the isomeric pairs ^{121g,m}Te and ^{119g,m}Te produced in ^{121}Sb(p,n)^{121g,m}Te and ^{121}Sb(p,3n)^{119g,m}Te reactions over the energies from threshold up to 40 MeV for proton induced reactions. Experimentally measured cross sections for the reactions ^{121}Sb(p,n)^{121g,m}Te over the energy range ~ 4.41 - 20 MeV, have been used as the standard reference for evaluating cross sections for other cases. Huizenga and Vandenbosch [3, 4] used the following expression, based on a statistical model, to determine the dependence of the nuclear level density on the spin

$$\rho(J) = \rho(0)(2J+1)exp[-(J+1)/2)^2/2\sigma^2] \tag{1}$$

where $\rho(0)$ and $\rho(J)$ are respectively the densities of states with spin 0 and J, and σ is the cut-off factor which describes the angular momentum distribution of the level density and is related to the moment of inertia and temperature of the nucleus. The isomer ratio depends initially on the spin distribution of the compound nucleus which is subsequently altered by the emission of particles and the accompanying gamma cascade. In the fission process the first step, which determines the initial spin distribution, is not easy to calculate since it involves a calculation of the angular momentum distribution of the pairing fragments formed in the fission process. According to Warhanek and Vandenbosch [5] the angular momentum distribution in fission can be described by the following functional form

$$F(J) = (2J+1)exp(-J(J+1)/B^2) \tag{2}$$

where B, a factor similar to the spin cut-off parameter σ, is related to I, the root-mean square angular momentum. The de-excitation steps which follow, i.e. particle and gamma emission, are treated as in the case of simple nuclear reactions, assuming some energy dependent factor of σ, the spin cut-off parameter, and I, the nuclear moment of inertia.

Experiment and Analysis

Experiment has been performed at the Variable Energy Cyclotron Center (VECC), Kolkata, India, employing stacked foil activation technique. The Antimony samples of thickness ~ 2.5mg/cm^2, were prepared by vacuum evaporation method on Aluminum backing. A proton beam of 20 MeV was used for the irradiation of the stack. The activity induced in each samples were followed using a precalibrated 100 cc HPGe detector coupled with a data acquisition system. Various standard sources of known strengths were used

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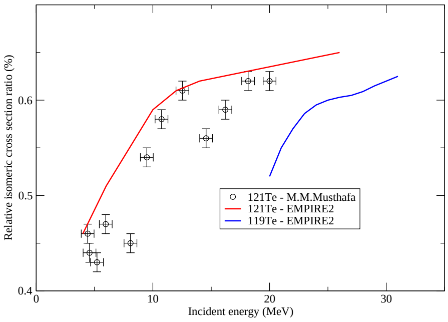

FIG. 1: Experimentally measured and theoretically calculated isomeric cross section ratio for the isomeric pairs ^{121g,m}Te and ^{119g,m}Te produced through various reactions channels.

to determined the geometry dependent efficiency of the detector at various gamma energies. Theoretical calculations of cross sections were carried out using EMPIRE 3.1 [6], which makes use of the Hauser Feshbach and the exciton model formalisms. Furthermore, 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 parameters, 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 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.

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	$T_{1/2}$
^{119}Te	$1/2^-$	16.05 h	0.3	$11/2^-$	4.68 d	0.2575	$3/2^+$	0.11 ns
^{121}Te	$1/2^-$	16.8 d	0.29398	$11/2^-$	154 d	0.21219	$3/2^+$	0.06 ns

Results and discussion

The ICR thus calculated for the production of ^{121}Te and ^{119}Te nuclei produced through various reaction channels are determined at various incident energies and are plotted in Fig.1. 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.

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 Pre-equilibrium emission.

References

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