Energy dependence of isomeric cross-section ratios for the residues populated via in-complete fusion reactions

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Introduction

During the last several years, the study of nuclear high-spin states has been a topic of interest for both the experimental and theoretical physicists. In order to produce the high-spin states in nuclei most common approach has been through the fusion reaction channels. In such reactions, the input orbital angular momentum may be transferred to the nuclear spin of the compound system. It may, however, be pointed out that the maximum induced nuclear spin is limited by the maximum impact parameter of the fusion reaction, and also by the competition from fusion and other open reaction channels. On the other hand, it has been shown that during the peripheral interactions, the angular momentum brought into the system is quite large, the projectile may break into constituents and partial fusion, commonly referred to as the in-complete fusion (ICF) of the projectile may take place. This may lead to the population of relatively high-spin states in the system[1]. As such, the nuclear reactions induced by heavy ions are important to obtain the information regarding the nuclear reactions mechanism and also the properties of excited states of nuclei[1, 2]. Such information may be obtained from the study of the isomeric cross-section ratios (ICR)[3, 4] deduced from the measured cross-sections. The ICR may be defined as the ratio of production cross-section for meta-stable (σ_m) to ground state (σ_g) i.e., σ_m/σ_g. According to the compound nucleus theory, the residual nucleus may be formed as a result of evaporation of nuclear particles from the composite system formed as a result of projectile-target interaction. The relative population of ground and isomeric states is governed by initial excitation energy, spin distribution of the coumpound nucleus, the number and type of nuclear particles that carry away energy and angular momentum. The study of isomeric cross-section ratios may give important information on the structure of the nucleus and on the mechanism of its production. In the present work an attempt has been made to study the dependence of isomeric production cross-section ratio on the energy of the incident heavy-ion for the residues populated, in ^{16}O + ^{130}Te and ^{12}C + ^{159}Tb systems, via in-complete fusion channels where the driven angular momentum is relatively large[1].

Experimental details

The experiments have been performed using the energetic ^{12}C and ^{16}O ion beams, obtained from the 15UD-Pelletron accelerator at the Inter-University Accelerator Center (IUAC), New Delhi, India. The targets of enriched ^{130}Te (≈61%) and natural ^{159}Tb (≈99.99%) of desired thicknesses have been used. Targets followed by catcher foils were irradiated at different beam energies in the

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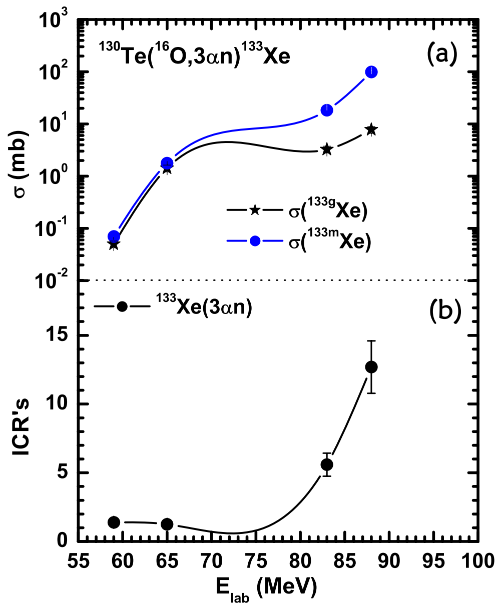

FIG. 1: (a) Experimentally measured cross-sections for both the isomeric and ground states of ^{133}Xe (b) Isomeric cross-section ratios for the residues ^{133}Xe(3αn) populated in ^{16}O+^{130}Te system.

General Purpose Scattering Chamber having invacuum transfer facility. The stacked foil activation technique has been used in the present work. Further details of the experiments and measurements are given elsewhere[5, 6]. The ground and isomeric states of the residues have been identified by their characteristic gamma lines and translated to the production cross-section using standard formulations[5].

Results and discussion

Isomeric production cross-section ratios for the residues populated in reactions ^{130}Te(^{16}O,3αn)^{133}Xe and ^{159}Tb(^{12}C,2α3n)^{160}Ho produced via complete and/or in-complete fusion channels have been determined. As an example the ^{133}Xe residues may be populated by complete fusion process as well as by the in-complete fusion process in ^{16}O + ^{130}Te interaction. It may, further, be pointed out that the PACE4 predictions based on statistical model calculations are found to give negligible cross-section values for the ^{133}Xe and ^{160}Ho residues. As such, the production of these residues may be considered only via the ICF reaction channels where the probability of high angular momentum transfer to the composite system is relatively large. As a typical example, the cross-section values for ^{133}Xe residues have been plotted in the upper pannel of Fig. 1. In order to study the energy dependence of ICR, the ICR for the residues ^{133}Xe(3αn) have been plotted in the lower pannel of the same figure. It may be noted from this figure that the isomeric cross-section ratio increases with energy. In case of ICF reactions, a relatively large amount of angular momentum is transferred which increases with energy. As such, the increase in isomeric population with energy indicates that a part of the input angular momentum may get converted to the nuclear spin and the isomeric population increases. As such, the ICR may depend strongly on the relative spins of isomeric and ground states and the energy difference between the levels. The details will be presented.

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