Exit channel effect of Isomeric Cross-section Ratio in the production of ^{197}Hg^{m,g}

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Introduction

Investigations on excitation functions and isomeric cross-section ratio of nuclear reactions are of considerable importance in testing the nuclear reaction models as well as in practical applications. The isomeric cross-section ratio (ICR) is expressed as relative population of isomeric state to the total cross section for the channel. The spin distribution of the compound system is dependent on the angular momentum brought in by the projectile that changes with its energy and also on that carried away by the ejectiles [1,2]. The study of ICR gives 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. Satheesh *et al* [3,4] reported that ICR found to depend on the magnitude of spins of the ground and isomeric states, 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. Various theoretical models give different representation of the reaction mechanism. Hence it is important to compare various reaction models.

In order to study the dependence of ICR on various parameters we studied the ICR for the formation of isomeric pairs 197Hgm,g produced through various channels viz. ^{197}Au(p,n), ^{198}Hg(n,2n) and ^{197}Au(d,2n). The spins of the ground and isomeric states respectively are 1/2- and 13/2+. The ground state($T_{1/2}$= 64.14 h) decay through electron capture while the 91.4% of isomeric state($T_{1/2}$= 23.8 h) decay through IT and 8.6% through electron capture. Further calculations are performed using two nuclear reaction codes, viz. EMPIRE [5] and TALYS [6], that are most commonly used for light ion induced nuclear reactions and the predictions are also compared. The ICRs thus calculated are shown in figures 1-3 respectively along with available literature data

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Nuclear Model calculation

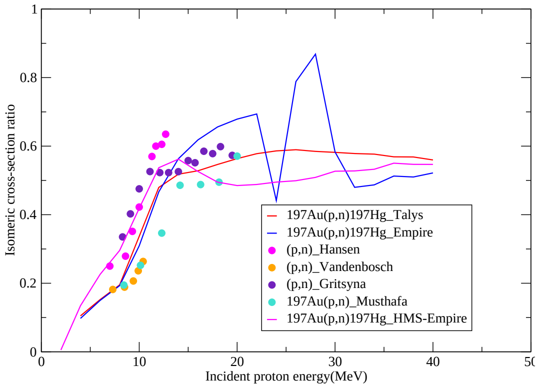
The cross-sections for the formation of ^{197}Hg^{g,m} through the reactions ^{197}Au(p,n), ^{197}Au(d,2n), and ^{198}Hg(n,2n) are calculated for incident particle energies from threshold upto 40 MeV using the nuclear reaction codes EMPIRE and TALYS.

TALYS calculations

The code TALYS uses optical model that is performed by ECIS-06 which uses DWBA for (near-)spherical nuclides, coupled-channels for deformed nuclides, the weak coupling model for odd nuclei, and also a giant resonance contribution in the continuum. Pre-equilibrium calculation based on Exciton model cover a sizable part of the reaction cross section for incident energies between 10 and (at least) 200 MeV.

EMPIRE calculation

The code accounts for the major nuclear reaction models, such as optical model, Coupled Channels and DWBA (ECIS06), Coupled Channels Soft-Rotator, Multi-step Direct, NVWY Multi-step Compound, Exciton model, hybrid Monte Carlo simulation, and the full featured Hauser-Feshbach model including the optical model for fission. A comprehensive library of input parameters based on the RIPL-3 library covers nuclear masses,



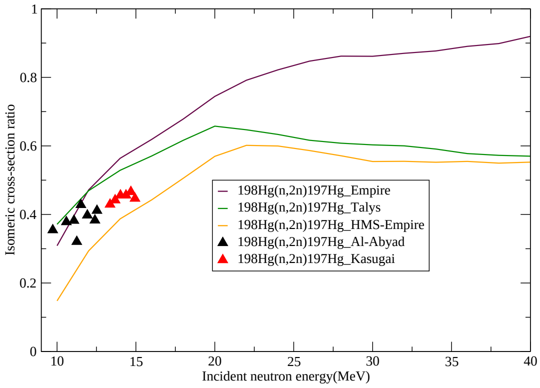


FIG. 2: ICR for ^{198}Hg(n,2n)^{197}Hg^{g,m}

optical model parameters, ground state deformations, discrete levels and decay schemes, level densities, fission barriers, and γ-ray strength functions.

Results and Discussions

From the above figures it can be seen that in general the predictions of Talys agee more or less satisfactorily with the experimental data. The Empire calculation with default set of parameters with Exciton model (MSD=0, MSC=0 PCROSS=1.5, HMS=0) overestimate ICR cosiderably in all the above cases. However calculation with Hybrid model reproduces the data satisfacorily for neucleon induced reactions. Further, it can be seen that ICR increses with incident paricle energy and

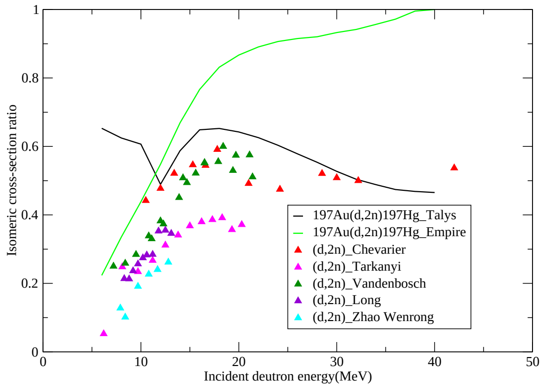


FIG. 3: ICR for ^{197}Au(d,2n)^{197}Hg^{g,m}

reaches saturation. This is because since the ground state being lower spin state will populate initially and as increase in energy can impart larger angular momentum and hence higher spin state start getting populated till an equilibrium is established between the levels. It can also be seen that the ICR increases sharply and reaches maximum earlier in the case of single particle emission whereas ICR increases slowly for multiparticle emission.

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