Experimental study of isomeric cross section ratio of $In^{115}(p,p')^{115m}In$ reaction at low energy

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Introduction

Nuclear reaction data is important in the field of research industries and medical sciences. Measurement of relative population of isomeric state of the nuclei in the reaction will provide information on transfer of energy and angular momentum as well as its dependence on various factors[1]. Relative population of the isomeric state is expressed as isomeric cross-section ratio defined as the ratio of formation cross section of the isomer of high isomeric state to the total production cross section ($\sigma m/(\sigma m + \sigma g)$). Previous report show that Isomeric cross section ratio dependence on nature of the input nuclei as well as the decay mode[2]. With a view to the study the nature of isomeric population of various nuclei we have measured the excitation function for the reaction $In^{115}(p,p')^{115m}In$ over the energy range 8-22 MeV. Isomeric cross-section ratio is analysed over this energy range using two statistical nuclear reaction codes EMPIRE-II and TALYS. Comparison of the performance of both codes is also done.

Analysis of the Data

Experiment has been performed at the Tata Institute of Fundamental Research Center (TIFR), Mumbai, India, employing stacked foil activation technique. A stack containing four foils of natural indium was irradiate with 22 MeV proton beam from pellatron accelerator. The thickness of the sample was ~13 mg/cm^2 and the beam current ~23 mA. The beam current was determined using both faraday cup coupled to the current integrator. The energy incident on each sample was calculated from the energy degradation of the sample as well as Al degraders sandwiched in the stack. The activity induced in the sample were followed using pre calibrated HPGe detector coupled to the PC based multichannel analyser. Detailed description of such measurement and error analysis is given elsewhere [3]. Excitation function thus measured for the above reaction is shown in figure.1.

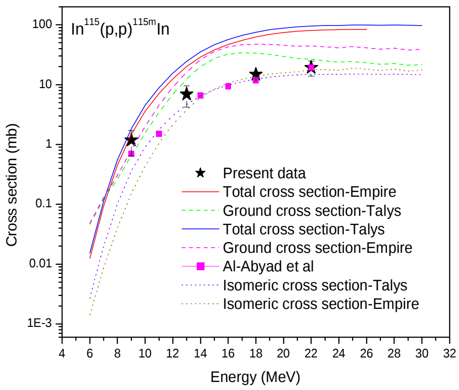

Fig.1 Excitation function for $In^{115}(p,p')^{115m}In$ reaction.

Theoretical analysis of the data has been performed using the nuclear reaction codes EMPIRE-II and TALYS. The code EMPIRE [4] make use of Hauser feshbach model for accounting compound nuclear modes and the NVWY model based on MSD-MSC (Multi Step Direct-Multi Step Compound) approach and exciton model for pre-equilibrium(PE) modes of decay. Provisions is aslo available to accommodate various PE models. The code TALYS [5] includes Hauser-Feshbach formalism including width fluctuation correction (WFC) for compoud nucleus. We generally use an effective level density model,ie., all collective enhancement are included in the level density parameters and two component exciton model with generalization of multiple pre-equilibrium processes.

Result and Discussion

Excitation functions for the reaction $In^{115}(p,p)In^{115m}$ calculated and are compared with the result using EMPIRE-II and TALYS as well as with the literature experimental data are plotted in fig.1. We present cross section data for the production of the isomeric state decaying overwhelmingly (IT=95 %) by internal transition to the ground state. In the investigated energy range the $In^{115}(p,p)^{115m}In$ reaction is the only contributing reaction. Theoretical analysis has been done using two computer codes EMPIRE-II and TALYS, that takes into account the pre-equilibrium emission, over the energy range from threshold to 30 MeV. Both the models more or less reproduce the data satisfactorly over the measured range. However calculations using EMPIRE-II with parameters specific level density- 1 and exciton model with default 1.5 MFP(Mean Free Path) better reproduces the experimental data. Data reported by Al-Abyad [6] also better matches with the EMPIRE-II.
Isomeric cross section ratio for this reaction has been deducted from the theoretical calculations, using parameters set that best matches the experimental data over the measured energy range, using both the codes and are plotted in figure.2.

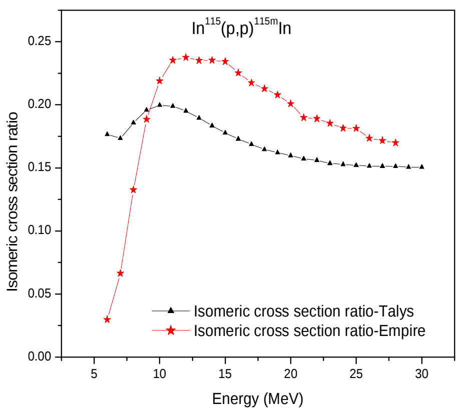

Fig.2. Isomeric cross-section ratio for $In^{115}(p,p')$ ^{115m}In reaction.

It is seen that the isomeric cross-section shows an initial shootup of higher energy state with lower spin up to 10 MeV in the incident channel and shows the reverse trend with a tendancy to populate more and more the state with higher spin (9/2+) even being the ground state. This is in tune with our previous observations[1&7]. Though both the models predict similar trend for isomeric cross section ratio, calculations with EMPIRE-II predicts relatively higher population of isomeric spin state (½⁻) than TALYS. Since the excitation functions calculated using EMPIRE-II better reproduces the measured data this prediction seems to be more dependable.

Conclusion

Proton induced reactions on ^{nat}In were studied over the energy range from 8-22 Mev and the excitation function of the product ^{115m}In was validated using the nuclear model calculation. The isomeric cross-section ratio for the isomeric pair ^{115m}In is described well using the EMPIRE-II and TALYS calculational codes.

Acknowledgments

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