Study of isomeric cross section ratios in proton induced nuclear reactions on ^{197}Au.

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Introduction

As a part of continuous program of systematic study of progress of nuclear reactions at low and intermediate energies and its dependence on various factors we have analyzed the isomeric cross section ratios (ICR) for the production of nuclei ^{197m,g}Hg, ^{195m,g}Hg and ^{193m,g}Hg produced in the reactions ^{197}Au(p,n),^{197}Au(p,3n) and ^{181}Ta(^{16}O,p3n) respectively over the energy range from 0 - 40 MeV for proton and 76 - 99 MeV for heavy ion induced reactions . Qaim et al [1] and 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. Experimentally measured cross-sections

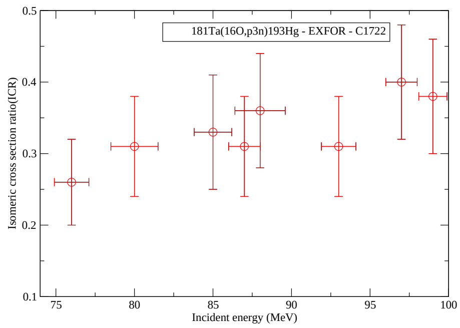

FIG. 1: The experimentally measured isomeric cross section ratios(ICR) for the isomeric pairs ^{197m,g}Hg produced in the reactions ^{181}Ta(^{16}O,p3n).

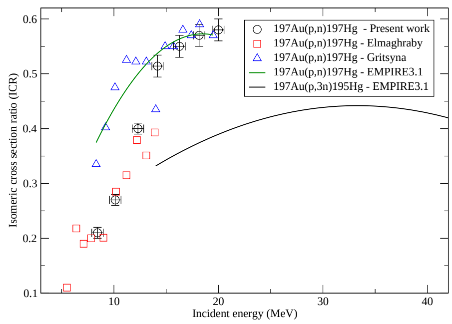

FIG. 2: The experimentally measured and theoretically calculated isomeric cross section ratios(ICR) for the isomeric pairs ^{197m,g}Hg and ^{195m,g}Hg produced in the reactions ^{197}Au(p,n) and ^{197}Au(p,3n).

TABLE I: Spins of the relevant states of the isomeric nuclide's of interest

Nuclide	Ground state		Isomeric state			Intermediate state		
	Jπ	$T_{1/2}$	MeV	Jπ	$T_{1/2}$	MeV	Jπ	$T_{1/2}$
^{193}Hg	$3/2^-$	4 h	0.1410	$13/2^+$	11 h	0.03949	$5/2^-$	0.63 ns
^{195}Hg	$1/2^-$	10 h	0.1760	$13/2^+$	41 h	0.03709	$3/2^-$	
						0.05330	$5/2^-$	0.72 ns
^{197}Hg	$1/2^-$	64.1 h	0.2989	$13/2^+$	23.8 h	0.1339	$5/2^-$	7.0 ns
						0.1522	$3/2^-$	

for the reactions ^{197}Au(p,n)^{197g,m}Hg over the energy range 8 to 20 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 Gold samples of thick-

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TABLE II: Decay mode of the isomeric nuclide's of interest

Reaction	Nuclide	Decay mode
		Isomeric state
^{197}Au(p,n)	^{197}Hg	IT 91.4%, ε 8.6%
^{197}Au(p,3n)	^{195}Hg	IT 54.2%, ε 45.8%
^{181}Ta(16O,p3n)	^{193}Hg	IT, ε <0.05%

ness 3.32 mg/cm^2, were prepared by rolling method. A stack of nine such samples were irradiated using diffused beam of proton of energy 20 MeV, with a beam current of 100 nA, for 12 h. Suitable thickness of Aluminum degrader's were introduced between the samples to have desired energy falling on each sample in 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 to determined the geometry dependent efficiency of the detector at various gamma energies. The isomeric cross-section ratios were calculated for the ^{197}Au(p,n)^{197g,m}Hg and ^{197}Au(p,3n)^{195g,m}Hg reactions using the EMPIRE-II (version 3.1 Rivoli) code developed by Herman et al. [3]. This code makes use of the Hauser-Feshbach model (including the width fluctuation correction (HRTW)) for the statistical part and the exciton model for the pre-compound part of a nuclear reaction. For input parameters, the standard library was used. The particle transmission coefficients for both the exciton and Hauser-Feshbach formalisms were generated via the spherical optical model using the computer code SCAT2 and a set of global parameters: for neutrons and protons of Koning and Delaroche, and for alpha particles of McFadden and Satchler. For calculations on the reactions ^{197}Au(p,n)^{197g,m}Hg and ^{197}Au(p,3n)^{195g,m}Hg reactions the HF+MSC+MSD model as well as the HF+DEGAS exciton model with angular momentum conservation and gamma emission, were used. For the level densities, the dynamic approach of the EMPIRE-II was applied with the formalism of the super fluid model (BCS) below the critical excitation energies, and the Fermi gas model above the critical energy. In this paper we report the study of the dependence of ICR on various factors as mentioned above as well as other factors.

2. Results and discussion

The relative production probability is expressed as isomeric cross section ratio defined as the ratio of the formation cross section of the isomers of high isomeric state to the total production cross section $\sigma_m/(\sigma_m + \sigma_g)$. The ICR thus calculated for the production of ^{197}Hg, ^{195}Hg and ^{193}Hg nuclei are determined at various incident energies and are plotted in Fig.1. along with the available experimental data. In order to study the energy dependence of ICR on beam energy, the ICR for the residues ^{193}Hg(p3n) have been plotted in Fig. 2. It may be noted from the Fig. 2, that the ICR increases with energy. It and hence increased population of isomeric states in the nuclei ^{193}Hg as compared to ground state population. Table 1 and 2 shows spins and decay mode of the relevant states of the isomeric nuclide's of interest. At relatively larger energies the system is seems to prefer higher spin states rather than the excitation energy available for the system as is indicated by relative population of the above nuclei. In general it can be seen that the isomeric cross section ratio increases with incident energy in the cases were the isomeric spin is larger than the ground state spin. the energy of the incident particle increases the state with lower spin get populated initially and thereafter the population of higher spin state getting more and more populated and finally reaches an equilibration between the states. The details will be presented.

References

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