A theoretical study on Isomeric cross section ratio for ^{116,118}Sb formed through different reaction channels

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Introduction

The study of isomeric cross section ratio (ICR) in nuclear reactions 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. Qaim *et al* [1] and Satheesh *et al* [2] found that ICR critically depends on the spins of ground state and isomeric state as well as the incident energy. Satheesh *et al* [3] indicated that ICR strongly depends 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. The ICR shows smooth behavior when decays through electron capture.

From this background, we have studied the ICR for the isomeric pairs ^{116,118}Sb^{g,m} produced through various channels over the energies from threshold up to 40 MeV using the nuclear reaction code EMPIRE 3.1[4]. The experimental data available from the literature are used for checking the validity of theoretical predictions.

Model Calculation

The ICRs for the isomeric pairs ^{116,118}Sb^{g,m} produced through the reactions ^{116}Sn(p,n)^{116}Sb, ^{117}Sn(p,2n)^{116}Sb, ^{113}In(α,n)^{116}Sb, ^{115}In(α,3n)^{116}Sb, ^{116}Sn(d,2n)^{116}Sb, ^{118}Sn(p,n)^{118}Sb, ^{119}Sn(p,2n)^{118}Sb, ^{115}In(α,n)^{118}Sb, ^{116}Sn(α,pn)^{118}Sb, ^{118}Sn(d,2n)^{118}Sb are calculated using the nuclear reaction code EMPIRE 3.1 which makes use of the Hauser-Feshbach and the exciton model formalisms. Hauser-Feshbach formalism helps in calculating the ground and isomeric cross sections seperately. The code accounts for the major nuclear reaction models, such as optical model, Coupled Channels and DWBA (ECIS06), Coupled Channels Soft-Rotator (OPTMAN), Multi-step Direct (ORION + TRISTAN), NVWY Multi-step Compound, Exciton model PCROSS, hybrid Monte Carlo simulation (DDHMS), and the full featured Hauser-Feshbach model including the optical model for fission. Heavy ion fusion cross section can be calculated with the simplified coupled channels approach (CCFUS). A comprehensive library of input parameters based on the RIPL-3 covers nuclear masses, optical model parameters, ground state deformations, discrete levels and decay schemes, level densities, fission barriers and γ-ray strength functions. Theoretical calculations are compared with the available experimental data.

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Results and Discussion

The ICRs thus calculated for the production of ^{116,118}Sb^{g,m} nuclei produced through various reaction channels are determined for incident energy ranges from threshold up to 40 MeV and are plotted in Fig.1. along with the available experimental data. The spins of the target, ground and isomeric states of residual nucleus, and the possible values of ΔL for each reaction are tabulated in Table.1. From the Fig.1(a), it can be found that ICR for the (α,n) and (α,3n) reactions increases sharply with the incident energy while that for other reactions increases slowly. In the Fig.1(b), for (α,n) reaction ICR increases sharply but for other reactions it shows slow increase. From the Table.1, it can be seen that for the cases where ΔL is small, ICR increases sharply and vice versa. This indicates that when the emitted particle carries larger angular momentum, the higher spin isomer is slowly populated. However, multiparticle emission is expected to carry away larger angular momentum. This effect could not be explicitly observed. More amount of experimental data is required to verify this fact.

The ICR for the production of ^{116}Sb^{g,m} and

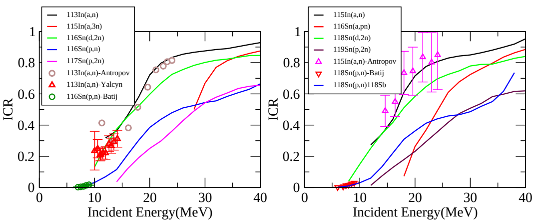

FIG. 1: Isomeric cross section for (a)^{116}Sb (b) ^{118}Sb produced through various channels

TABLE I: Spins of target and residual nucleus and also the possible vaues of ΔL

Reaction	Spin		Possible ΔL
	Target	Res. nucl	
^{116}Sn(p,n)^{116}Sb	0^+	3^+, 8^-	7,8
^{117}Sn(p,2n)^{116}Sb	$1/2^+$	3^+, 8^-	6,7,8,9
^{113}In(α,n)^{116}Sb	$9/2^+$	3^+, 8^-	3,4
^{115}In(α,3n)^{116}Sb	$9/2^+$	3^+, 8^-	2,3,4,5
^{116}Sn(d,2n)^{116}Sb	0^+	3^+, 8^-	6,7,8,9
^{118}Sn(p,n)^{118}Sb	0^+	1^+, 8^-	7,8
^{119}Sn(p,2n)^{118}Sb	$1/2^+$	1^+, 8^-	6,7,8,9
^{115}In(α,n)^{118}Sb	$9/2^+$	1^+, 8^-	3,4
^{116}Sn(α,pn)^{118}Sb	0^+	1^+, 8^-	7,8,9
^{118}Sn(d,2n)^{118}Sb	0^+	1^+, 8^-	6,7,8,9

^{118}Sb^{g,m} produced through similar channels are plotted in the Fig.2. Eventhough the spins of isomeric pairs are different for ^{116}Sb^{g,m} and ^{118}Sb^{g,m}, both of them show identical behavior of ICR with incident energy and relative spin. This means that isomeric cross-section ratio has no direct dependence on the magnitude of spin states or spin difference between the isomeric pairs. The general trend of ICR, increasing with the incident energy in the biginning and then getting saturated for the pairs with higher isomeric spin as indicated by Satheesh *et al*[2], is observed for these cases also.

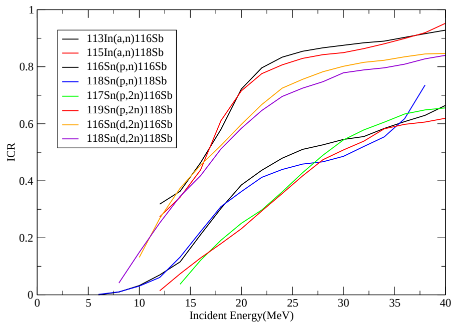

FIG. 2: Isomeric cross section ratio of ^{116}Sb and ^{118}Sb produced through similar channels

Conclusion

It is found that the isomeric cross-section ratio critically depends on the spins of ground state and isomeric state as well as the incident energy. At extremely low energy, the ground state is preferentially populated irrespective of the spin state. As the energy increases, the higher spin state gets more populated. The ICR increases slowly for the cases in which excess angular momentum carried away by the emitted particle is large and it increases sharply when ΔL is smaller. However, there is no direct observable relationship between the spin difference of the isomeric pairs and ICR values.

References

[1] S. M. Qaim, S. Sudar, and A. Fessler, Radiochim. Acta., **93**(2005)503 - 506.
[2] B. Satheesh, M. M. Musthafa, Int. J. Mod. Phys. E**20**(2011)21192131.
[3] B. Satheesh, M. Musthafa, B.P. Singh, R. Prasad, Int. J.Mod. Phys. E**21**(2012)1250059.
[4] M. Herman, Empire 3.1 Rivoli , Modular system for nuclear reaction calculations and nuclear data evaluation, NEA Data Bank,(2012).