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Cross section calculation in ^{76}Ge(^{11}B,X) Reaction

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Abstract: Theoretical cross section calculation for the reaction in ^{76}Ge(^{11}B,X) is carried out from 45 MeV to 55 MeV using the code PACE 4 (A monte carlo simulation) for the first time . These calculation shows that the 4n channel cross section is the most dominating among all outgoing evaporation residue. This finding is also experimentally verified with the same reaction with similar energy by the present experimental group.

Keywords — Heavy ion reactions, gamma ray production, compound nucleus,excitation function ,cross section, complete fusion.

I. INTRODUCTION

The gamma rays produced by bombarding medium mass target nuclei with accelerated beam carry important nuclear structural information. It also provides nuclear data for different applications like medical radioisotopes production or reactors design. The information on the excitation functions (i.e the variation of cross section of the residual nuclei with excitation energy) of residual nuclei are also important for testing statistical model calculation like PACE4 [1] or CASCADE[2] in order to understand the reaction mechanism and to estimate the radionuclide impurities in a compound target. In heavy-ion fusion reactions many studies concentrated on the energy, angular momentum and charge distribution of reactions products and considerable interest was given to the study of complete fusion (CF) and incomplete fusion (ICF) which are the dominant reaction mechanisms [3]. In complete fusion reaction process of the projectile with the target, the highly excited nuclear system decays by evaporation of low energy nucleons and alpha particles during thermalization at the equilibrium stage while in the incomplete fusion a part of the projectile fuses with the target nucleus and the remaining part moves in the forward direction at almost the same velocity but with an incomplete linear momentum transfer [4]. In this paper our aim is to estimate the cross section of the different evaporation residue produced in the Complete Fusion (CF) reaction ^{76}Ge+^{11}B from 45 MeV to 55 MeV using the computer code PACE4[1] which is based on the Monte Carlo simulation.

II. PACE4 FORMALISM

The statistical model code Projection Angular Momentum Coupled Evaporation (PACE) [1] is a modified version of JULIAN [5], the Hillman–Eyal evaporation code using a Monte Carlo code coupling angular momentum. It uses Monte Carlo procedure to determine the decay sequence of an excited nucleus using the Hauser Feshbach formalism. The code assumes the reaction to occur in two steps, first the formation of compound nucleus and then the statistical decay of the equilibrated system so it does not consider the possibility of incomplete fusion (ICF) nor the pre-equilibrium emission of nucleons from the composite system. The main advantage of Monte Carlo calculations is to provide correlations between various quantities, such as particles and gamma-rays or angular distribution of particles. A random number selection determines the actual final state to which the nucleus decays to and the process is, then, repeated for other cascades until all the nuclei reach the ground state. The light particle emission (n, p, α) transmission coefficient were determined using optical model potentials [6,7].Evaporation residual cross section is primarily depends on 1) The ratio of level densities at the saddle point and at the ground state.2) The height of the fission barrier which in turn depends on its spin. According to the PACE calculations, the lower energy part of the light charge particle are controlled by the transmission coefficients. On the other hand, the high energy part of the spectra depends on level density parameter at high spin.

The level density (number of levels per unit energy at certain excitation energy) ρ(E,J) used in the calculation above ~5MeV is given by the relation

$$\rho(E,J)=\rho_0(U)(2J+1)\exp\{2[a(U-E_{rot}(J))]^{\frac{1}{2}}\}$$

where U= E-P and P is the pairing energy. J is the spin. $E_{rot}(J)$ which is the rotational energy for a particular spin is obtained using Ref. [8]; $\rho_0(U)$ was taken from the Gilbert and Cameron formalism [9]. The partial cross-section for Compound Nucleus formation at angular momentum (l) and a particular bombarding energy is given by $\sigma_l=\frac{\pi\lambda^2}{4\pi^2}(2l+1)T_l$. Here λis the wavelength and T_l is the transmission coefficient is given by $T_l=[1+\exp(\frac{l-l_{max}}{\Delta})]^{-1}$ where Δ is the diffuseness parameter and l_{max} (the maximum angular momentum) is governed by total fusion cross section σ_F. The σ_F is equal

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to $\sigma_F = \sum_{l=0}^{\infty} \sigma_l$.

III. CROSS SECTION CALCULATION USING PACE4

The Coulomb barrier-value calculated in the laboratory system for the ^{76}Ge(^{11}B,X) reaction is 22 MeV. The calculation is done high above the coulomb barrier i.e from 45 to 55 MeV. The results are obtained in the tabular form below (Table 1).Here we assume the level density parameter as 10 which is taken from the systematics.

Table-1

Energy (MeV)	Total cross section (□) (mb)	Maximum yrast spin
45	1169.73	54 $\hbar$
47	1221.95	55 $\hbar$
50	1289.45	56 $\hbar$
53	1345.7	57 $\hbar$
55	1377.85	58 $\hbar$

The individual dominant cross section channel of the evaporation residue is also calculated with the beam energy from 45 MeV to 55 MeV and is represented in the Table 2

Table 2

Energy (MeV)	Nuclei populated	The outgoing channel	Cross section(mb)
45	^{84}Rb	3n	127
	^{83}Rb	4n	664
	^{83}Kr	p3n	221
	^{84}Kr	p2n	50
47	^{84}Rb	3n	83.1
	^{83}Rb	4n	731
	^{83}Kr	p3n	253
	^{80}Br	□3n	53.8
50	^{84}Rb	3n	59.3
	^{83}Rb	4n	648
	^{83}Kr	p3n	276
	^{82}Rb	5n	113
	^{80}Br	□3n	95.4
53	^{83}Rb	4n	537
	^{83}Kr	p3n	245
	^{82}Rb	5n	258
	^{82}Kr	p4n	129
	^{80}Br	□3n	80.7
55	^{83}Rb	4n	463
	^{83}Kr	p3n	198
	^{82}Rb	5n	358
	^{82}Kr	p4n	129
	^{80}Br	□3n	107

From the calculation it is evident that the 4n channel cross section is dominating in the energy range from 45 MeV to 55 MeV. This reaction was utilized experimentally to find the structural information in ^{83}Rb (4n) [10] and ^{83}Kr (p3n) [11] and ^{82,84}Rb. No experimental result is found for the calculation of cross section in the reaction ^{76}Ge+^{11}B from energy range 45-55 MeV. Further investigation is required to calculate experimentally the reaction cross section of different dominant channel produced in the aforesaid reaction.cross section is dominating in the energy range from 45 MeV to 55 MeV. This reaction was utilized experimentally to find the structural information in ^{83}Rb (4n) [10] and ^{83}Kr (p3n) [11] and ^{82,84}Rb. No experimental result is found for the calculation of cross section in the reaction ^{76}Ge+^{11}B from energy range 45-55 MeV. Further investigation is required to calculate experimentally the reaction cross section of different dominant channel produced in the aforesaid reaction.

IV. CONCLUSION

The theoretical cross section has been measured for ^{76}Ge(^{11}B,X) reaction from 45 MeV to 55 MeV using Monte Carlo simulation code PACE4. These calculation shows the enhancement of 4n channel cross section(^{83}Rb) (see Table 2). Previously the structure of ^{83}Rb studied in same reaction by the present group [10] with the excitation energy of 50 MeV. So the theoretical calculation predicted by the present calculation also verified by the experiment.

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