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

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ABSTRACT

Theoretical cross section calculation for the reaction in $^{76}\text{Ge}(^{11}\text{B},\text{X})$ is carried out from 45 MeV to 55 MeV using the code PACE 4 for the first time. This 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 energies.

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

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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 PACE4¹ or CASCADE² 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 mechanisms³. 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 the realization 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 transfer⁴. In this paper our aim is to estimate the cross section of the different evaporation residue produced in the Complete Fusion (CF) reaction $^{76}\text{Ge}+^{11}\text{B}$ from 45 MeV to 55 MeV using the computer code PACE4¹ which is based on the Monte Carlo simulation.

PACE4 formalism

The statistical model code Projection Angular Momentum Coupled Evaporation (PACE)¹ is a modified version of JULIAN⁵, 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.

The level density parameter $\rho(E, J)$ used in the calculation above ~ 5 MeV is given by the relation $\rho(E, J) = \rho_0(U)(2J + 1) \exp\{2[a(U - E_{rot}(J))]^2\}^{\frac{1}{2}}$ where $U = E - P$ and P is the pairing energy. $E_{rot}(J)$ is obtained using Ref. [8]; $\rho_0(U)$ was taken from the Gilbert and Cameron formalism [9]. The partial cross-section for CN 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 λ is 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} is governed by total fusion cross section σ_F . The σ_F is equal to $\sigma_F = \sum_{l=0}^{\infty} \sigma_l$.

Cross section Calculation using PACE4

The Coulomb barrier-value calculated in the laboratory system for the $^{76}\text{Ge}(^{11}\text{B}, \text{X})$ 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 systematic.

Table-1

Energy (MeV)	Total cross section (σ) (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 Tables

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	\square 3n	53.8
50	^{84}Rb	3n	59.3
	^{83}Rb	4n	648
	^{83}Kr	p3n	276
	^{82}Rb	5n	113
	^{80}Br	\square 3n	95.4
53	^{83}Rb	4n	537
	^{83}Kr	p3n	245
	^{82}Rb	5n	258
	^{82}Kr	p4n	129
	^{80}Br	\square 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 ⁸³Rb (4n)¹⁰ and ⁸³Kr (p3n)¹¹ and ^{82,84}Rb. No experimental result is found for the calculation of cross section in the reaction ⁷⁶Ge+¹¹B 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.

REFERENCE:

1. A. Gavron, *Statistical model calculations in heavy ion reactions*, Physical Revue C, 01/1980; **21**(1): 230–236
2. F. Pulhofer, Nuclear Physics A, 1977; **280**; 267
3. P.E. Hodgson, E. Gadioli, E. Ggadioli Erba, *Introductory Nuclear Physics* (Oxford Science Publications, New York, 1997
4. L.F. Canto, R. Donangelo, Lia M. de Matos, M.S. Hussein, P. Lotti, *Complete and incomplete fusion in heavy ion collisions*, Physical Revue C, 1998; 58(2): 1107–1117
5. M. Hillman and Y. Eyal (Unpublished).
6. C. M. Perey and F. G. Perey, Atomic Nucl. Data Tables 1976; 17(1)
7. J. R. Huizenga and G. Igo, Nucl. Phys. 1962 ; **29**: 462
8. Subroutine FISROT, F. Plasil, Oak Ridge National Laboratory
9. A. Gilbert and A. G. W. Cameron, Can. J. Phys. 1965; 43: 1446
10. S. Ganguly, P. Banerjee, I. Ray, R. Kshetri, S. Bhattacharya ,M. Saha-Sarkar, A. Goswami, S. Muralithar, R.P. Singh,R. Kumar R.K. Bhowmik, Nucl.Phys A 2006; 43: 768
11. S. Ganguly · Aparajita Dey · P. Banerjee, S. Bhattacharya · R. P. Singh, S. Muralithar,., Kumar , R. K. Bhowmik, Brazilian Journal of Physics 2011; 41: 135