Identification of residues in $^{19}F+^{165}Ho$ system at energies near the Coulomb barrier

Unnati Gupta[1*], Abhishek Yadav[1], Arshiya Sood[2], M. Kaushik[2], Pushpendra P. Singh[2], D. P. Singh[3], Indu Bala[4] , Suresh Kumar[5] and Alpana Goel[1]

[1]*Amity Institute of Nuclear Science and Technology, Amity University Uttar Pradesh-Noida,201313-India*
[2]*Department of Physics, Indian Institute of Technology Ropar, Rupnagar, Punjab-140 001, India*
[3]*Department of Physics, University of Petroleum & Energy Studies, Dehradoon-248 007, India*
[4]*NP Group: Inter University Accelerator Centre, New Delhi - 110 067, India*
[5]*Department of Physics and Astrophysics, University of Delhi, Delhi-110007, India*
Corresponding author:**ugupta@amity.edu*

Introduction:

In recent years the study low-energy (near the Coulomb barrier energies) incomplete fusion (ICF) reactions are of current research due to their presence at such low energies, also the ambiguous dependence of ICF fraction, which is the measurement of ICF contribution to the total fusion cross-section, on various entrance channel parameters [1]. Fusion occurs when the effective two-body potential has a "fusion pocket" that can trap the system, and around the Coulomb barrier energy complete fusion (CF) dominates in medium-mass systems, where the projectile merges with the target nucleus in central or near-central collisions, influenced by nuclear forces (angular momentum window: $0 < \ell < \ell_{crit}$). At higher energies or peripheral collisions, repulsive Coulomb and centrifugal forces prevent CF, leading to ICF, where the projectile breaks up, and one fragment fuses with the target, while others continue along the beam path. During the past decade several dependencies of ICF reactions on incident energy, linear momentum, angular momentum, Coulomb factor (Z_PZ_T), alpha-Q-value, system parameter, etc. have been presented, as well as several theoretical models have been proposed. It is not out of place to mention that to date there is no theoretical model available which can satisfactorily reproduce the low-energy ICF reaction data. Hence, the study of low-energy ICF reactions and its dependence on various entrance channel parameters is of great interest and importance. In the present work, a non-alpha clustered ^{19}F beam has been used to study the low-energy ICF reactions with ^{165}Ho target, as the data with non-alpha clustered beam are scarce.

Experimental Details:

In the present experiment the interaction of ^{19}F with^{165}Ho, forming a compound nucleus ^{184}Os, have been investigated. The experiment was performed using General Purpose Scattering chamber (GPSC) beam line of the Inter-University Accelerators Centre (IUAC), New Delhi, India. The targets of ^{165}Ho having a thickness ~1.5-3 mg/cm^2 were used for the irradiations and prepared by the rolling methods. The thicknesses were measured using alpha transmission method. The Aluminum degraders were also prepared by rolling methods and like the targets, the thicknesses were measured by the same method. The target and degraders arranged in the GPSC at 90^0 of the beam direction. These targets were irradiated using $^{19}F^{7+/8+}$ beams of current ~ 20-40 nA and energies ~95, 97, 104, 102 and 112 MeV. These targets of ^{165}Ho were backed by Aluminum foils of different thicknesses, to serve as catchers as well as energy degraders. In the present work, the residual nuclei populated via C/F/ICF may be decayed by neutron, proton and/or gamma-ray emission. Fission is also a possible mode of decay. The residues populated in the interaction of the above-mentioned reaction are identified by the characteristic gamma rays and their corresponding half-lives. To record the gamma-ray emission a High Purity Germanium (HPGe) detector supplied by CANNBERA was used. The detector's resolution was 1.7 keV and 2.0 keV at gamma-ray energies 661.66 keV of ^{137}Cs and 1.33MeV of ^{60}Co, respectively. The energy calibration was done using standard radioactive gamma sources viz., ^{60}Co, ^{133}Ba, ^{137}Cs, and ^{152}Eu. A calibration curve is shown in Fig. 1, depicts the linear response of the detector. The spectra were recorded for 18 *m* for ^{152}Eu and 30 *m* for the rest of the standard gamma sources was kept 4.2 cm far from the detector. Further, the efficiency of the detector was determined using the above cited standard sources, which is defined as the ratio of gamma rays detected to that of the gamma rays emitted by the source at the time of measurement, the efficiency curve is shown in Fig. 2. To determine the efficiency, the dead time of the detector and a subtraction of the background was also considered. For the identification of residues, recorded spectra were analyzed using the software CANDLE (Collection and Analysis of Nuclear Data using Linux nEtwork) [2] developed by the IUAC, New Delhi.

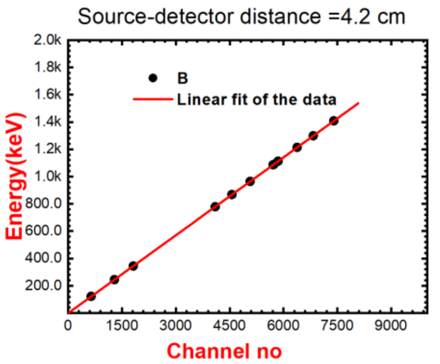

Fig.1 Calibration of the HPGe detector done using the ^{152}Eu Standard gamma source**.**

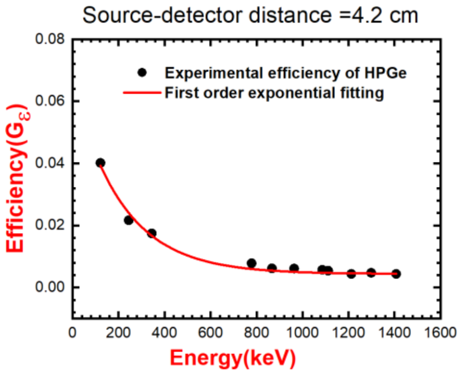

Fig.2 Efficiency of the HPGe detector determined using the standard gamma source ^{152}Eu**.**

Further, ^{179}Os, ^{178,179}Re, and ^{178,182m}Ta, residues are identified by their gamma ray energies and confirmed by plotting the half-lives [3]. A list of identified residues at different energies is given below.

Result and Discussion

The 10 residues are identified with characteristics gamma ray energies and measured half-lives. The identified residues along with the gamma rays, half-lives and branching ratios are listed in the Table 1. As a representative case, the half-life of the ^{178}Re is plotted in Fig.3. The measured half live is extraction from the graph and compared with the literature. It is observed the measures half-life is in agreement with the half-life reported in the literature[3]. For the determination of excitation functions above mentioned energies are used and compared with the statistical model PACE4[4] based on Hauser-Feshbach formulation of compound nucleus. The detailed analysis of the data is in the progress and will be presented during the symposium.

Table.1 The list of residues along with the half-lives, gamma rays and branching ratio.

S. N.	Residues	Half life	E_γ (*keV*)	I_γ (%)
1.	^{181}Os	105 *m*	238.75 827.0	44.0 19.19
2	^{178}Re	13.2 *m*	106.0 237.0	23.4 44.5
3	^{179}Re	19.5 *m*	289.9 430.24	27.0 28.1
4	^{182m}Ta	15.84 m	146.79 171.59	36 48
5	^{178m}Ta	9.31 *m*	93 .13 1350.55	6.6 1.18
6	^{178}Ta	2.36 *h*	325.36 426.36	94** 97 **
7	^{173}Hf	23.6 *h*	123.68 296.97	83** 33**
8	^{178m}Lu	23.1 *m*	426.36 325.6	97** 94.1**
9	^{178}Lu	28.4 *m*	93.2 1340.8	6 3.4
10	^{179}Yb	8.0 *m*	592.1 612.3	75** 36**

****Relative abundance**

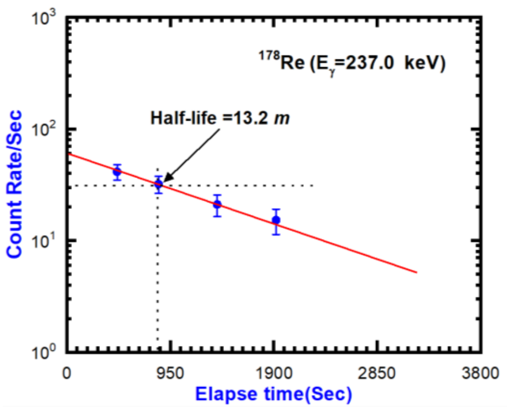

Fig. 3 Measured half life of the ^{178}Re (Eγ=237.0 keV) populated in the ^{19}F+^{165}Ho system at 104 MeV projectile energy.

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