$1n$ transfer followed by breakup of ^{9}Be in the field of ^{209}Bi

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1. Introduction

The experimental study on the cross sections for breakup of ^{9}Be (into $\alpha + \alpha + n$ with breakup threshold E_{th} = 1.57 MeV) is relatively much less explored compared to other weakly bound stable nuclei like ^{6,7}Li. One of the reasons is the complexity involved in detecting all the breakup fragments (2α and n) where one needs both charge particle as well as neutron detectors similar to Ref. [1]. A few measurements exist involving detection of only two α particles in coincidence. These α particles can either be produced in the process of $1n$ stripping transfer followed by breakup of ^{8}Be or by direct breakup into $\alpha+\alpha+n$. Rafiei *et al.* have made such measurements to understand the reaction mechanism and systematics of breakup of ^{9}Be scattered off ^{209}Bi, ^{208}Pb, ^{196}Pt, ^{186}W, ^{168}Er, and ^{144}Sm [2]. However, none of these studies provides absolute experimental cross sections for any of the projectile breakup modes. Also, a simultaneous explanation of the breakup cross section along with elastic and other important outgoing channels, which is very important to understand the complete reaction mechanism, is not available. With these things in mind, we have carried out both exclusive and inclusive measurements of angular distributions for elastic and inelastic scattering and 2α breakup cross sections for ^{9}Be + ^{209}Bi system at a beam energy of 47 MeV. In this paper, the results of the experimental cross sections and the coupled channels calculations are presented.

2. Data Analysis & Results

The experimental data was obtained using the setup as described in Ref. [3]. The present work focuses on the analysis of the detected 2α events produced in the breakup of the projectile and understand the reaction mechanisms for the production of these events. By constructing a two dimensional plot of Q-value versus relative energy for all the two-α events, as shown in Fig.1, the possible production processes have been identified as done in Ref. [2]. The Q-value has been calculated assuming a neutron being transferred to the target and only two α particles and the recoil ^{210}Bi are in the outgoing channel, i.e., ^{209}Bi(^{9}Be, ^{8}Be$\rightarrow 2\alpha$)^{210}Bi reaction. The Q-value ($E_{\rm rel}$) distribution provides information on target (projectile) excitations. For the events where a neutron is also emitted along with two alpha particles, the calculated Q-values may not be proper. However, one can carefully select the regions (1 & 2, above the black solid line) in the 2D plot to identify the pure (^{9}Be, ^{8}Be$\rightarrow 2\alpha$) events. The dashed line corresponds to the optimum Q-value (=-0.35 MeV) around which an intense band of events is observed as expected from theory, thus confirming them to be produced in $1n$ transfer reaction. A solid line below this band separates the above transfer events from the regions 3 & 4 lying below where the contribution from other sources like breakup of ^{9}Be $\rightarrow \alpha + \alpha + n$ through ^{8}Be$_{\rm gs}$ and ^{8}Be*, respec-

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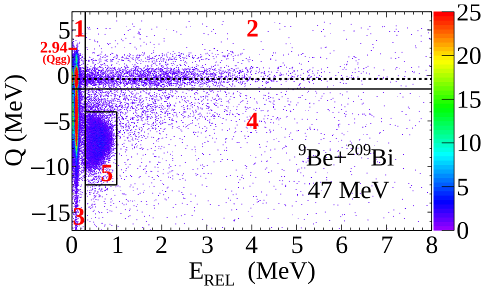

FIG. 1: Q-value versus relative energy spectrum generated from the coincident 2α events, which is divided into 5 regions based on different reaction processes (see text).

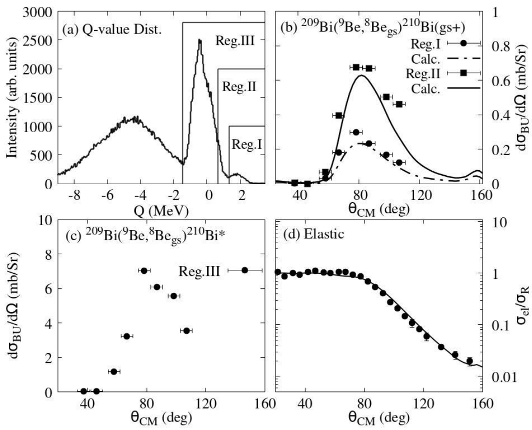

FIG. 2: (a) 1D projection on Q-value distribution of Region 1 of Fig. 2 corresponding to ^{209}Bi(^{9}Be, ^{8}Be$_{gs}$ $\to 2\alpha$)^{210}Bi* reaction (b) Experimental & theoretical cross sections for the above reaction corresponding to Region I and II, c) Experimental cross sections for Region III and (d) Ratio of elastic to Rutherford scattering angular distribution.

tively, may be possible. Events of region 5 is known to arise due to breakup of ^{9}Be(2.43 MeV,$\frac{5}{2}^{-}$)$\to$^{8}Be(2^{+}) $\to \alpha + \alpha$ [1].

The breakup events in Region 1, corresponding to the relative energy of 92 keV, shows a distribution of Q-value (Q_{gg} to $Q_{gg} -$ 4.6 MeV), as shown in Fig. 2(a). It implies that the $1n$ transfer reaction has populated different excited states of ^{210}Bi. The number of excited states being very large ($\approx$ 90) and very difficult to include all of them in CC calculations, the above Q-distribution has been attempted to understand in 3 steps by defining 3 different regions (I, II & III) corresponding to the excitations of the recoiled ^{210}Bi with $0 \leq E_x \leq 1.6$, $0 \leq E_x \leq 2.4$ and $0 \leq E_x \leq 4.6$ MeV respectively. By calculating the detection efficiencies for the respective regions, the experimental breakup cross sections for the ^{209}Bi(^{9}Be, ^{8}Be$_{gs}$ $\to 2\alpha$)^{210}Bi* reaction have been extracted and shown by circles and squares in Fig. 2(b) and circles in Fig. 2(c). The experimental cross section for elastic scattering, normalized to Rutherford scattering, is shown in Fig. 2(d).

3. Coupled channels calculations

Continuum Discretized Coupled Channels (CDCC) as well as Coupled Reaction Channels (CRC) calculations were carried out using FRESCO to understand the above experimental cross sections. For breakup coupling, an excitation of up to 5 MeV above the breakup threshold (1.67 MeV) of ^{9}Be with a cluster of n+^{8}Be was considered. The continuum was discretized in equal steps of momentum bins with $dk = 0.2$ fm^{-1}. For $1n$ transfer calculations 62 low lying states (up to excitation energy of 2.4 MeV) of ^{210}Bi were included. To constrain the potential and coupling parameters, a simultaneous description of elastic, transfer and breakup coupling has been attempted by including all these channels in a single coupled channels calculation. The calculated cross sections (represented by lines) for transfer and elastic channels have been compared that reasonably agree with the experimental cross sections in Fig. 2(b) & (d) respectively.

References

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