Inclusive breakup-α in ^{6}Li+^{209}Bi reaction

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Introduction

The reactions involving weakly bound projectiles are observed to have a large cross section for α produced by breakup and transfer reactions. Systematics made by different authors [1, 2] for ^{6}Li show that the inclusive breakup-α cross section follow a universal curve with respect to normalized energy ($E_{c.m.}/V_b$). It is surprising because both breakup and transfer are peripheral reactions whose cross sections are expected to increase with the size of the target nuclei. Besides, the transfer contributions that depend on the target structure could be quite different. So, it would be interesting to revisit this issue involving a different target (^{209}Bi).

In this contribution, the details of the inclusive measurements for ^{6}Li+^{209}Bi at energies around the Coulomb barrier and analyses are presented. The systematics of inclusive α production is discussed to investigate the target dependence and verify the universality behavior. Coupled channels (CC) calculations are made to unfold the reaction mechanism involved in the total α production.

Measurements and analyses

The experiment was performed using ^{6}Li beam from the BARC-TIFR 14-UD pelletron facility in Mumbai, a self-supporting target (^{209}Bi,$\sim$ 330 μg/cm^2), four ΔE-E telescopes and two monitors of Si surface barrier detectors. A broad ($\sim$ 9 MeV) but distinct alpha peak, with centroid equal to two-third of the projectile energy, is possibly due to the projectile breakup by either direct or sequential processes. From the yields under this peak, the angular distributions of the inclusive breakup alpha are extracted and shown in Fig. 1.

The angle integrated cross sections of inclusive breakup-α for the present system are shown as half-filled circles in Fig. 2. To test the universality of the alpha production involving same projectile (^{6}Li) from targets with different masses and atomic numbers (^{28}Si, ^{58}Ni, ^{118,120}Sn[1], ^{59}Co[3], ^{90}Zr[2], and ^{208}Pb[4, 5]), σ_α^{incl} has been plotted in Fig. 2 as a function of normalized energy ($E_{c.m.}/V_b$). It is interesting to see that cross sections for present system are higher and do not fall in the universal curve as claimed in Refs. [1, 2]. It shows distinct behavior corresponding to high (A$\sim$209) and medium (A$\sim$60-120) mass targets. The cross sections with low mass (A=28) have a tendency to be lower than the medium mass. Reason for the discrepancy in ^{208}Pb data lied in the value of Coulomb barrier (V_b) which was taken as 25 MeV[1] by previous papers. However, from the recent precision fusion measurements for ^{6}Li+^{209}Bi [6], a correct value of V_b = 29.7 MeV for ^{6}Li+^{208}Pb was estimated and used in the present analysis. As-

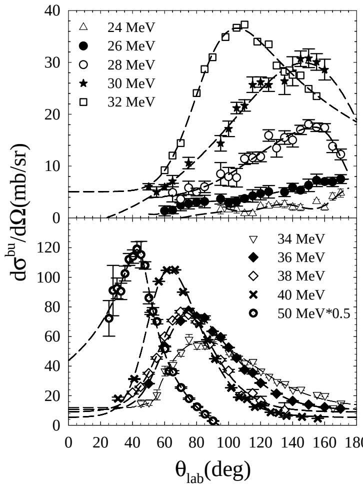

FIG. 1: Inclusive breakup α angular distribution for ^{6}Li+^{209}Bi at different energies E_{lab}=24-50 MeV. Lines are χ-square minimized fit to the data and used to obtain the angle integrated cross sections.

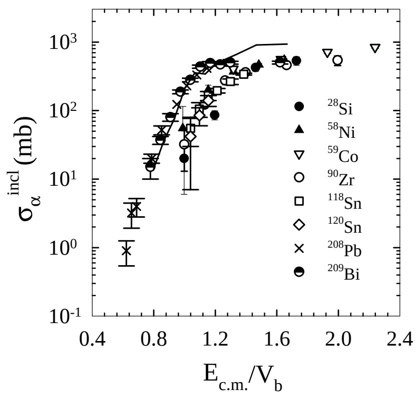

FIG. 2: Inclusive breakup alpha cross sections for different targets plotted as a function of energy normalized to Coulomb barrier. Solid line corresponds to the values of "$\sigma_R - \sigma_{CF}$".

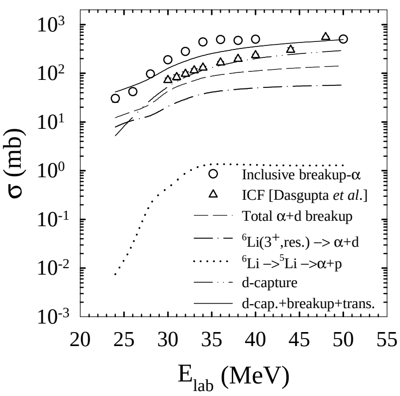

FIG. 3: Inclusive breakup alpha and contributions from different transfer and breakup channels (see text for details).

suming alpha production to be the dominant direct reaction mechanism, the difference of reaction cross section obtained from OM analysis and complete fusion data ($\sigma_R - \sigma_{CF}$) was calculated for ^{6}Li+^{209}Bi (solid line in Fig. 2) which also shows a similar trend and compares well with σ_α^{incl} data.

CC calculations and discussions

To unfold the production mechanism for such a large cross section for σ_α^{incl}, the CC calculations were performed and the results are shown in Fig. 3. The major contribution to inclusive-α is found to be from '^{6}Li $\rightarrow$ α + d' breakup processes. Total non-capture breakup (direct + sequential breakup) cross section obtained from CDCC calculations (dashed line) is found to be dominated by the sequential breakup through the 3^+ resonant state of ^{6}Li (dash-dotted line). In case of d-capture, the complimentary fragment (α) flies out to contribute to σ_α^{incl}. So, from ICF data[6] (triangles-up in Fig. 3), the d-capture cross sections(dash-dot-dotted line) are estimated by calculating the ratios of 1-D BPM fusion for d+^{209}Bi to α+^{209}Bi at same beam velocities, using the barrier parameters from systematics[10] in Wong's formula. CC calculations show that the maximum contribution from the transfer reactions comes from the '^{6}Li$\rightarrow$^{5}Li$\rightarrow$ $\alpha + p$' process which is shown as dotted line in Fig 3. The combined cross sections of transfer, non-capture breakup and d-capture, shown as the solid line, are reasonably close to the measured σ_α^{incl} at low and high energies but fall short in the intermediate energies.

References

[1] A. Pakou *et al.*, Phys. Rev. Lett. **90** (2003) 202701, and references therein.

[2] H. Kumawat *et al.*, Phys. Rev. C **81** (2010) 054601

[3] F. A. Souza *et al.*, Nucl. Phys. **A821** (2009) 36.

[4] R. Ost *et al.*, Phys. Rev. C **5** (1972) 1835.

[5] C. Signorini *et al.*, Eur. Phys. J. A **10**(2001) 249.

[6] M. Dasgupta *et al.*, Phys. Rev. C **70** (2004) 024606.

[7] E. F. Aguilera *et al.*, Phys. Rev. Lett. **84** (2000) 5058.

[8] G. R. Kelly *et al.*, Phys. Rev. C **63** (2000) 024601.

[9] N. Keeley *et al.*, Phys. Lett. B **427** (1998) 1.

[10] L. F. Canto, *et al.*, J. Phys. G, **36** (2009) 015109.