Investigation of Breakup Fusion and Transfer using Inclusive α-spectra for ^{6}Li+^{93}Nb System

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Introduction

In recent studies, identification and quantification of breakup-fusion (breakup followed by fusion) and transfer-fusion (no breakup before transfer) is being investigated by observing α-particle energy spectra in inclusive and exclusive measurements [1, 2]. In general, the transfer Q-value is large for lighter mass targets thus the effect of Q-value can be observed more pronounced in the energy spectra of the α-particles if the Q-value is shared with α-particles. The Q-value is shared with outgoing α-particle in case of transfer-fusion and it is not shared if breakup happened before fusion. The lighter mass targets suffer from contamination from evaporated α-particles from complete fusion. Exclusive and inclusive measurements for ^{7}Li + ^{93}Nb reported that transfer fusion is dominant (>70%) over breakup-fusion [2]. Inclusive measurements for ^{6}Li + ^{51}V and ^{9}Be + ^{51}V observed that the α-particle energy spectra are peaking close to breakup energies around Couloumb barrier energies of the projectile [1]. With a view to understand the various mechanisms responsible for α-emission in general and α-emission from breakup-fusion or transfer-fusion in particular, measurements have been carried out for α-particles emitted in the ^{6}Li + ^{93}Nb system. The ^{6}Li energy was high enough to have a clear separation between compound nuclear and direct reactions in the α-particle spectra. The α-particle spectra peak close to breakup energies suggests the dominance of breakup-fusion over transfer-fusion.

Experimental details

The experiment was carried out at BARC-TIFR Pellteron LINAC facility, Mumbai, India. A self-supporting ^{93}Nb target of thickness $\sim$1 mg/cm^2 was bombarded with 40 MeV ^{6}Li beam in a 1m dia. scattering chamber. Four silicon surface barrier detector (ΔE-E) telescopes were mounted around grazing angle (20°, 30°, 40°, 50°) and two strip detectors were placed at back angles (140°-160°) to detect the evaporation like particles. The coincidence data were measured between evaporated proton and α-particles. Here α-particles may come from breakup with subsequent capture of deuteron or transfer of deuteron and emission of α-particle. Neutron transfer followed by breakup of ^{5}Li into α + p or proton transfer followed by breakup of ^{5}He into α + n may also give α-particles. Natural Carbon target of thickness $\sim$30μg/cm^2 was irradiated for energy calibration at 40MeV and 20MeV ^{6}Li beam energies. Thorium-229 source was also used for energy calibration.

Results and Discussion

Inclusive α-particle energy spectra were obtained at 20°, 30°, 40°, 50° around grazing angle (33°). The energy calibration was measured from Th-229 α-source, ^{6}Li+^{12}C at 40MeV and 20MeV, ^{6}Li+^{93}Nb at 40MeV and ^{6}Li+^{197}Au at 40MeV beam energies and has been shown in Fig. 1. Statistical model code PACE2 was used to get the compound nuclear contribution. The peak of α-particles from evaporation is $\sim$13 MeV and has small contribution compared to major α-peak. The breakup energy in the c.m. system is around

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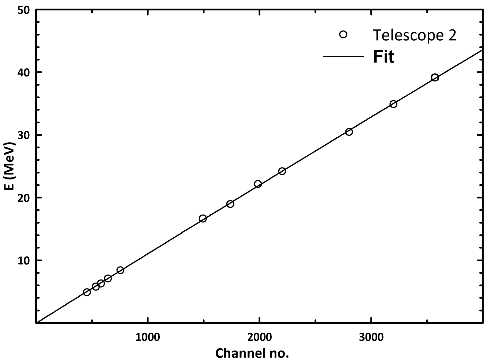

FIG. 1: Detector energy calibration using Th-229 source and ^{6}Li beam at different targets.

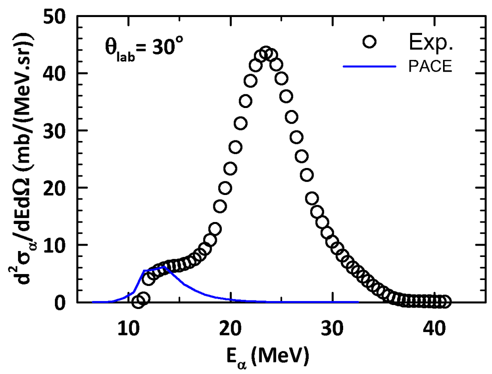

FIG. 2: Energy spectra of α-particles for ^{6}Li + ^{93}Nb system at 40 MeV.

24 MeV. The optimum Q-value and kinematics estimate breakup-fusion α-peak around 26 MeV. The deuteron transfer and α-emission Q-value is 12.2 MeV for ^{6}Li + ^{93}Nb system. If transfer-fusion was a dominant process then a major peak could have been above 30 MeV and we didn't observe it which suggests that breakup-fusion is dominant over transfer-fusion for this system (see Fig 2). α and deuteron coincidence spectra between 20° and 30° detectors is shown in Fig. 3 which shows sequential breakup peaks corresponding to sum energy of the fragments at $E_{c.m.}$ = 36.5MeV. Direct breakup α particles were also

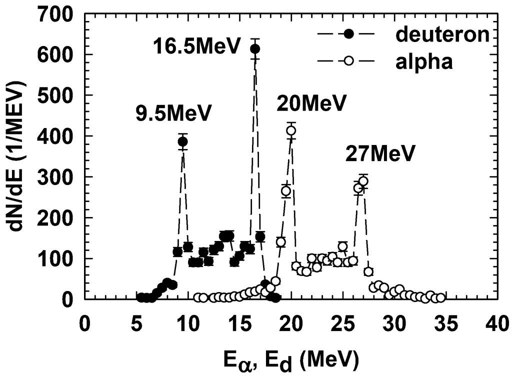

FIG. 3: Energy spectra of deuteron and α-particles in coincidence between 20° and 30° detectors.

observed in between the peaks with a broader Gaussian around 24MeV. In summary, measurement of α-particle spectra for ^{6}Li induced reactions on ^{93}Nb at a bombarding energy of 40 MeV has been reported. A dominant contribution of α-particles resulting from the process of breakup-fusion compared to transfer-fusion is observed.

References

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