EPJ Web of Conferences **86**, 00032 (2015)
DOI: 10.1051/epjconf/20158600032

1n-transfer reaction using ^{6}Li with heavy mass target

D. Patel[1,a], S. V. Surayanarayana[2,b], S. Mukherjee[1], B. K. Nayak[2], E. T. Mirgule[2], D. C. Biswas[2], A. Saxena[2], and J. Lubian[3]

[1] *Physics Department, Faculty of Science, M. S. University of Baroda, Vadodara - 390002, India.*
[2] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, India.*
[3] *Instituto de Fisica, Universidade Federal Fluminense, Avenida, Niteroi, R. J. 24210 -340, Brazil.*

Abstract. Influence of 1n-transfer coupling on quasi-elastic scattering excitation function has been investigated for ^{6}Li + ^{209}Bi system. Coupled Reaction Channels Calculations have been carried out for the energies around the Coulomb barrier. Corresponding barrier distributions obtained with and without including 1n-transfer coupling, have been compared with experimental data. 1n-transfer effect on quasi-elastic excitation function has been observed to be insignificant for the present system. In the reaction of ^{6}Li with ^{208}Pb and ^{209}Bi, an experimental relative contributions for breakup and 1n-transfer channels have been reproduced by simultaneous calculation using CDCC and CRC formalism.

1 Introduction

Recently, a great attention has been given to the breakup channel in the nuclear reaction studies with weakly bound nuclei [1, 2]. The observed enhancement and/or suppression in the fusion cross sections at around the Coulomb barrier are associated with the breakup and also other reaction channels such as transfer (pickup/ stripping), which trigger the projectile breakup [3]. For example the weakly bound projectile ^{6}Li may directly breakup into two fragments ($d + \alpha$) or the breakup may occur after some nucleon transfer (pickup/ stripping). In a very recent experimental study involving stable weakly bound projectile (^{6}Li) [3] the 1n-stripping is found more preferable channel leading to ($p + \alpha$) and the contribution from 1n,1p-pick up is found negligible at below barrier energy in the reaction with ^{207,208}Pb and ^{209}Bi targets. It will be of interest to know the 1n-transfer coupling effect on quasi-elastic scattering excitation function for the ^{6}Li + ^{209}Bi system. In the present work, Coupled Reaction Channels(CRC) Calculation have been carried out to study the 1n-transfer effect on quasi-elastic scattering excitation function. In addition to that we have also done simultaneous calculation for breakup and transfer using CDCC and and CRC formalism, to understand their relative contributions which have been reported in the Ref.[3].

2 Experimental Details

The experiment was performed with ^{6}Li$^{(3+)}$ beam at the 14UD BARC-TIFR Pelletron facility in Mumbai, India.

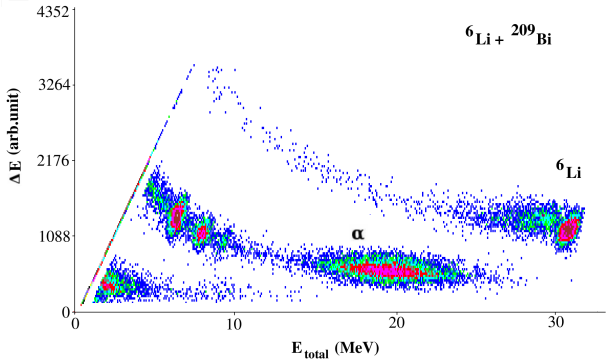

Figure 1. (Color online) A typical two-dimensional spectrum of ΔE vs E_{total} for ^{6}Li + ^{209}Bi at E_{lab} = 34 MeV and θ_{lab} = 140°

The experimental measurements were done at 140° employing a detector telescope with the thickness of ΔE = 15 μm and E=1.5 mm. The spectra were recorded in the energy range from 22.0 to 39.0 MeV in steps of 1.0 MeV. Two monitor detectors were placed at ±18° for normalization and beam monitoring. A self supported ^{209}Bi target of thickness ~ 1.2 mg/cm^2 was used. The bombarding energies were corrected for the energy loss in half the target thickness, ranging from 0.12 to 0.18 MeV for ^{6}Li. Fig. 1 shows a typical two dimensional $\Delta E + E_{total}$ spectrum obtained at E_{lab} = 34 MeV and θ_{lab} = 140°. Other details of the experiments are available elsewhere [4].

3 CRC calculation and Discussions

We have performed Coupled Reaction Channels (CRC) calculations using Fresco code [5]. The calculations have

[a] e-mail: dipika.physics@gmail.com
[b] e-mail: suryanarayan7@yahoo.com

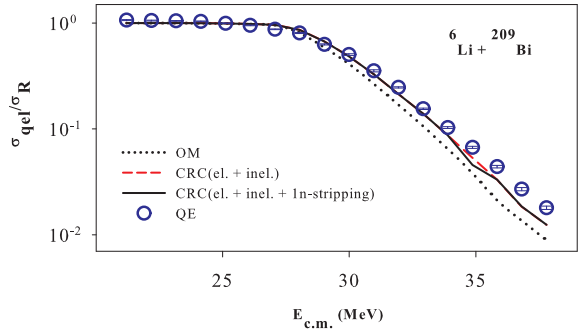

Figure 2. (Color online) "Qausi-elastic" excitation function for ^{6}Li + ^{209}Bi at θ_{lab} = 140°. The dotted line indicates excitation function obtained with OM potential. The dashed and continuous lines show results obtained with the inclusion of target inelastic coupling and with the inclusion of target inelastic coupling as well as 1n-stripping channel respectively.

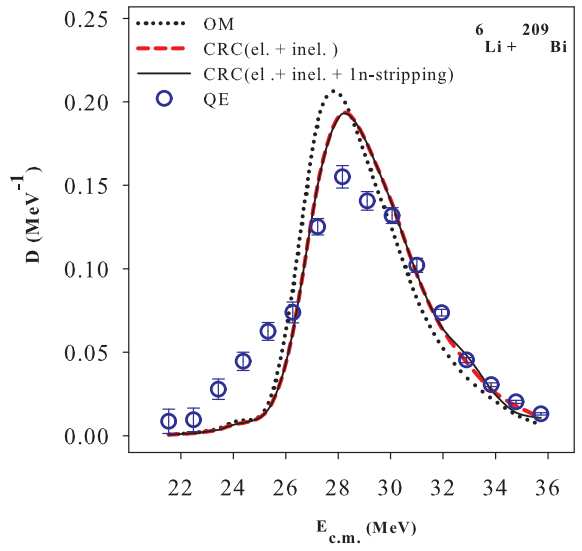

Figure 3. (Color online) Corresponding barrier distribution for ^{6}Li + ^{209}Bi at θ_{lab} = 140°. The dotted line indicates excitation function obtained with OM potential. The dashed and continuous lines show results obtained with the inclusion of target inelastic coupling and with the inclusion of target inelastic coupling as well as 1n-stripping channel respectively.

been carried out for the energy range from 22.0 to 39.0 MeV. In these calculations the 1n-transfer was considered from ground state of ^{6}Li to ground state of ^{209}Bi, which may lead to ^{5}Li and final nucleus ^{210}Bi in its ground state, as the Q-value for this reaction is -1.058 MeV. To consider the effects from target (^{209}Bi) excitation, Couplings to collective multiplet [^{208}Pb(3$^-$)$\otimes$ 1$h_{9/2}$]j_π were also included as given in table 1. The entrance channel potentials were of Woods-Saxon form with r_0=1.2 fm and a_0=0.67 fm. For the 1n-transfer channel, the real part was calculated using broglia and Winther parametrization with r_0=1.167

Table 1. The excitations of ^{209}Bi included in the calculation taken from Ref.[6]

Energy (MeV)	I^π	B(E3) (W.u.)
0.0	$9/2^-$	-
2.493	$3/2^+$	16.0
2.564	$9/2^+$	28.0
2.583	$7/2^+$	25.0
2.599	$11/2^+$	30.0
2.6	$13/2^+$	22.0
2.617	$5/2^+$	22.0
2.714	$15/2^+$	25.0

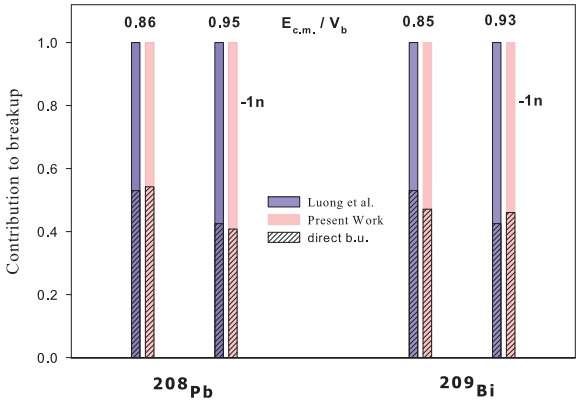

Figure 4. (Color online) Relative contribution of direct breakup and 1n-stripping channel in the reaction of ^{6}Li with ^{208}Pb, ^{209}Bi

fm and a_0=0.63 fm [7]. The imaginary part was of short range type with W_0= 50 MeV, r_0=1.06 fm and a_0=0.4 fm. The binding potentials for the valence (n) and core (^{5}Li and ^{210}Bi) nuclei were of the Woods-Saxon and spin orbit form. The depths were adjusted to obtain the required binding energies. These calculations were done with spectroscopic amplitudes equal to 1.

Figure. 2 shows the experimental quasi-elastic (elastic + inelastic) excitation function along with the results of Coupled Reaction Channels Calculations. The dotted line indicates excitation function obtained with OM potential. The dashed and continuous lines show the excitation functions obtained with the inclusion of target inelastic and (target inelastic + 1n-transfer) respectively. The corresponding barrier distributions are plotted in the Fig. 3 which shows reasonable agreement between the present calculations and the experimental results. From the Fig. 2, it is seen that the inelastic and 1n-transfer coupling effect on quasi-elastic excitation function is negligible. The similar result can be observed in the Fig. 3 with no difference in barrier distribution heights obtained with the inclusion of target inelastic and (target inelastic + 1n-transfer). Also, no transfer coupling effect was observed on the quasi-elastic excitation function in the reaction of weakly bound nuclei (^{7}Li) with ^{144}Sm [8].

Table 2. Cross-sections for α+d breakup and 1n-stripping for ^{6}Li + ^{208}Pb, ^{209}Bi systems.

	^{6}Li + ^{208}Pb			^{6}Li + ^{209}Bi		
Energy (MeV)	$\sigma_{breakup}$ (mb)	$\sigma_{1n-stripping}$ (mb)	σ_{total} (mb)	$\sigma_{breakup}$ (mb)	$\sigma_{1n-stripping}$ (mb)	σ_{total} (mb)
26.5	25.0	21.1	46.2	25.0	28.1	53.1
29.0	39.3	57.2	96.5	39.1	45.2	84.4

4 Simultaneous calculation for breakup and transfer

We have made an attempt to investigate the relative contributions for breakup and 1n-transfer in the ^{6}Li + ^{208}Pb, ^{209}Bi reactions using CDCC and CRC formalism. In the literature for the ^{6}Li + ^{208}Pb, ^{209}Bi system, it is reported that major contributions to the breakup α comes from the direct breakup as well as from 1n-stripping reaction but no theoretical investigation was made. In this work simultaneous calculations for breakup and 1n-transfer have been carried out at 26.5 and 29.0 MeV using Fresco code [5]. All the resonant states of ^{6}Li with finer binning and maximum excitation energy upto $\sim$ 8.5 MeV have been included in the CDCC calculations. Also, the target spin has been set to $1/2^{-}$ to reduce the computing time. The calculations have been carried out at 26.5 and 29.0 MeV laboratory energies. In the 1n-stripping calculation coupling to ground state has been considered and no target inelastic states have been included as the coupling to target inelastic states gives negligible cross sections. In these calculations, the binding energies for core and valence particles have been taken as 0.1MeV and the spectroscopic amplitudes were 2.0. This has been varied to assume the ground state of ^{5}Li to be weakly bound [9].

Figure. 4 shows the results of present calculations (pink) with the inclusion of breakup as well as 1n-stripping channels and have been compared with the experimental data reported by Luong *et al.*[3]. By adjusting the spectroscopic amplitude and binding energy of valence particle, a reasonable agreement can be observed between the present calculations and the experimental results as shown in Fig. 4. Table 2 shows the cross sections for α+d breakup and 1n-stripping at 26.5 and 29.0 MeV, in the reaction of ^{6}Li with ^{208}Pb, ^{209}Bi.

5 Summary and Conclusions

1n-transfer coupling effect on quasi-elastic scattering excitation function have been studied using CRC calculation for ^{6}Li + ^{209}Bi system. The influence from 1n-transfer coupling was observed to be insignificant on quasi-elastic scattering excitation function and no difference was observed in barrier height with the inclusion of 1n-transfer coupling in the CRC calculation. Simultaneous calculation for breakup and transfer reproduce the experimentally obtained relative contribution for breakup and 1n-stripping channels using CDCC-CRC formalism for the reaction of ^{6}Li with ^{208}Pb and ^{209}Bi at below barrier energies.

Acknowledgment

D. Patel gratefully acknowledges HRDG-CSIR (Ack. No. 162033/2K12/1) for the award of SRF fellowship in carrying out this work.

References

[1] L. F. Canto *et al.*, Phys. Rep. **424**, 1 (2006).
[2] D. Patel *et al.*, Pramana – J. Phys. **81**, 587 (2013).
[3] D. H. Luong *et al.*, Phys. Rev. C **88**, 034609 (2013).
[4] D. Patel et al, AIP Conf. Proc. **1524**, 171 (2013).
[5] I. J. Thompson, Comput. Phys. Rep. **7**, 167 (1988).
[6] A. Diaz-torres *et al.*, Phys. Rev. C **68**, 044607 (2003).
[7] R. A. Broglia and A. Winther, *Heavy Ion recations*, Part I and II (Addison-Wesley, Redwood City, CA, 1991).
[8] D. R. Otomar *et al.*, Phys. Rev. C **80**, 034614 (2009).
[9] N. J. Davis *et al.*, Phys. Rev. C **69**, 064605 (2004).