Effect of pair transfer on multi-nucleon transfer reaction: A theoretical investigation on ^{10}B+^{40}Ca system

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Introduction

Transfer of nucleons from projectile to target or vice versa is one of the dominant processes in heavy ion reaction around the barrier. Multi-Nucleon Transfer (MNT) reaction can take place simultaneously or sequentially depending on the mass asymmetry factor [1]. Besides deformation and orientation of colliding nuclei, neck formation process enhances the transfer cross-section [2, 3]. Transfer of two nucleons probes to paring correlations in nuclei which is useful in identifying isoscalar and isovector states. In heavy nuclei, identical particles are coupled to n-n and p-p pairs (isovector) and n-p pairs with T=1, S=0 (isovector) and T=0, S=1(isoscalar) states. T=1, S=0 states is well defined from isospin symmetry, but T=0, S=1 state is not well defined. Experiments on odd-odd nuclei shows that T=1 states are bound as ground state of neighboring even-even nuclei due to isovector paring, whereas T=0 state is found to be less bound [4, 5]. Heavy ion reaction or medium mass reaction is useful to study the superfluidity of nuclei which enlights the paring phenomenon. Tunneling of nuclei near the Coulomb barrier is similar to that of a supercurrent passing through the insulating barrier between two superconductors. The systems Sn + Sn and Sn + Dy has shown large enhancement for pair transfer [6].

In this paper we investigate effect of pair transfer on MNT cross section for the system ^{10}B+^{40}Ca at energies above the barrier using the widely celebrated coupled channel code FRESCO [7]. It is interesting to observe that ^{40}Ca being doubly magic nucleus where proton and neutron wave functions overlap in the same orbital which provides extra stability to the nucleus, thereby affecting the transfer process.

Theoretical background

Nuclear interaction between a pair of nuclei is described by the potential consisting of Coulomb potential (V_C), nuclear potential (V_N) and centrifugal potential which affect the interaction process leading to various elastic and non-elastic processes. The interacting potential is given as

$$V=V_C(r) + V_N(r) + \frac{h^2 l(l+1)}{4\pi^2 \mu r^2}$$

where l is the angular momentum quantum number, μ is the reduced mass of the system and r is the inter-nuclear distance. In the code FRESCO, the nuclear potential is of the Wood-Saxon type [8]. For the description of a typical transfer reaction A+b = a+B, where a=b+C and A=C+B, DWBA approximation is employed and cross section is calculated by using the following formula as given in ref. [8] with description of the terms involved in the equation.

$$\frac{d\sigma}{d\Omega} = \left(\frac{2\mu_\beta \mu_\alpha}{\hbar^2}\right)\left(\frac{k_\beta}{k_\alpha}\right)|T(k_\alpha k_\beta)|$$

FRESCO ANALYSIS

Using FRESCO angular distributions at energies 40 MeV, 50 MeV, 60 MeV and 70 MeV are obtained for 1n, n-n, 1p-1n and 2p-2n channels corresponding to the entrance channel ^{10}B+^{40}Ca. The Q-values for these channels are tabulated in **Table. 1**. Here, 1n transfer channel is considered so that this can be compared with correlated pair transfers such as n-n, 1p-1n and 2p-2n. The optical model parameters used in the code FRESCO for the system ^{10}B+^{40}Ca are taken from Glover *et al.* [9].

Table 1: Q-value for different channels

Channel	Q-value(MeV)
1n	-7.30
2n	-9.04
1p-1n	-7.72
2p-2n	-10.18

Result and conclusion

Angular distribution for 1n, 1p-1n and 2p-2n channels are shown in **Fig. 1, Fig. 2** and **Fig. 3** at energies of 50 MeV, 60 MeV and 70 MeV. The distribution is bell shaped where the peak is around the grazing angle, indicating maximum transfer probability at the grazing. 1n channel has the maximum probability in each case. Probability decreases for pair transfer channels- 1p-1n, 2p-2n and n-n as well as with increasing energy. Compared to these channels, n-n (or 2n) channel has the lowest probability which is separately shown in **Fig. 4.** However, cross section increases with energy for n-n channel. 1p-1n channel has the highest cross section among the paired channels.

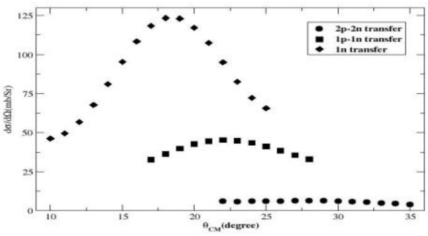

Fig. 1 Angular distribution for different channels at energy of 50 MeV.

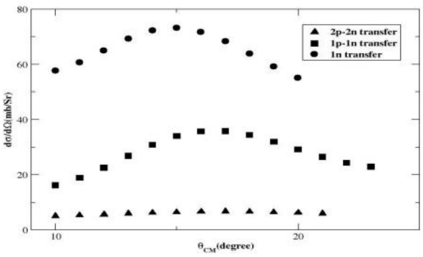

Fig. 2 Angular distribution for different channels at energy of 60 MeV.

The decrease of cross section with the pair transfer indicates that the stability of doubly magic nucleus ^{40}Ca suppresses the transfer cross section indicating that in even-even nucleus probability of pair transfer is very low. Once a neutron is transferred from the projectile to target, sequential transfer of another neutron or proton may take place thereby opening up the 2n or 1p-1n channel. As proton and neutron occupy the same orbital state in ^{40}Ca, transfer probability becomes very low. This attributes to the stable nature of magic nucleus.

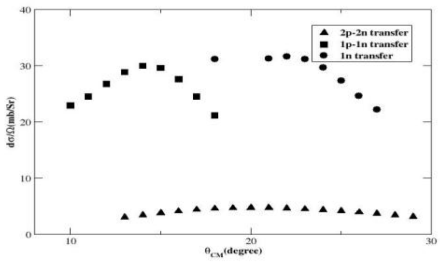

Fig. 3 Angular distribution for different channels at energy of 70 MeV.

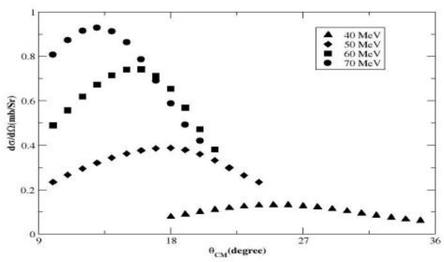

Fig. 4 Angular distribution for n-n channel at different energies.

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