Systematic Study of Multi-nucleon Transfer Reactions for $^{12}C + ^{58}Ni$ and $^{12}C + ^{56}Fe$ systems at $E_{Lab}(^{12}C)$ = 45 and 60 MeV

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Reactions involving a large number of nucleons transferred from the projectile to the target and/or vice-versa in a heavy ion induced reactions at around and above the Coulomb barrier can be an useful tool to investigate the interplay of different reaction processes. Measurement of such multi-nucleon transfer cross sections may provide insight into the underlying peripheral reaction processes. In spite of a considerable progress, the reaction mechanism of multi-nucleon transfer and its effect on other channels is not so well understood. With a motivation to understand the reaction mechanism aspects, we have made a systematic study of multi-nucleon transfer in different projectile + target combinations. Data taken at the BARC-TIFR Pelltron – LINAC facilty, Mumbai for the systems $^{18}O+^{206}Pb$ and $^{18}O+^{12}C$ both studied at an incident energy of $E(^{18}O)$ = 140.4 MeV are reported in different communications to this proceedings [1, 2]. The present communication reports our measurements for $^{58}Ni(^{12}C, x)$ and $^{56}Fe(^{12}C, x)$ at incident ^{12}C energies of $E(^{12}C)$ = 45 and 60 MeV carried out at the pelletron accelerator facility, IUAC, Delhi.

The experiment was performed using the general purpose scattering chamber at IUAC. Two ΔE - E surface barrier detector telescopes of suitable thickness were used for detection and identification of projectile like fragments (PLF). Elastic scattering angular distributions have also been measured. A good charge and mass separation has been achieved for the PLFs corresponding to the transfer of several nucleons. The four nucleon transfer reaction (^{12}C, ^{8}Be) is not so well studied due to the complexity involved in detection of the unstable ^{8}Be nucleus which decays into two alphas. On the other hand, cross section for this channel is expected to be largest due to Q-value effect. The primary aim of this experiment was to study the reaction (^{12}C, ^{8}Be) through α-α coincidence measurement. This has been achieved by detecting two α's in coincidence. Fig.1 shows a typical α – α coincidence spectrum [3].

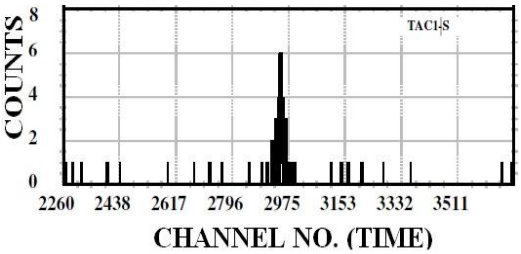

Fig.1 *A typical α – α coincidence spectrum in $^{12}C(^{58}Ni, ^{8}Be)$ at $E(^{12}C)$= 60 MeV with $^{8}Be \rightarrow \alpha\alpha$.*

Table 1. Optical model potential parameters obtained using the SEARCH code SFRESCO.

Potential Parameter	$^{12}C+^{56}Fe$ 60 MeV	$^{12}C+^{58}Ni$ 60 MeV	$^{12}C+^{58}Ni$ 45 MeV
V_o (MeV)	48.0	48.0	48.0
r_o (fm)	1.191	1.044	0.95
a_o (fm)	0.643	0.634	0.91
W (MeV)	12.0	12.0	12.0
r_i (fm)	1.191	1.136	1.255
a_i (fm)	0.634	0.502	0.49

The measured angular distributions for the elastic scattering cross section (Fig.2) have been analyzed and the optical model potential has been derived by fitting the measured data with the optical model search code SFRESCO. Starting with the potential parameters for the system $^{12}C+^{56}Fe$ (table 1), as obtained from our earlier study [4], the best fit to the present set of data was obtained with the optical potential given in Table 1.

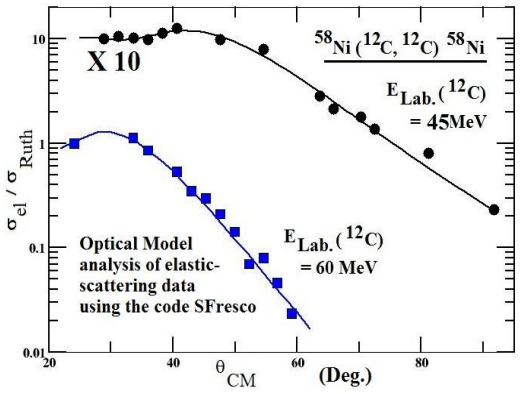

Fig.2. *Elastic scattering angular distribution for ^{12}C + ^{58}Ni at E(^{12}C) = 45 MeV (Top) and at 60 MeV(bottom) along with SFresco calculations.*

Detailed Coupled Reaction Channel calculations are being done with FRESCO for the alpha transfer channel in order to understand the role of one step alpha transfer vis-à-vis multi step sequential transfer of four nucleons. From our earlier studies, significant contribution from multi-step sequential processes are expected.

Cross-section for the multi-nucleon transfer reactions are obtained (Fig.3) and can be compared with the data for $^{12}C+^{56}Fe$, measured by us[3], at the same energy. Both ^{56}Fe and ^{58}Ni nuclei are close to the doubly closed shell (Z=28, N=28) with ^{58}Ni being the proton shell closed nucleus, detailed comparison between these two systems would indicate possible effect of the shell closure on multinucleon stripping reactions.

The other aim of the experiment done at IUAC was to investigate the formation of fully strip ions using transfer reactions. In this connection X-ray spectra from the atomic transitions were recorded by a HpGe detector placed at 90° and data for the reactions were also collected in the inverse kinematics i.e., ^{58}Ni beams of 175 MeV on carbon target and will be reported somewhere else [4].

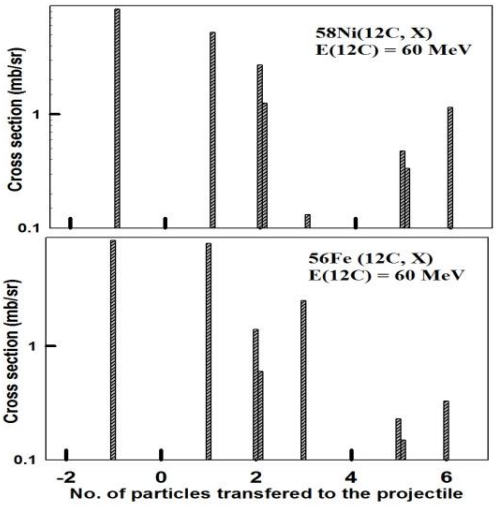

Fig.3 *Reaction cross section versus number of particles transferred for $^{58}Ni(^{12}C,x)$(top) and $^{56}Fe(^{12}C,x)$(bottom). Cross section for the alpha striping reaction i.e., (^{12}C,^{8}Be) channel is being extracted from the measured coincidence spectrum.*

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References:

[1] B. J. Roy et al., "Multi-nucleon Transfer Reactions in $^{18}O+^{206}Pb$", contribution to present proceedings.

[2] B. J. Roy et al., "Study of the Reaction $^{12}C(^{18}O, X)$ at an Incident Energy of $E_{CM}(^{18}O) \sim 5xV_{Coulomb}$, contribution to present proceedings.

[3] H.S.Patel, .., B.J.Roy et al, Pramana, **51**, 433 (98)

[4] T.Nandi, B.J.Roy et al., Symp. Nucl. Phys. (2011)