Two Neutron Transfer Reaction ^{206}Pb(^{18}O, ^{16}O)^{208}Pb: Microscopic Calculations

A. Parmar[1], B. J. Roy[1,*], V. Jha[1], Sonika[1], U.K. Pal[1], V. V. Parkar[1],
K. Ramchandran[1], A. Pal[1], A. Parihari[2], S. Santra[1] and A. K. Mohanty[1]

1: Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400 085
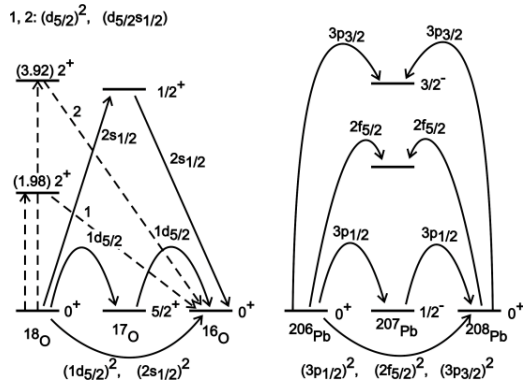*2: Department of Physics, M. S. University of Baroda, Vadodara – 390002*

* corresponding author: bjroy@barc.gov.in

One of the main interests in the study of multi-nucleon transfers between heavy ions is to search for multi-nucleon correlations in nuclear states. If such correlations, the origin for which is due to the residual interaction, are strong it would correspond to a tendency for the formation of spatially localized clusters and would enhance the corresponding transfer cross sections. In our earlier study[1] we have analyzed the angular distribution for two neutron transfer reaction in an extreme cluster model assuming a di-neutron transfer. The g.s.(0+) $\rightarrow$ g.s.(0+) transition in ^{206}Pb(^{18}O, ^{16}O)^{208}Pb at E(^{18}O) = 79 MeV were considered. In this extreme cluster model[2], the di-neutron was assumed to be in a 0s internal state (L=0, S=0, and T=1) and the interaction involved was assumed to be dependent only on the position of the centre of mass of the di-neutron (thereby neglecting the interaction dependent on the internal variables of the cluster). This situation, in a way, is similar to the case of a single nucleon transfer. Such an assumption of treating cluster of x-nucleons as a well-defined physical entity may be valid for tightly bound ^{4}He nucleus and was successful for the description of light ion induced α-transfer reaction (^{6}Li, d), (^{7}Li, t) etc. (due to the well-established α-cluster structure of the lithium nuclei). However, for the heavy ion reactions such as the present one this may not be a good approximation and needs a detailed investigation.

In the following sections we present a more microscopic treatment of the 2n transfer reaction ^{206}Pb(^{18}O, ^{16}O)^{208}Pb. The experiment and data reduction procedure are described in the Ref.[1, 3]. In the extreme cluster model, the transfer of two neutrons was regarded as a cluster (di-neutron) in a well-defined state while in the microscopic approach, the two nucleons is not restricted to be in the 0s internal motion and the transition potential is assumed to act separately on each of the transferred nucleons. The overlaps / two nucleon form factors were then evaluated microscopically by transforming the two single-particle eigenfunctions of a Saxon Wood potential well. The single-nucleon radial wave functions were calculated using the same well geometry (r_o = 1.2 fm and a_o = 0.6 fm) as we have used for calculation of two nucleon transition matrix elements in the extreme cluster model[1] and the half-separation energy procedure[2] was used to fix the well depths. The choice of half of the two-neutron separation energy, which ignores any mutual potential energy due to the residual interaction, is seems reasonable in the present case of weekly interacting neutron pair.

The calculations were performed using the coupled reaction channel code Fresco version FRES-2.9 with two-particle form factor KIND=6. The coupling scheme used in the present calculations has been described in other communications to this proceedings[1,3], here only the transfer coupling details are described in the present context. As is shown in the coupling diagram, Fig.1, the direct and two-step paths were considered in predicting the cross section for the reaction ^{206}Pb(^{18}O,^{16}O)^{208}Pb. The levels in ^{17}O and ^{207}Pb, concerned in the transfer paths, are $d_{5/2}$ and $s_{1/2}$ single-particle states and $p_{1/2}$, $f_{5/2}$ and $p_{3/2}$ single-hole states, respectively. The one nucleon spectroscopic amplitudes were taken from the experimentally reported values while for the two nucleon (simultaneous) amplitudes, the shell model calculated values were used.
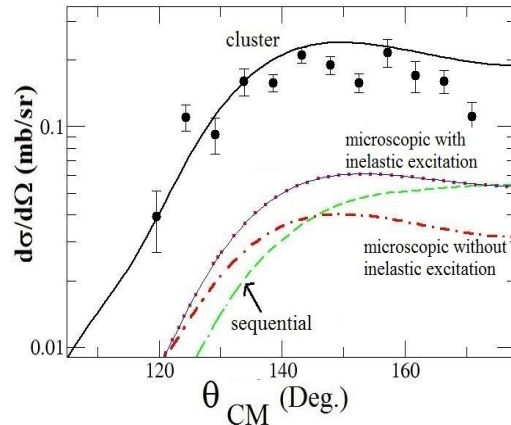
Fig.1: Coupling diagram showing different transfer paths used in the calculation for the 2n transfer reaction: one step simultaneous transfer and two step successive transfer.

The CRC results for the microscopic calculations are shown in Fig.2 along with the experimental data. Also shown are the results from the sequential two-step processes (dash green curve) and extreme cluster model calculation (solid black curve) for the comparison purposes. The dash – dot - dash line (red) in Fig.2 are results of CRC calculations for the simultaneous transfer using the two-nucleon formfactors calculated microscopically. The combined microscopic and sequential calculations have also been performed (not shown here)

Though the shape of the measured 2n angular distribution is reasonably reproduced in all the cases, the discrepancy with the data in absolute magnitude is large. Both the microscopic and sequential calculations, are very much down in magnitude as compared to the measured data, so is the case for the combined microscopic + sequential calculation.

Since inelastic excitation prior or after the transfer (higher order effects) can have a significant contribution in the transfer cross section especially for heavy ion transfer reactions, we have also added in the coupling scheme(Fig.1) the projectile excitations (two 2^+ state at 1.98 MeV and 3.92 MeV that were observed to excite strongly in the present data (Fig.1 of Ref.[3]). The shell model configuration and spectroscopic amplitude for these 2^+ states (in $<^{18}O|^{16}O+2n>$ configuration) were taken from

literature. We have also included the inelastic excitation in ^{206}Pb (2^+ at 0.8 MeV) (not shown in Fig.1 here) and the corresponding two nucleon spectroscopic information were taken from the shell model calculations. It has been observed in the present study that the Coulomb excitation (virtual) in ^{18}O (2^+ level, 1st excited state) has a very strong effect on the transfer cross section (dotted curve). About 70% increase for larger angle data from this excitation alone.

Fig.2. (colour online) Measured ($d\sigma/d\Omega$) for the 2n transfer reaction $^{206}Pb(^{18}O,^{16}O)$ at E_{Lab} = 79 MeV along with the CRC calculations in the microscopic approach. The results from the extreme cluster and sequential calculations are taken from Ref.[1] for comparison purposes.

The present microscopic calculations indicate a strong effect from projectile inelastic excitation in the 2n transfer reaction. The calculations assuming a di-neutron transfer in the extreme cluster model seems to better reproduce the absolute magnitude of the 2n cross section without the need of any arbitrary normalization. These results along with our earlier study on the basis of transfer probability consideration[1] suggest the dominance of a di-neutron cluster transfer as the mechanism for present 2n transfer reaction $^{206}Pb(^{18}O, ^{16}O)^{208}Pb$ at below Coulomb barrier.

References:
[1] B.J.Roy et al, contribution to this conference
[2] G. R. Satchler, "Direct Nuclear Reactions", Clarendon Press, New York, 1983
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