Two-neutron Transfer Reaction Mechanism in $^{18}O+^{206}Pb$ below the Coulomb Barrier: Extreme Cluster Model Calculations Assuming Di-neutron transfer

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The pairing interaction induces nucleon–nucleon (N-N) correlation. Extensive studies have been made in the literature to understand the pairing effect. However, it is still an open question whether the pair correlation can be probed in heavy ion(HI) reactions. In a very recent work on $^{60}Ni+^{116}Sn$, the measured 2n transfer probabilities (both magnitude and slope) were reproduced, for the first time, in a microscopic calculation by incorporating the N-N pairing correlations. With a motivation to have further understanding of the role played by pairing correlations in nuclei, we have studied the 2n-transfer reaction $^{206}Pb(^{18}O,^{16}O)$. As a first step to this, we have studied the relative contribution from different processes that are contributing to the absolute cross section. The energy was chosen at below the Coulomb barrier. For HI reaction below the Coulomb barrier- though characteristic of low transfer cross section- the two colliding nuclei interact at very large distances so that the effect of the attractive nuclear force on the Coulomb elastic waves is small and can easily be accounted for.

The measurement details are reported in an another communication to this proceedings[1]. For the 2n transfer reaction, the g.s.→g.s transition is well separated due to +ve Q-value of this channel. Angular distribution for transfer cross section was measured simultaneously with elastic scattering and various non-elastic processes and were analyzed in the Coupled Reaction Channel(CRC) model (using FRESCO). The details of the coupling scheme and choice of the double folding potential(real part) are discussed in Ref.[1]. For 1n transfer, various intermediate states in ^{17}O and ^{207}Pb, as shown in Fig.1(a), are coupled while the coupling diagram for 2n transfer is given in Fig.1(b). The 2n transfer reaction (g.s.→g.s. transition), was then followed in the "extreme Cluster" model assuming a di-neutron transfer. In this one step transfer, the two neutron was assumed to be spatially correlated and in the S=0, T=1 & 0s internal motion. The quantum numbers of the centre-of-mass motion was calculated using the harmonic-oscillator energy conservation relation. The bound state wave function for the di-neutron was generated in a Woods Saxon potential (r_o= 1.2 fm, a_o= 0.6 fm) with the depth of the well was adjusted to reproduce the two-neutron separation energy.

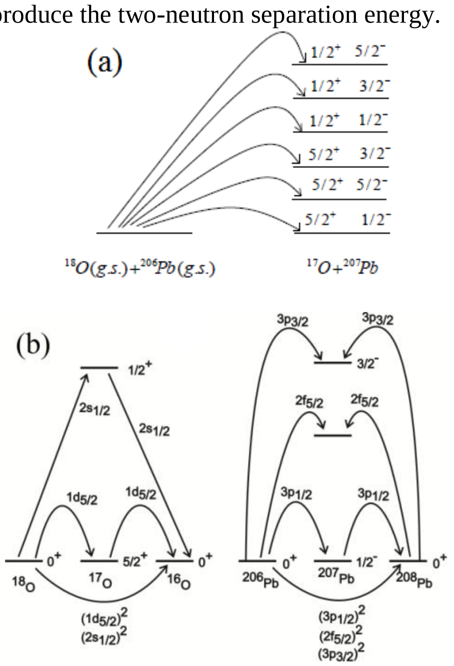

Fig.1: Coupling diagram showing different transfer paths used in the calculation for (a) 1n and (b) 2n transfer: successive transfer of two single nucleons and one step di-neutron cluster transfer.

Two-step successive transfer calculations, usually the dominant mechanism for heavy ion reactions, have also been performed. The g.s. of ^{206}Pb is described as (two-particle hole in N=126 core) $\Psi = 0.769\,(3p_{1/2})^o + 0.477\,(2f_{5/2})^4 + 0.426\,(3p_{3/2})^2$, thus, in the description of sequential processes, the relevant transitions were considered as is shown in the Fig.1.

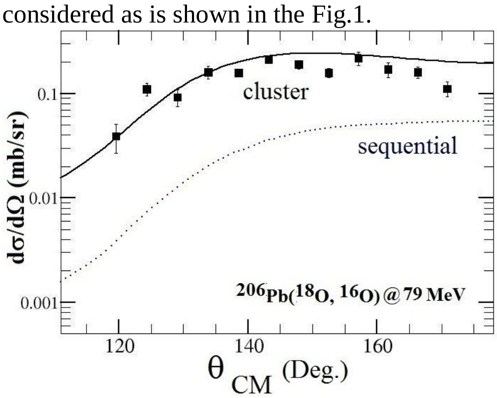

Fig.2. The measured ($d\sigma/d\Omega$) for ^{206}Pb(^{18}O,^{16}O)^{208}Pb along with FRESCO results.

The results are shown in Fig.2. The di-neutron model(extreme cluster transfer) seems to account for the observed two nucleon transfer cross section (both shape and magnitude). It is to mention that no arbitrary normalization- the so called unhappiness factor- was needed. The contribution from the two-step sequential processes, though shape agrees reasonable well, but the absolute magnitude is far below the data. More realistic microscopic calculations for the simultaneous transfer is being carried out to understand further [3].

In an another approach[3] to understand the relative importance of one step cluster vs multi-step sequential transfer is to compared the corresponding transfer probabilities(P_{xN}). P_{xN} is defined as the ratio of transfer yield over the elastic one and is expressed as a function of the distance of closest approach(R_{min}) for the Coulomb trajectory[3]. In a simple approximation, the probability for successive transfer of two single nucleon can be written as $(P_{1N})^2$ and hence an "Enhancement Factor" can be defined as $EF = P_{2N} / (P_{1N})^2$ and would be indicative of the importance of the interaction responsible for correlated pair transfer. This may be an over simplified model, however, a large enhancement factor would be suggestive of one-step cluster transfer over the multi-step sequential processes.

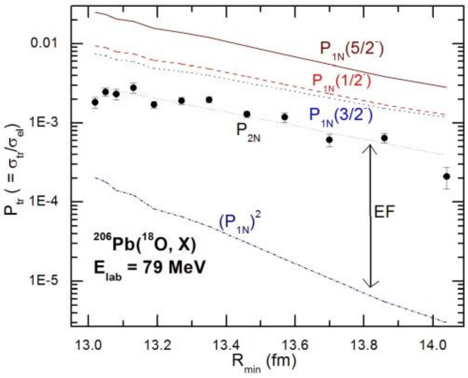

Fig.3. The transfer probabilities for 1n- and 2n-stripping reactions plotted as a function of the distance of closest approach R_{min}. P_{2N} is derived from the present data while for P_{1N}, calculated transfer cross sections are used for transitions to the $1/2^-$, $5/2^-$ and $3/2^-$ states in ^{207}Pb. Expression used to calculate $(P_{1N})^2$ is given in the text.

The deduced transfer probabilities for 1n- and 2n-transfer data are shown in Fig.3. As discussed above, the "Enhancement Factor" in the present case can be written as ($EF = P_{2N} / (P_{1N})^2$)

$$EF = \frac{P_{2N}\,(\text{g.s.}\,(0^+) \rightarrow \text{g.s.}\,(0^+))}{\alpha^2(P_{1N})^2\{1/2^-\}+\beta^2(P_{1N})^2\{5/2^-\}+\gamma^2(P_{1N})^2\{3/2^-\}},$$

where the spectroscopic amplitudes α, β, γ are taken from the literature. The large EF as seen in the above plot seems to suggest the "di-neutron" cluster transfer for the $^{206}Pb_{gs}(0^+) \rightarrow {}^{208}Pb_{gs}(0^+)$ transition.

In conclusion, the present study supports the dominance of cluster transfer over the un-correlated sequential transfer of two single nucleons.

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References:

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