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Multi Three-Cluster Coupling Model of Nuclear Reactions

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Although there exists a number of the so-called N-body connected kernel scattering theories, for the understanding of nuclear reactions, we believe it not only wise but essential to build our physical insights by first analyzing these reactions in terms of a three-body model. In order to analyze a wide class of nuclear reactions, we have to take into account not only the initial three-cluster partitions as in the ordinary Faddeev theroy, but also the coupling to partitions other than the original one. The absorptive effect of the coupling in the two-body propagator $\tau(E)$ has been considered in ref.1. For some cases, however, the absorptive effect via $\tau(E)$ alone is not sufficient, as evidenced by the gross failure of the d-α calculation at 56 MeV.[1] The introduction of the coupling effect through the driving term Z_{ij}(see Eq.(1)) is expected to be crucial, since it can not only influence elastic scattering as we demonstrate in this work, but also it leads to rearrangements as well as inelastic processes.

We propose a theory in the spirit of the Amado-Lovelace (A-L) formalism, which we name the Multi Three-Cluster Coupling (MTCC) model. It is a physical, phenomenological yet divergence-free approach, in which all physically important processes that we wish to consider are coupled within the limitation of three-cluster partitions.

The theory can be best explained by an example. Let us consider the d-α scattering. To introduce the partition n-d-^{3}He in addition to the initial one, n-p-α, we couple the two-body channel (p,α) to (d,^{3}He), so that all three-body processes with both partitions can be generated. Similarly, the partition p-d-t can be introduced by coupling (n,α) to (d,t). Also, the inelastic channel (p,α*) can be coupled to (p,α). For the sake of exposition, let us forget (p,α*). The MTCC as applied to this simplified case is depicted in Fig.1. Each box represents a three-body Faddeev system coupled to others via interactions between subsystems (wavy lines). Parentheses indicate interacting pairs. If necessary, more Faddeev boxes can be added.

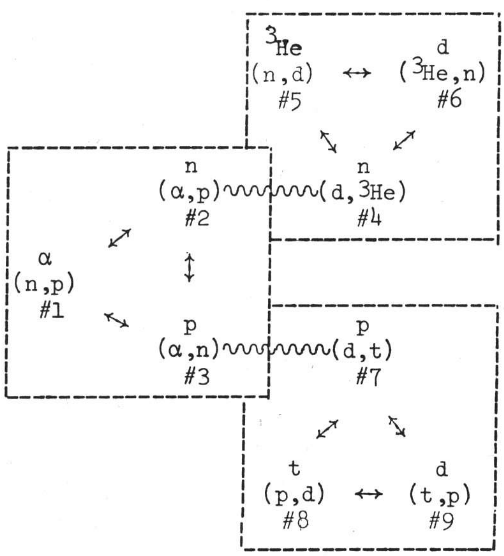

Fig.1. The schematic diagram of the MTCC as applied to a simplified model of the d-α scattering.

Specifically, we assume separable potentials for interacting two clusters, and denote by X_{im} the reaction amplitude from particle channel m to particle channel i (for channel numbers, see Fig.1). As our Ansatz, we set up the following A-L type coupled equation for X_{im}.

$$X_{im} = Z_{im} + \sum_{j(\neq i)} Z_{ij}\,\tau_j\,X_{jm} \qquad (1)$$

Here, Z_{ij} is the Born amplitude for the exchange process from channel j to i. Eq.(1) can be simplified considerably if we consider n-d-^{3}He to be the same as p-d-t, Ignoring the Coulomb force and mass differences. Then we find

$$\begin{bmatrix} Y_{1j} \\ Y_{2j} \\ X_{5j} \\ X_{6j} \end{bmatrix} = \begin{bmatrix} 0 \\ Z_{21}+Z_{46} \\ Z_{56} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 & Z_{12} & 0 & 0 \\ 2Z_{21} & Z_{32} & Z_{45} & Z_{46} \\ 0 & Z_{54} & 0 & Z_{56} \\ 0 & Z_{64} & Z_{65} & 0 \end{bmatrix} \begin{bmatrix} \tau_1 & 0 & 0 & 0 \\ 0 & \tau_2 & 0 & 0 \\ 0 & 0 & \tau_5 & 0 \\ 0 & 0 & 0 & \tau_6 \end{bmatrix} \begin{bmatrix} Y_{1j} \\ Y_{2j} \\ X_{5j} \\ X_{6j} \end{bmatrix} \quad (2) \quad (j=1,6)$$

where $Y_{1j} = X_{1j}/2$ and $Y_{2j} = X_{2j} + X_{4j}$. For the incident channel, we need to add particle channel j with the deuteron pole part in the (n,p) subsystem and particle channel 6 with the ^{4}He pole part in the (n,^{3}He) subsystem. In the calculation of ref. 1, we took into account only the part of Eq.(2) that refer to particle channels 1,2 and 3, ignoring channels 4,5 and 6.

We emphasize that all processes involved in the MTCC are within the three-body boundary conditions and no disconnected diagram exists. The exclusion of Pauli forbidden bound states can be effected by the orthogonal projection method of Kukulin[2] as has been done in ref.1.

We have carried out a preliminary investigation of the importance of the MTCC processes to the d-α elastic scattering by computing the contribution of the first order process from channel 1 to channel 6 as shown in Fig.2. In the (p,α) subsystem, the elastic channel is coupled to the hybrid reaction channel at E_2=18.4 MeV as in ref.1. This hybrid channel is split into the (d,^{3}He) component and the rest with relative weight w for (d,^{3}He) component. In this preliminary calculation, no actual fit to the p+α → d+^{3}He data is considered, but we simply vary w to see its effect. For the n-^{3}He interaction, an s-wave separable potential that fits the low energy phase shift with the ^{4}He pole at -19.815 MeV is constructed. To the d-α amplitude obtained in ref.1, we add the contribution of Fig.2 for the states with j^π=1/2+,3/2+ and 5/2+. The resulting cross section and A_{yy} at E_d(Lab)=56 MeV are shown in Fig.3. The solid lines are with w=1.0, the dashed lines with w=0.5, and the dot-dashed lines with w=0. (w=0 corresponds to the calculation of ref.1) As can be expected, the first order diagram of Fig.2 is important at backward scattering angles. Other vector and tensor analyzing powers also show similar large variations with w. The calculation at E_d=21 MeV with the same first order diagam as Fig.2 yielded very little variation with w for the cross section and T_{11} and T_{22}, but T_{20} and T_{21} are found to be sensitive to it. These results clearly show the necessity for detailed investigation in terms of the full effect of the MTCC.

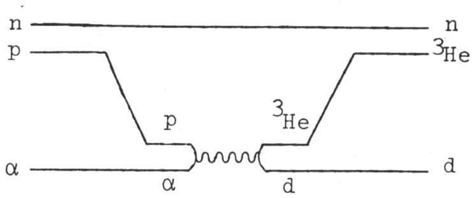

Fig.2. First order contribution $Z_{12}\cdot\tau_{24}\cdot Z_{46}$ to the d-α elastic scattering via the (p,α) to (d,^{3}He) coupling from channel 1 to channel 6.

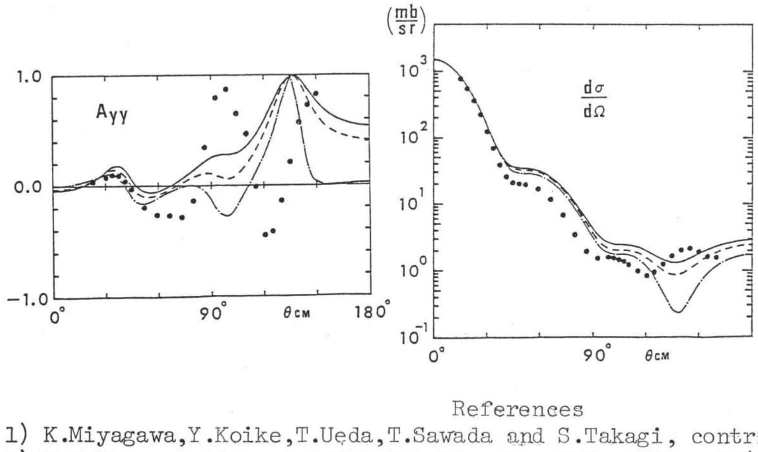

Fig.3. The d-α elastic cross section and A_{yy} with and without the first order diagram of Fig.2 and the RCNP data[3] at E_d=56 MeV. The solid, dashed, and dot-dashed lines correspond to the weight w=1.0,0.5 and 0, respectively.

References

1) K.Miyagawa,Y.Koike,T.Ueda,T.Sawada and S.Takagi, contribution to this conference.
2) V.M.Krasnopol'sky and V.I.Kukulin, Sov.J.Nucl.Phys.20(1975)470
3) K. Nisimura et al, Nucl.Phys.A432(1985)378