The Coupled-Channel Method 
and the Integral-Equation Formalism 
for Nuclear Rearrangement Reactions.

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Summary. — The standard coupled-reaction-channel formalism for nuclear rearrangement reactions is compared with bound-state approximations obtained by starting from modern N-body scattering theory. This comparison will allow us to clarify the origin of nonorthogonality terms in standard coupled-reaction-channel equations as well as the reason of their absence in N-body formalisms. Contributions neglected by the bound-state approximation are taken into account in a three-body context by introducing interacting-particle representations. Thus we can also establish interrelations between different three-body formalisms.

1. — Introduction.

In the last several years a considerable deal of experimental and theoretical effort has been devoted to the study of multistep processes in direct nuclear reactions. When rearrangement of the interacting particles into different partitions is involved, the coupled-reaction-channel method (CRC) \(^{(1)}\) is


\(^{(3)}\) L. J. B. GOLDfarB and K. TAKEUCHI: Nucl. Phys. A, 181, 609 (1972); 218, 396, 226
usually employed. In this method, the total wave function is written as a sum of terms corresponding to the most important open two-cluster channels. Each term is the product of a state function describing the intrinsic state of the two clusters in the given channel, times a relative-motion wave function. Contributions from three- or more-cluster channels are usually disregarded. When the above truncated expansion for the total wave function is inserted into the Schrödinger equation, one obtains a set of coupled CRC integro-differential equations for the relative-motion wave functions. As is well known, since the channel wave functions (and, obviously, the intrinsic ones) corresponding to different partitions are not orthogonal, the CRC equations contain nonorthogonality terms, which make their solution extremely difficult.

In this paper we compare the CRC method with modern $N$-body integral-equation formulations of nuclear-reaction theory. To this end, we derive CRC equations in integral form, starting from sets of simultaneous Lippmann-Schwinger (LS) equations. We shall be able to show that the nonorthogonality terms arise because of the insertion of the same CRC expansion for the total scattering state into the different LS equations.

The nonorthogonality problem can be avoided, by resorting to the techniques of modern $N$-body theory. In this framework the basic LS set is transformed into more appropriate sets of coupled connected-kernel integral equations having as many unknowns as equations (7). These unknowns can be expanded in terms of the intrinsic-state parts of the eigenstates of any two-cluster channel Hamiltonian; such a representation will be referred to as interacting-particle representation, and is alternative to the standard plane-wave one. We shall show that, in the so-called bound-state approximation (BSA) (8)—namely, if only the terms describing two bound clusters are retained in the above interacting-particle expansions—one can derive coupled integral equations without any nonorthogonality term. This can be achieved by starting from suitable sets of exact $N$-body integral equations, and introducing as many expansions as the two-cluster partitions are (a different expansion for each equation of a given set). For other relevant investigations on the nonorthogonality problem see ref. (7).