Role of Tensor Forces in Neutron-Deuteron Elastic Scattering.

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Summary. — With the aim of treating the elastic scattering of neutrons by deuterons at low energies in presence of tensor forces, the resonating-group method is considered, which gives a set of coupled integro-differential equations. The Hulthén wave function is used for the s-state component of the deuteron ground state and it is shown that the coupled integro-differential equations results essentially from the inclusion of the tensor forces.

1. - Introduction.

In recent years, a number of theoretical investigations (1) have been made to examine the properties of light nuclear systems using the method of the resonating-group structure (2-3). The results of these calculations have been very encouraging, since for light nuclear systems the agreement between the calculated and experimental results was found to be quite satisfactory over a wide range of energies.

The resonating-group method has been found to be a powerful tool in treating the three-body scattering problem as long as the break-up channel can be neglected. The results of these calculations (4) clearly indicated that the effects introduced by the antisymmetrization procedure are important and cannot

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be omitted if satisfactory agreement with the experimental data is to be obtained.

A logical step is to apply this procedure to more complicated problems, which are difficult to handle with integral-equation methods (5), such as neutron-deuteron scattering with tensor forces. It is of course well known that s-wave forces are grossly inadequate for the representation of two-body data. The obvious answer is the inclusion of at least tensor forces which are known to be important not only for two-body scattering but also for producing the requisite 4% D-state in the deuteron.

It should be more interesting to look into the effects of the tensor force on the n-d problem, in so far as such a force has an accepted status in the two-body potential. The tensor force formalism, with proper antisymmetrization of the three-nucleon wave function, has already been applied to the calculation of several triton parameters. The binding energy already shows a good deal of improvement over the corresponding results of a pure s-wave theory. This fact should warrant the expectation of a corresponding improvement in the results of the n-d scattering problem.

With the inclusion of tensor forces we expect a significant modification in the results of $a_{\frac{1}{2}}$, and negligible corrections for $a_{\frac{3}{2}}$, for the following reasons. The quartet n-d amplitude is expected to show only a slow variation with changes in the two-body potential, typified by the replacement of an effective s-wave force by a sum of s-wave and tensor forces. And, in so far as the s-wave force is much bigger than the tensor force, the modification due to the tensor force must be regarded as a relatively small contribution to the two-body potential, at least for low energies. Therefore the effect of the tensor force on the quartet n-d scattering amplitude at low energies must be small. Not so, however, for doublet n-d scattering whose amplitude has a pole structure near threshold, due to the existence of the nearby triton state with the same quantum numbers $T=J=\frac{1}{2}$. As a result, even small changes in the two-body potential could make a significant alternation in its magnitude. A second reason for the sensitivity of the doublet scattering length is the smallness of the parameter $a_{\frac{3}{2}}$ (0.7 fm).

In the present paper we have considered the n-d elastic-scattering problem with tensor forces in resonating-group approximation. Section 2 provides the set of coupled integro-differential equations using the method of the angular-momentum decomposition. The Yukawa potentials and the deuteron ground-state wave function follow in Sect. 3. With this choice of potentials and the deuteron wave function, an expression of the direct-interaction term has been derived.

Then angular integrations and the matrix element of the tensor operators are given in the Appendices.