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VALIDITY OF DWBA IN A THREE-BODY MODEL OF STRIPPING

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MASTER

A major assumption made in deriving the distorted wave Born approximation (DWBA) amplitude for deuteron stripping is that the three-body wave function ψ_0 describing the deuteron in the presence of the unexcited target nucleus may be replaced by a product of the deuteron ground state wave function ϕ_d and the deuteron elastic scattering wave function u_d defined by $u_d = \langle \phi_d | \psi_0 \rangle$:

$$\psi_0 \approx \phi_d u_d \quad (1)$$

We have shown recently¹⁾ that an exact form of DWBA can be derived if the neutron-proton interaction V_{np} binding the deuteron is separable. Our result is that if the replacement

$$\psi_0 \rightarrow \phi_d F \equiv \psi^{ND} \quad (2)$$

is made, then the resulting stripping matrix element is unchanged. The spectator function F (like u_0) is a center-of-mass (CM) wave function, and includes effects of breakup not present in u_0 . In a three-body model in which V_{np} is separable, then F is identical to the adiabatic wave function recently introduced by Johnson and Soper²⁾.

Three-body model calculations by Reiner and Jaffe³⁾ showed that the angular distribution obtained by use of (1) in the stripping matrix element T was in good agreement with the exact model angular distribution. As we noted in 1), this implies that $u_0 \approx F$. We have recently undertaken calculations to test this hypothesis, and report some of our results in this note.

We have used a special case of the Mitra model⁴⁾, in which each of the model nucleons forming the deuteron is assumed to interact via the same S-wave separable potential with an infinitely heavy core (producing a bound state of energy 3.300 MeV). The nucleons interact with each other via another S-wave, separable potential yielding a binding energy of 2.225 MeV. Yamaguchi⁵⁾ form factors $f(q) = (q^2 + \beta^2)^{-1}$ were chosen, with $\beta = 1.45 \text{ F}^{-1}$ for the nucleon-nucleon interaction and $\beta = 1.06 \text{ F}^{-1}$ for the nucleon-core interaction. Calculations were made for incident deuteron energies of 1.78, 6.7, 11.2 and 15.12 MeV. Results are presented only for the 11.2 MeV case; these are typical of results at the other energies.

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The DWBA matrix element T^{DW} is given by¹⁾

$$T^{DW} = -\frac{\hbar^2}{2M} \langle \chi_{k_i}^{(-)} \phi_j | f u_d \rangle, \quad (3)$$

while the exact matrix element T is¹⁾

$$T \equiv T^{ND} = -\frac{\hbar^2}{2M} \langle \chi_{k_i}^{(-)} \phi_j | f F \rangle; \quad (4)$$

T^{ND} and T^{DW} differ only in the functions F and u_d . Here, M is the nucleon mass, $\chi_{k_i}^{(-)}$ is an ingoing state of momentum k_i for nucleon i interacting with the core, ϕ_j is the bound state of nucleon j , and f is the form factor for the nucleon-nucleon interaction.

We have calculated partial wave elements of the amplitudes and the wave functions u_d and F using

$$T^{ND} = \sum_l (2l+1) T_l P_l(\hat{k}_d \cdot \hat{k}_i)$$

and

$$F(\underline{R}) = \sum_l F_l(R) P_l(\hat{k}_d \cdot \hat{R}),$$

with similar expansions for T^{DW} and u_d . In these equations, k_d is the incident deuteron momentum, $\hat{k} = \underline{k}/|\underline{k}|$, and $\underline{R}$ is the deuteron CM coordinate.

FIG. 1

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The 11.2 MeV angular distributions are shown in Fig. 1. Agreement is good although the DWBA is closest to the exact result for the 6.7 MeV case (in contrast to the Reiner-Jaffe results where the DWBA is better for the 11.2 MeV case). Despite the generally good agreement between $|T_l^{DW}|^2$ and $|T_l^{ND}|^2$, we have found that T_l^{DW} and T_l^{ND} are in poor agreement for $l < 2$ at all the energies studied. This is seen in the table, where we compare the partial wave values. These disagreements for the smaller values of l suggest that u_d is not approximately equal to F . This is indeed the case, as seen in Fig. 2, where we have compared the real parts of $RF_l(R)$ and $Ru_{d,l}(R)$ for $l=0$ and $l=3$. In the region $R \leq 1.5F$, F_l and $u_{d,l}$ are substantially different, and it is this region of configuration space that makes the most significant contribution to the stripping matrix elements. Although $T_3^{DW} \approx T_3^{ND}$, this is not an indicator that $\text{Re } RF_3 \approx \text{Re } Ru_{d,3}$: the stripping matrix element involves complicated overlaps (recall that stripping is a rearrangement process), and four functions rather than one determine its

magnitude. Similar results hold for $l=1$ and 2, and at the other energies.

We have thus shown that while DWBA produces reasonable angular distributions in the model, it does not provide good agreement in detail. Appearances are deceiving. The implication for many-body reactions from these results is that DWBA is not as accurate as the adiabatic approximation, a conclusion also confirmed by fitting experimental (p,d) data⁶.

Partial Wave Stripping Matrix Elements, $E = 11.2$ MeV

l	$\text{Re}T_l^{\text{ND}}$	$\text{Im}T_l^{\text{ND}}$	$\text{Re}T_l^{\text{DW}}$	$\text{Im}T_l^{\text{DW}}$	T_l^{BORN}
0	1.265	-0.254	-0.137	-1.631	-6.190
1	0.523	-0.185	-0.032	-0.399	-3.946
2	-1.320	0.016	-1.184	-0.209	-2.273
3	-1.129	0.036	-1.065	-0.049	-1.263
4	-0.681	0.013	-0.662	-0.007	-0.693
5	-0.381	0.003	-0.376	-0.001	-0.380
6	-0.211	0.001	-0.210	-	-0.380
7	-0.115	-	-0.115	-	-0.115
8	-0.064	-	-0.064	-	-0.064
9	-0.035	-	-0.035	-	-0.035

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