POLARIZATION OF THE NUCLEAR WAVE FUNCTIONS IN $^{40}Ca(^{16}O,^{15}N)^{41}Sc$ and $^{208}Pb(^{12}C,^{11}B)^{209}Bi$.

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In comparing distorted waves Born approximation predictions for heavy ion induced transfer reactions with experiment two basic types of systematic discrepancies have been observed in a large number of recent studies. The first type consists of an experimental cross section biased towards forward angles with little or no peaking at the grazing angle while the DWBA predicts the contrary. The second type of discrepancy consists of the DWBA predicting the correct shape of the peak while overestimating the peak angle, sometimes by as much as 30°. The latter has been observed in single nucleon transfer reactions and in two nucleon transfer between a light projectile and a heavy target . This discrepancy decreases with increasing bombarding energy and increases with decreasing binding of the final state.The DWBA can be made to fit the data only by arbitrarily varying the optical model parameters away from those determined from elastic scattering, which indicates the presence of some reaction mechanism other than direct transfer. One possible candidate for this is a two-step reaction mechanism involving a transition through a low-lying collective state which, in some cases, does lead to a shift forward in angle relative to the DWBA prediction. This does not seem a likely explanation, however, in those cases where the peak angle discrepancy appears as a systematic effect in a number of states in the same nucleus. The reason is that the relative strengths and phases of the parentage amplitudes are not expected to be similar for transitions to different final states.

We have investigated a reaction mechanism which may yield a systematic shift of the grazing peak angle relative to the prediction of a direct transfer mechanism. We allow the single particle states to continuously adjust to an instantaneous two-centre potential formed during the collision. Transfer reactions then occur between "polarized" (two-centre) states rather than between asymptotic states. The polarized states contain high angular momenta, so that much larger orbital angular momenta can be transferred. This will deemphasize contributions to transfer from the grazing partial waves, and will give rise to a forward shift of the peak angle.

Polarized single particle states for various nucleus-nucleus systems have been calculated in the adiabatic (i.e. static nuclei) limit, using both a schematic modified two-centre oscillator and a realistic two-centre Woods-Saxon potential[1,2]. Cross sections for transitions between polarized states were evaluated in the DWBA, with the single particle states in the transition amplitude replaced by polarized states. The DWBA calculations are difficult because large intrinsic angular momenta enter (l' up to 14) and severe numerical problems arise for $l' > 7$[3]. Also,the computation time for each transition increases quadratically in l' and is measured in hours even on the CDC7600.

For the proton transfer reaction ^{40}Ca(^{16}O,^{15}N)^{41}Sc$_{1f_{7/2}}$ at E_{lab}=48 MeV it was found that inclusion of polarization gave rise to an 18° forward shift of the peak angle, which was close to that required by experimental data[4]. We have also begun calculations of the proton transfer reaction ^{208}Pb(^{12}C,^{11}B) ^{209}Bi to excited states of Bi. In this reaction a systematic shift in peak angle of the DWBA predictions (dashed curves, see figure) with respect to experimental data taken at E_{lab}=77 MeV (dots) has been observed previously. Our, as yet incomplete, calculations including polarization (solid curves) reproduce both the magnitude of the shift and the trend of growing shift with decreasing binding in ^{209}Bi.

The polarization calculation described above can be understood as the lowest order approximation to a dynamical process involving transitions through many high lying intermediate states. If the Hilbert space is truncated to include only the initial channel α, the final (weakly bound) channel β and many high lying levels β' in the nucleus having the weakly bound state, the transition amplitude is

$$T_{\alpha\to\beta} = <\chi_\beta^{(-)}|(\phi_\beta|\hat{V}_\alpha|\phi_\alpha) + \sum_{\beta'}(\phi_\beta|\hat{V}_\beta|\phi_{\beta'})\frac{1}{E_{\beta'}^{(+)}-H_\beta}(\phi_{\beta'}|\hat{V}_\alpha|\phi_\alpha)|\chi_\alpha^{(+)}> \quad (1)$$

where the first term is the usual DWBA. Here we have neglected rescattering among the intermediate states β' at energies $\varepsilon_{\beta'}$ with $E_{\beta'} = E - \varepsilon_{\beta'}$ the energy of the intermediate relative motion. It can be shown that, in the adiabatic limit of fast internal and slow relative motion, eq. (1) can be approximated by

$$T_{\alpha\to\beta} = <\chi_\beta^{(-)}|\left\{(\phi_\beta| + \sum_{\beta'}\frac{(\phi_\beta|\hat{V}_\beta|\phi_{\beta'})}{\varepsilon_\beta - \varepsilon_{\beta'}}(\phi_{\beta'}|\right\}\hat{V}_\alpha|\phi_\alpha)|\chi_\alpha^{(+)}> \quad (2)$$

This shows that the transition is from the state α to a polarized state represented by the term in curly brackets, which is the first order stationary perturbation expression for a two-centre shell model state. It is the theoretical justification for our polarized DWBA calculation. We are currently investigating the dependence of the polarization effect upon bombarding energy by calculating the full expression of eq. (1).

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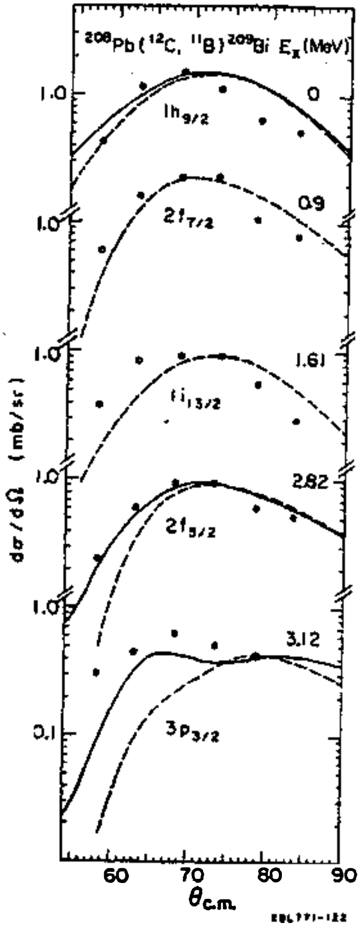

Fig.1 DWBA predictions with (solid curves) and without (broken curves) polarization of the final state in the reaction $^{208}Pb(^{12}C,^{11}B)^{209}Bi$ at 77 MeV bombarding energy. The data are those of ref[5].