Polarization potentials for the ^{208}Pb(^{7}Li,^{6}Li)^{209}Pb transfer

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Recent optical model analyses of near-barrier ^{7}Li+^{208}Pb elastic scattering data found a peak in the energy dependence of $W_{\rm OM}$, the strength of the imaginary part of the optical model potential at the strong absorption radius. It was speculated that this might be due to the polarization potentials produced by couplings to the ^{208}Pb(^{7}Li,^{6}Li)^{209}Pb transfer channels. In this Brief Report we show explicitly that such couplings do indeed produce polarization potentials with the same energy dependence as that observed for the empirical optical potentials. [S0556-2813(97)05811-1]

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Recent analyses of ^{7}Li+^{208}Pb elastic scattering data [1,2] found a marked peak in the near-barrier energy dependence of $W_{\rm OM}$, the strength of the imaginary part of the optical model potential at the strong absorption radius. It was speculated [2] that this peak might be due to coupling to ''barrier'' channels that contribute only to the imaginary potential at energies close to the Coulomb barrier. The ^{208}Pb(^{7}Li,^{6}Li)^{209}Pb transfer was suggested as a possible candidate for these barrier channels. In this Brief Report we show explicitly that coupling to the ^{208}Pb(^{7}Li,^{6}Li)^{209}Pb transfer produces a polarization potential with the same energy dependence as the empirical optical model potentials [2].

A series of coupled-reaction channel (CRC) calculations was carried out using the code FRESCO [3]. In order to provide an unambiguous result only couplings to the ^{6}Li+^{209}Pb partition were included in these calculations. The diagonal optical model potential in the entrance channel consisted of a double-folded real part ($V_{\rm bare}$) and an interior imaginary part of Woods-Saxon squared form ($W_{\rm bare}$). The double-folded potential was calculated using the code DFPOT [4], with the M3Y [5] effective nucleon-nucleon interaction and ^{7}Li and ^{208}Pb densities from electron scattering measurements [6], suitably corrected for the proton charge distribution. The imaginary potential parameters were $W_s=10.0$ MeV, $r_s=1.0$ fm, and $a_s=0.3$ fm [7]. The diagonal optical potential in the ^{6}Li+^{209}Pb channel, the spectroscopic factors, and the neutron binding potentials were those used by Rusek *et al.* [8,9].

Couplings to the ground state and the $5/2^+$ excited state at 1.567 MeV of ^{209}Pb were included in the CRC calculations, both separately (i.e., two-channel calculations) and together (three channels), as these were found previously to be the most important single-neutron-transfer channels [8]. Good agreement with the available data for differential cross section and T_{20} analyzing power backward angle angular distributions at 33 MeV [9] and 29 MeV was obtained.

The effect of coupling to the reaction channels can be simulated by a complex effective polarization potential V_p+iW_p, which gives the same elastic scattering differential cross section as the CRC calculation when added to the entrance channel diagonal potential in a single-channel calculation. In the present work effective polarization potentials were derived from the CRC calculations according to the method described by Thompson *et al.* [10] using an option within the code.

In Fig. 1, V_p (12.4 fm) and W_p (12.4 fm) are plotted as functions of bombarding energy for coupling to the ground state of ^{209}Pb only (open circles), coupling to the $5/2^+$ state of ^{209}Pb only (filled circles), and coupling to both states (asterisks). It can be seen that W_p shows an energy dependence similar to that of $W_{\rm OM}$, the imaginary part of the optical potentials of Martel *et al.* [1,2]. In particular, W_p for the three-channel calculations shows a marked peak at a bombarding energy of about 35 MeV, close to the observed

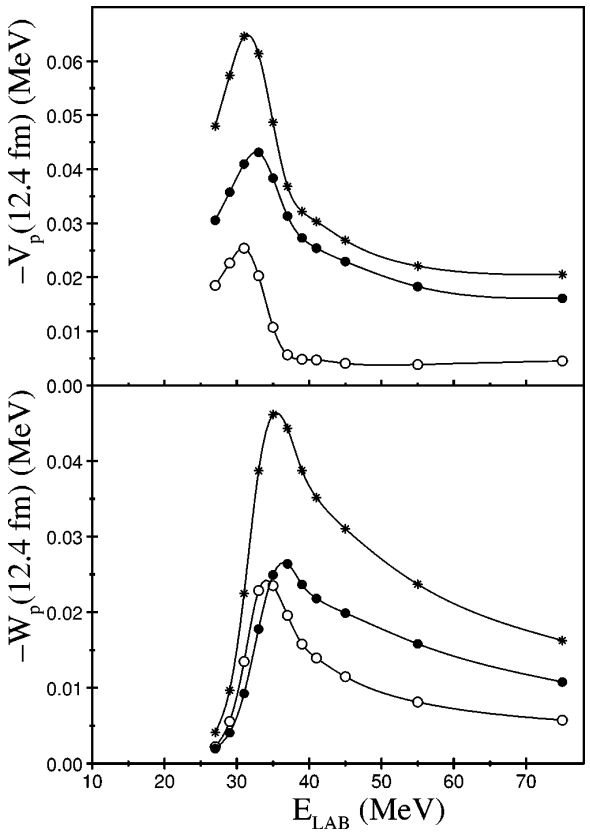

FIG. 1. Effective polarization potentials derived from calculations with couplings to the ground state of ^{209}Pb only (open circles), coupling to the $5/2^+$ state of ^{209}Pb only (filled circles), and coupling to both states (asterisks). The lines are merely to guide the eye.

one in $W_{\rm OM}$ at 33 MeV [2]. The energy dependence of V_p is also similar to that of $V_{\rm OM}$, the real part of the empirical potentials, showing a pronounced peak at a somewhat lower bombarding energy than that of the peak in W_p.

The magnitudes of both V (12.4 fm) and W (12.4 fm), where $V=V_{\rm bare}+V_p$ and $W=W_{\rm bare}+W_p$, are both smaller than $V_{\rm OM}$ (12.4 fm) and $W_{\rm OM}$ (12.4 fm) [$V_{\rm bare}$ (12.4 fm) $=0.234$ MeV and $W_{\rm bare}$ (12.4 fm) ≈ 0], particularly W, which is an order of magnitude smaller than $W_{\rm OM}$, even for the three-channel calculations. It should be noted that the potential strengths of [2] are somewhat smaller than those of [1] as they include the effect of the dipole polarizability. However, as our calculations included just couplings from the ground state to two transfer channels, this is hardly surprising. It is reasonable to assume that couplings to other channels would also contribute to V_p and W_p, increasing the overall magnitude of the potentials. Previous work [11] suggests that couplings between the reaction channels (multistep effects) could provide a considerable part of the missing strength in W_p.

It is interesting to note that the peaks in W_p as functions of energy for the two two-channel calculations are staggered in energy by an amount equivalent to the excitation energy of the $5/2^+$ state (i.e., the difference in Q value). This Q-value dependence of peak position leads to a broadening of the peak for the three-channel calculations, the polarization potentials for these calculations being (to a very good approximation) the sum of those derived from the two sets of two-channel calculations.

Test calculations were also performed for couplings to the ^{208}Pb 2_1^+ and 3_1^- states at excitation energies of 4.085 and 2.615 MeV, respectively. The effective polarization potentials produced by these couplings displayed a similar energy dependence to those due to the transfer coupling but of a considerably smaller magnitude. Thus, although these couplings will make a contribution to the observed peaks in $V_{\rm OM}$ and $W_{\rm OM}$, it is an entirely negligible one.

To summarize, by means of effective polarization potentials derived from a series of simple CRC calculations we have shown that the unusual energy dependence of the empirical $W_{\rm OM}$ obtained in recent optical model analyses of ^{7}Li+^{208}Pb elastic scattering data is largely due to coupling to the ^{208}Pb(^{7}Li,^{6}Li)^{209}Pb transfer partition. We have also shown that the position of the peak due to coupling to individual final states in ^{209}Pb is dependent on the reaction Q value, leading to a broadening of the peak in W_p derived from calculations including more than one transfer channel.

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