Dispersive contribution to $^{6}Li+^{12}C$, ^{58}Ni real potential

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The dispersive contribution to the real part of the optical potential arising due to the energy dependence of the imaginary part of the potential has been estimated for $^{6}Li+^{12}C$, ^{58}Ni systems.

The anomalous increase of the heavy-ion real potential observed at barrier energies has been explained[1] in terms of the dispersion relation approach, which connects the imaginary and the real parts of the potential. This has been successful in explaining the data for a number of projectiles like nucleons (Refs. 2 and 4), ^{4}He (Refs. 2 and 3), ^{16}O (Refs. 1 and 2), and ^{32}S (Refs. 2 and 5). For weakly bound projectiles like ^{6}Li, Sakuragi[6] has shown that the coupling to breakup channels gives rise to a repulsive contribution to the real part of the optical potential and this dynamical polarization potential cancels approximately 40% of the attractive real folding potential. It is of interest to know whether or not the dispersive contribution is significant for a weakly bound projectile like ^{6}Li. With this aim, in the present work, the energy-dependent contribution to the real potential that arises from the imaginary potential through the dispersion relation has been estimated for $^{6}Li+^{12}C$, ^{58}Ni systems. Unlike the typical heavy ions for which the potential is mainly sensitive to the energy-independent strong absorption radius, for ^{6}Li like the light ions the radial region of sensitivity changes with the bombarding energy. It is for this reason several groups[7-9] have gone on to use the volume integrals for describing $^{6}Li+$nucleus interaction. They have shown that the volume integrals are well behaved quantities with respect to E and A variations. Gupta *et al.*[9] have shown that the volume integrals for projectiles with $A=1-6$ can be successfully explained in terms of a simple unified parametrization. In view of this, for the present analysis we have computed the volume integral per projectile-target pair of the imaginary part of the potential (J_I) at several energies starting with the individual best fit optical parameters available at every energy for both the targets.[7,8] It is found that at lower energies even though the real potential changes considerably due to discrete ambiguity problems, the imaginary part is rather well constrained. For example, at $E=36$ MeV for the $^{6}Li+^{12}C$ system, the real volume integrals (J_R) determined are 298, 391, and 531 MeV fm^3 while the corresponding J_I values are 93, 86, and 103 MeV fm^3, respectively. In Figs. 1(a) and 2(a), the average values of the volume integrals of the imaginary part (J_I) are plotted as a function of Li energy for $^{6}Li+^{12}C$ and $^{6}Li+^{58}Ni$ systems, respectively. In both cases it is observed that the J_I values increase steeply at lower energies. While in the case of the $^{6}Li+^{12}C$ system, the J_I values are nearly the same for energies between 100 and 210 MeV, in the case of the $^{6}Li+^{58}Ni$ system the J_I values increase by about 20% over the same energy region. The increase in J_I values at higher energies is rather small as compared to the steep increase observed at lower energies. Hence in the present work it has been assumed that the J_I values for all energies above 210 MeV have the same values as found at 210 MeV. The E values at which J_I values become zero have been obtained by smooth extrapolation of J_I for E less than 50 MeV. In the case of the $^{6}Li+^{12}C$ system the E dependence of J_I

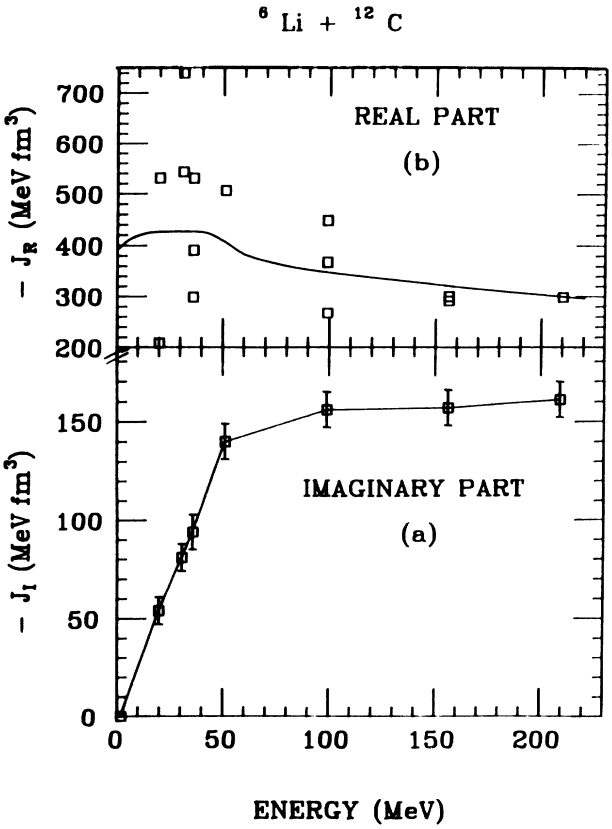

FIG. 1. The volume integrals (J_R and J_I) for the $^{6}Li+^{12}C$ system. The empirical values of J_I and J_R are represented as squares. The J_I values are joined by straight lines (a). The computed J_R values are plotted in (b). (See text for details.)

reported in the present work starting from individual best parameters is consistent with the result of an independent global analysis of the data for this system carried out in the E range 4–63 MeV.[10] As mentioned before, Gupta *et al.*[9] have already explained the E dependence of J_I for all the light ions with $A=1-6$ in a simple unified prescription. While the phenomenological analyses have clearly indicated E dependence for J_I, the microscopic folding model analyses have yielded mixed results. While Gomez-Camacho *et al.*[11] have explained the elastic scattering data for ^{6}Li+^{58}Ni system in the E range 12–74 MeV using E-independent folding potential for both the real and the imaginary parts, Satchler and Love,[12] in carrying out an analysis of the ^{6}Li+^{40}Ca system, using folding model for the real part and phenomenological prescription for the imaginary part, find the J_I values to be E dependent. In the present work we are mainly concerned with the phenomenological results.

The dispersion relation in the so-called subtracted form links the real and the imaginary potentials through the relation

$$J_{\Delta V,E_s}(E)=(E-E_s)\frac{P}{\pi}\int\frac{J_I(E')}{(E'-E_s)(E'-E)}dE\ , \tag{1}$$

where E_s is a convenient reference energy and P is the principal value of the integral

$$J_{\Delta V,E_s}(E)=J_{\Delta V}(E)-J_{\Delta V}(E_s)\ . \tag{2}$$

Basically there are two contributions to the energy dependence of the potential: One is intrinsic in nature and the other is "spurious" arising due to the nonlocality effect. The dispersion relation of interest is mainly concerned with the intrinsic energy dependence of the potential. If we can neglect the nonlocality effect, which may be a reasonable assumption to make for a projectile like ^{6}Li, we can proceed to make estimates of the dispersive contribution for ^{6}Li+^{12}C, ^{58}Ni systems. To estimate the dispersive contribution to the real part, we have represented J_I by several linear segments[2] with the computed J_I values for the vertices. The contribution due to each segment at a given E is given as

$$\pi J_{\Delta V_{ij}}(E)=[J_I(E_j)-J_I(E_i)](\epsilon_i\ln|\epsilon_i|-\epsilon_j\ln|\epsilon_j|)\ , \tag{3}$$

where $E_j>E_i$ and J_I values are taken to be positive. Further,

$$\epsilon_i=(E-E_i)/(E_j-E_i)\ ,$$

$$\epsilon_j=(E-E_j)/(E_j-E_i)\ .$$

It can be easily seen from the relation (3) that if J_I is constant as a function of E, then there can be no dispersive contribution from this part of the energy range. As mentioned earlier, as we have taken J_I to be a constant for E above 210 MeV, the dispersive contribution to the real

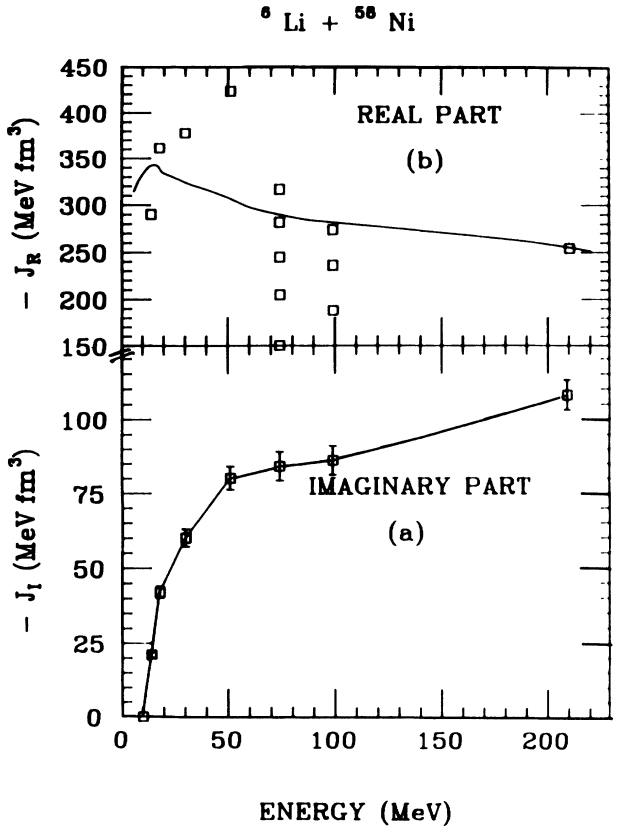

FIG. 2. The volume integrals (J_R and J_I) for the ^{6}Li+^{58}Ni system. The empirical values of J_I and J_R are represented as squares. The J_I values are joined by straight lines (a). The computed J_R values are plotted in (b). (See text for details.)

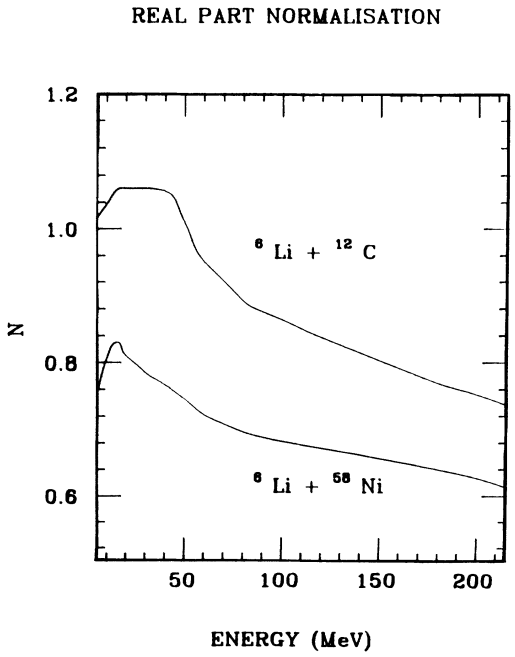

FIG. 3. The normalization value (N) plotted as a function of E for the systems ^{6}Li+^{12}C, ^{58}Ni. (See text for details.)

part is zero for all energies beyond 210 MeV. The total $J_{(\Delta V)}(E)$ is obtained by summing the contributions over all the segments. Finally the effective contribution to the real part is obtained using the relation (2). We have taken $E=210$ MeV as the reference energy[8] because at this E the real potential is more uniquely determined. The J_R values are -298 and -254 MeV fm^3 at this E for ^{12}C and ^{58}Ni, respectively. The dispersive contributions at other E values evaluated using Eq. (2) are added to the J_R value determined at $E=210$ MeV and are plotted in Figs. 1(b) and 2(b). It is found that the values of J_R are 30–40 % higher at the lowest energies as compared to the ones at the highest energy.[8] We have also plotted at the corresponding E values the J_R values determined from the optical model analysis just to indicate that the J_R values are scattered mainly due to the discrete ambiguity problem at lower energies.

It may be recalled that in the case of ^{6}Li, the folding model real potential[12] had to be reduced by about 30–40 % in order to make the calculations fit the elastic scattering data. As mentioned earlier, this reduction in the normalization value (N) has been mainly ascribed to the breakup effect of the projectile, which is supposed to add a repulsive contribution to the real part.[6] As both the strength and the shape of the folding potential do not depend on E, we can define J_R (obtained from phenomenological analysis)$=J_F$ (obtained from folding model) $\times N$. We have normalized the J_R values (obtained using the dispersion relation) to the known N values at $E=156$ MeV and converted the J_R plot to N vs E plot. It has been found[13] that the N values are 0.79 and 0.65 (interpolated between ^{40}Ca and ^{90}Zr), respectively, for ^{12}C and ^{58}Ni at $E=156$. By normalizing the J_R values [Figs. 1(b) and 2(b)] to these N values at $E=156$ MeV, we obtained the N values at other energies. In Fig. 3 we have plotted the N values as a function of E for both ^{12}C and ^{58}Ni. It is found that the N values increase as E is lowered and reach maximum values of 1 and 0.8 in the case of ^{12}C and ^{58}Ni, respectively.

In conclusion, we have calculated the dispersive contributions to the real part of ^{6}Li+^{12}C, ^{58}Ni systems using the dispersion relation that connects the real and the imaginary parts. We have found that at lower energies, due to the attractive component arising due to the dispersion relation, the J_R values are 30–40 % higher as compared to their values at the highest energy of 210 MeV.

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