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A POTENTIAL FOR THE DESCRIPTION OF ALPHA SCATTERING ON ^{7}Li AND ^{12}C AT LOW ENERGIES

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A simple potential is proposed for the description of the elastic cross sections of alpha scattering on ^{7}Li and ^{12}C at alpha energies 5 and 6 MeV. The potential described well the anomalous large angles scattering (ALAS). Also the optical potential parameters are extracted. Satisfactory fit between theory and experiment is obtained.

Key Words : Alpha Scattering; ^{7}Li, ^{12}C; Relativistic Nuclear Forces; Frnahaufer Effect; Complex Woods-Saxon Potential Real Phase-Shift Analysis

INTRODUCTION

RECENTLY, the interaction between α-particles at low energies has been investigated on the basis of relativistic nuclear forces. The α-interaction has an interesting feature that it produces only weak relative binding for two α-particles in spite of the strong internal binding of itself. This understanding brings about a new viewpoint on the structure of light nuclei.[1] Therefore, it is indispensable for developing further the understanding of the structure of light nuclei to clarify that the mechanism causing the interesting feature of the α-scattering is reproduced by an energy-independent but angular-momentum dependent potential which has the features both of outer weak attraction and of the inner strong repulsion. The inner strong repulsion is considered to reflect the compositeness of the interacting α-particle, as well as the angular-momentum dependent feature.

The elastic scattering of alpha particles on light nuclei has been found to show diffraction scattering of Franhaufer type at forward angles. In addition, anomalous large scattering (ALAS) has been observed.

The elastic scattering of alpha particle by ^{7}Li nucleus has been widely studied from incident energy $E_\alpha = 12$MeV to $E_\alpha = 42$MeV. These experimental data have been interpreted by assuming that the α-^{7}Li interaction can be parameterized into a complex Woods-Saxon potential. The optical parameters obtained by the study of these results have been collected in the compilation of the work performed by C M Perey and F G Perey.[2] The α-^{12}C interaction has also investigated extensively from $E = 8.76$ to $E = 166$ MeV by using optical model analysis.[2] In addition, the α-^{12}C elastic scattering below ^{15}N + P threshold has also been studied by several authors.[3–8] Some excited states of 0 up to excitation energy $E_x = 11.63$ MeV have also been investigated. Some recent studies about the nature of α-states in light nuclei give rise to a deeper understanding of such process.[9–13]

Some analyses were conducted[9–11] using the repulsive part of the alpha nucleus interaction for system α-α[9] and α-^{12}C[10,11] at energies between 2.6 and 6.5 MeV. Purely real potentials reproduce the experimental quantities E_x, Γ_x and elastic cross sections quite satisfactory. The angular distributions of α-particles scattered elastically by nuclei ^{12}C and ^{40}Ca at incident energies of 26.6 and 29MeV. The total amplitude was obtained by adding the optical amplitude to the amplitude of the exchange processes and interference between them. The differential cross sections have been interpreted by using real phase-shift analysis.[13] The real phase-shift analysis method is successful at energies investigated.

In this contribution, a proposed potential is used for the discription of the elastic cross sections of α-scattering on ^{7}Li and ^{12}C at alpha energies 5 and 6 MeV.

THEORETICAL CONSIDERATION

In the present paper, we discuss the subsequently proposed phenomenological effective surface potential with a repulsive core (ESP). One of the most prominent features of this potential is a nonlocality in form of an angular momentum-dependent radius of the repulsive core $R_{cor}(l, E)$, on the other hand, it should be recalled that the depth and geometry of the attractive Woods-Saxon potential did not depend on the alpha cluster states.

A nonlocality of such a type is as well implied by resonating group method (RGM). It is connected with the fact that states, which are prohibited by the Pauli principle, are to be extracted from the function of the relative motion of the alpha-particle and target nucleus leading to a nonlocal angular-momentum dependent repulsion. As a consequence, the even and odd levels are split due to the difference in the quantum numbers of the subshells from which the revelant alpha-clusters are formed.

The proposed potential is taken to be in the form:

$$V_{Esp} = V_{OM} + V_{cor}, \qquad \ldots(1)$$

where V_{OM} stands for the standard optical model potential

$$V_{OM} = V_{coul}(r) - Vf(X) - iWf(X)_i - V_{so}\,\frac{1}{r}\,\frac{d}{dr}f(X)\,\mathbf{L.S}, \qquad \ldots(2)$$

where $f(X) = [1 + \exp(r - r_0 A^{1/3})/a]^{-1}$

and

$$f(X_i) = [1 + \exp(r - r_i A^{1/3})/a_i]^{-1}.$$

The different terms denote Coulomb interaction, real central nuclear potential, imaginary and spin-orbit interaction, respectively. The Coulomb potential was assumed to be that of radius $R_{coul} = r_{coul}\,A^{1/3}$

and
$$V_{cor} = \begin{cases} C\,\mathrm{Sech}^2\,\dfrac{(r - \Delta r(-1)^l)}{a_c} & r - \Delta r(-1)^l \geqslant R_{cor} \\ 0 & r - \Delta r(-1)^l < R_{cor}, \end{cases} \qquad \ldots(3)$$

where C is compressibility modulus of finite nuclear matter.

The philosophy of the (ESP) is such that the optical potential is presumed to provide an adequate description for the normal case, i.e. $d\sigma/d\Omega$ for forward angles, while the additional phenomenological repulsive V_{cor} is adjusted to experimental data to account for the (ALAS).

CALCULATIONS AND DISCUSSION

In this contribution, the computations were carried out at the Physics Department, Tanta University, on an IBM (P.C.) computer using program code OPSECH 20.

The elastic channel of α-^{12}C interaction at $E_\alpha = 5$MeV it is only open channel, however, for $E_\alpha = 6.$ MeV, where there is a possibility of exciting the ^{12}C nucleus to its first excited state at $E_x = 4.439$MeV. The computation of $d\sigma/d\Omega$ for elastic α-particle scattering at energies 5,6MeV corresponds well with the experiment at low energies concerned. Since the role of channels other than the elastic one is small for energies and the quantity V_{om} was taken to be purely real, these results could be obtained when $C = 0$, i.e. is just the usual optical model equation with $V_{cor} = 0$. $C \neq 0$ implies that V_{cor} will also be different from zero. In such a way, the authors have extracted the parameter of the optical model at forward angles, hence C, the adjustable parameter available to improve the correspondence between theory and experiment. The results of calculations are illustrated in Figs. 1*a*, 1*b* for $E_\alpha = 5$MeV and 6MeV respectively. The obtained parameters using the proposed potential (1) are displayed in Table I.

In the case of α-^7Li elastic scattering at energies mentioned, the role of channels is open for which the target nucleus is excited to its first excited state of $E = 0.4776$MeV, V_{OM} should be complex. We have tried to describe the angular distribution with the potential (1) taking V_{OM} real a fit between theory and experiment could not be obtained. Including the imaginary part W to V leads to a quite good correspondence to experiment. The results of calculations are displayed in figs. 2*a*, 2*b*. On these figs. the full line represents the results of calculations with the pure real potential and the parameters in Table I, dashed line represents the results of calculations with imaginary part W and parameters in Table I. It

TABLE I

Parameters used in optical model plus repulsive core

Target	E_α (MeV)	V(r) (MeV)	r_v (fm)	a_v (fm)	W_s (MeV)	r_{ws} (fm)	a_{ws} (fm)	R_{cor} (fm)	a_{cor} (fm)	Δr_{cor} (fm)	C (MeV)
^7Li	5	140	1.3	.66	4.0	1.3	.66	1.3	.66	0.2	20
^7Li	6	140	1.3	.70	7.0	1.3	.60	1.3	.65	0.2	20
^{12}C	5	140	1.3	.65	0	0	0	1.3	.65	0.2	20
^{12}C	6	140	1.3	.65	0	0	0	1.3	.65	0.2	20

Note : Experimental data is from ref. 13.

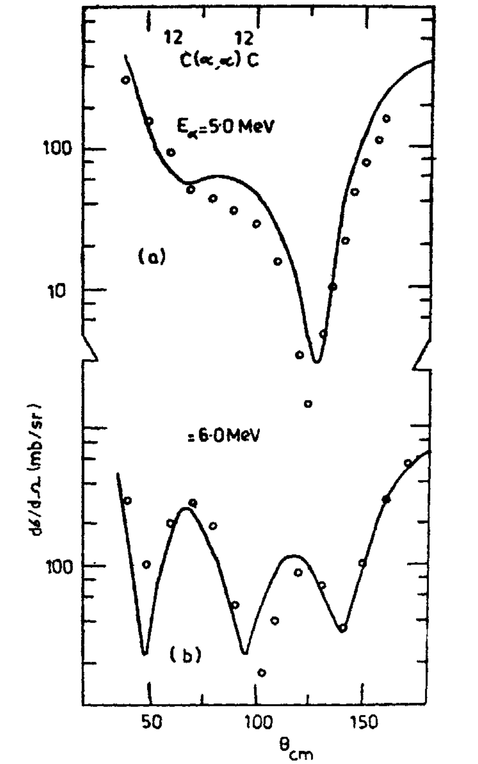

FIG 1 Experimental and theoretical angular distributions for the elastic scattering of α-particles by ^{12}C are illustrated, *full line*-calculations with a purely real potential and parameters from Table I. (*a*) at E_α = 5MeV and (*b*) at 6MeV circles—exp. data.[13]

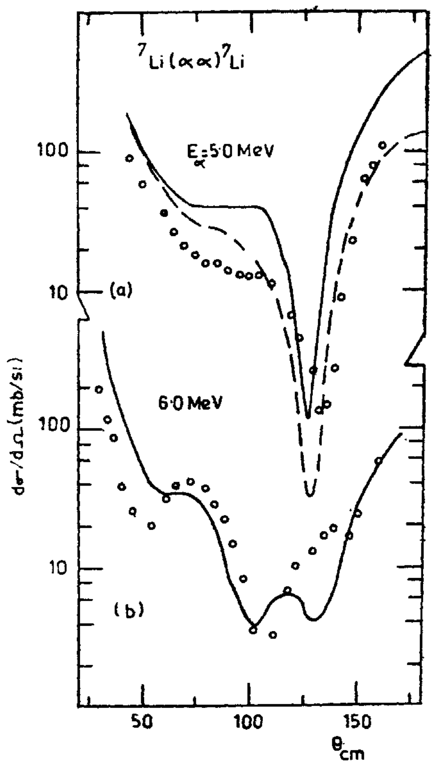

FIG 2 Experimental and theoretical angular distributions for the elastic scattering of α-particles by ^{7}Li are illustrated full line-calculations with a purely real potential;—*dashed line*—calculations with imaginary part w = 4 MeV., and parameters from Table I, at energy E_α = 5MeV (2*a*) and only with w = 7Mev at 6MeV (2*b*) circles—experimental data.

was pointed out[13] that the spin-orbit effect plays a relatively unimportant role in the case of ^{7}Li interaction at energies just mentioned.

CONCLUSION

It may be concluded that for light nuclei this phenomenological potential could reproduce well the angular distribution of the experimental differential cross sections for the elastic scattering of alpha particles. The results of this model calculation with the proposed potential are very encouraging giving rise to the hope that further studies into the exact form of the repulsive core will provide us with more insight into the reaction mechanism enabling us to extend the analysis to even higher energies and other nuclei,[14] also for projectiles close to α-particle.

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