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SINGLE NUCLEON TRANSFER REACTIONS IN $^{6}Li+^{6}Li$ COLLISIONS AT 156 MeV

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Abstract

Single nucleon transfer reactions in collisions of 156 MeV ^{6}Li ions with ^{6}Li nuclei, leading to unstable final nuclei (^{5}Li, ^{5}He) have been experimentally studied. The measured ^{6}Li(^{6}Li, ^{7}Li)^{5}Li$_{gr}$ and ^{6}Li(^{6}Li, ^{7}Be)^{5}He$_{gr}$ differential cross sections have been analysed on the basis of a FR-DWBA procedure, extracting information about the optical potentials acting in the exit channel.

EIN-NUKLEON TRANSFER-REATIONEN IN ^{6}Li+^{6}Li KOLLISIONEN BEI 156 MeV

Ein-Nukleon Transfer-Reaktionen bei Stößen von 156 MeV ^{6}Li-Ionen mit ^{6}Li-Kernen, die zu instabilen Endkernen (^{5}Li, ^{5}He) führen, wurden experimentell untersucht. Die gemessenen ^{6}Li(^{6}Li, ^{7}Li)^{5}Li$_{gr}$ und ^{6}Li(^{6}Li, ^{7}Be)^{5}He$_{gr}$ differentiellen Wirkungsquerschnitte wurden auf der Basis einer "finite-range" DWBA-Beschreibung analysiert, um Informationen über die optischen Potentiale, welche die Distortion im Ausgangskanal bewirken, zu gewinnen.

1. Introduction

Single nucleon pick-up reactions from ^{6}Li leading to the unbound systems of ^{5}Li and ^{5}He (with ground state widths $\Gamma = 0.6$ and 1.5 MeV, respectivley) provide the possibility to study the nuclear structure of such systems as well as the implications for the reaction mechanism, in particular of the distortion by the optical potentials acting between the observed (stable) ejectile and a metastable system. In fact, when analysing [1] measured ^{6}Li(p,d)^{5}Li [2] and ^{6}Li(n,d)^{5}He [3] differential cross sections on the basis of a conventional distorted waves Born approximation (DWBA) approach, it has been found that the experimental data rather sensitively require optical potentials in the exit channels which are significantly different from the ^{6}Li+d optical potential. By such effects, some information about optical potentials of unstable systems, otherwise hard to explore, seems to be accessible. The case of single nucleon transfer processes in ^{6}Li+^{6}Li collisions enables studies of two of such systems: ^{7}Li+^{5}Li and ^{7}Be+^{5}He, with an identical entrance channel, for which the optical potential has been recently extensively investigated at E_{Li} = 156 MeV [4]. At that relatively high projectile energy the parameters of the optical potential are fairly well determined, so that some problems from the well-known ambiguities at lower energies appear to be removed.

The present work reports the results of measurements of the differential cross sections for the ^{6}Li(^{6}Li,^{7}Li)^{5}Li$_{gr}$ and ^{6}Li(^{6}Li,^{7}Be)^{5}He$_{gr}$ reactions, induced by 156 MeV ^{6}Li projectiles. The experimental data are analysed with the aspect of their information about the interaction potentials of the scattering systems in the outgoing channels. The finite-range-DWBA analyses attempt to reproduce shapes and magnitudes of the measured cross sections with values of the spectroscopic factors which do not significantly differ from theoretical values, but by adjusting properly the (^{7}Li+^{5}Li) and (^{7}Be+^{5}He) optical potentials, respectively.

Some additional interest in the cross sections of producing ^{5}Li and ^{5}He arises from the question to which extent subsequent decays of ^{5}Li and ^{5}He do feed the α-particle channels e.g. and contribute there to the continuum spectra [5].

2. Experiment

The experiments studying single nucleon transfer reactions by bombarding ^{6}Li by ^{6}Li ions, have been performed at the Karlsruhe Isochronous Cyclotron, in the context of measurements of the differential cross sections of ^{6}Li+^{6}Li elastic and inelastic scattering [4,6]. The 156 MeV ^{6}Li beam has been focussed onto a ca. 3 mg/cm^{2} metallic ^{6}Li target (isotopic enrichment > 99 %) and the energy spectra of the charged ejectiles have been measured by a ΔE-E surface barrier detector telescope, mounted on a movable arm in a 130 cm Ø scattering chamber. Coincident pulse-pairs from the ΔE-E detectors were stored event by event on magnetic tape. Sorting and particle identification were performed off-line by software applying the Goulding method. At all emission angles a clear ^{6}Li-^{7}Li-^{7}Be separation was achieved over the full energy range. Some further details of the experimental set up and of the procedures are given elsewhere [7,4,6].

Fig. 1 displays the energy spectra of ^{7}Li and ^{7}Be ejectiles emitted at $\Theta_{Lab} = 6.3°$. In addition to the ground state transition peaks, there are some not-resolved states evident at excitation energies $E_x = 16 - 21$ MeV in ^{5}Li and ^{5}He. The states identified at $E_x \approx 16.7$ MeV in ^{5}He and ^{5}Li are experimentally well established [8,1] with $J^{\pi}=3/2^{+}$, and there is also evidence for a number of broad overlapping states in that region [3,8] in ^{5}He and ^{5}Li. We do not consider these excited states furtheron and extract from the spectra only the differential cross sections, leading to the ground states of ^{5}Li(Q = 1.586 MeV) and ^{5}He(Q = 1.015 MeV).

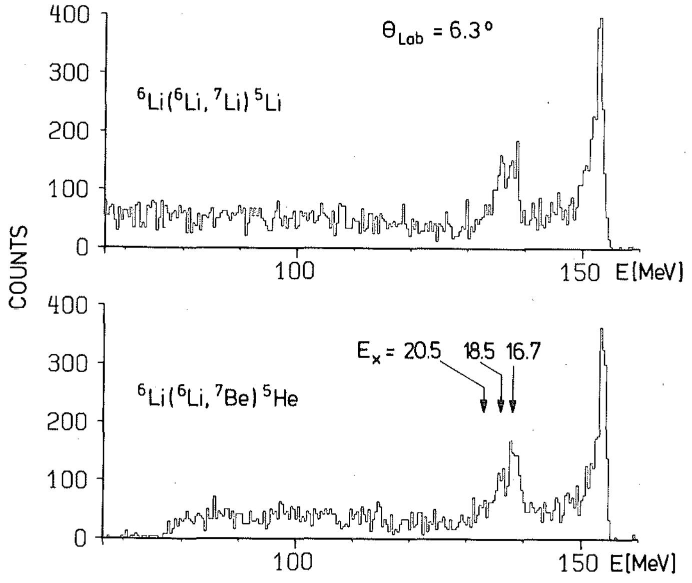

Fig. 1
Energy spectra of ^{7}Li and ^{7}Be ejectiles from ^{6}Li+^{6}Li collisions at 156 MeV. The asymmetric shapes of the ground state peaks may manifest (p+α) and (n+α) final state interaction effects [9].

The experimental cross sections are given in Fig. 2 (together with typical misfits of the DWBA analyses, discussed below). The cross sections are strongly forward peaked and show less structure, immediately indicating that not only the nuclear surface is sampled by the observed reactions. The angular distributions resemble very much the angular distributions observed in ^{6}Li(p,d)^{5}Li [1] and ^{6}Li(n,d)^{5}He [3] reactions. The angle-integrated cross sections for the ground state transitions for the neutron pick up ^{6}Li(^{6}Li,^{7}Li)^{5}Li$_{gr}$ equal to 2.7 ± 0.2 mb and to

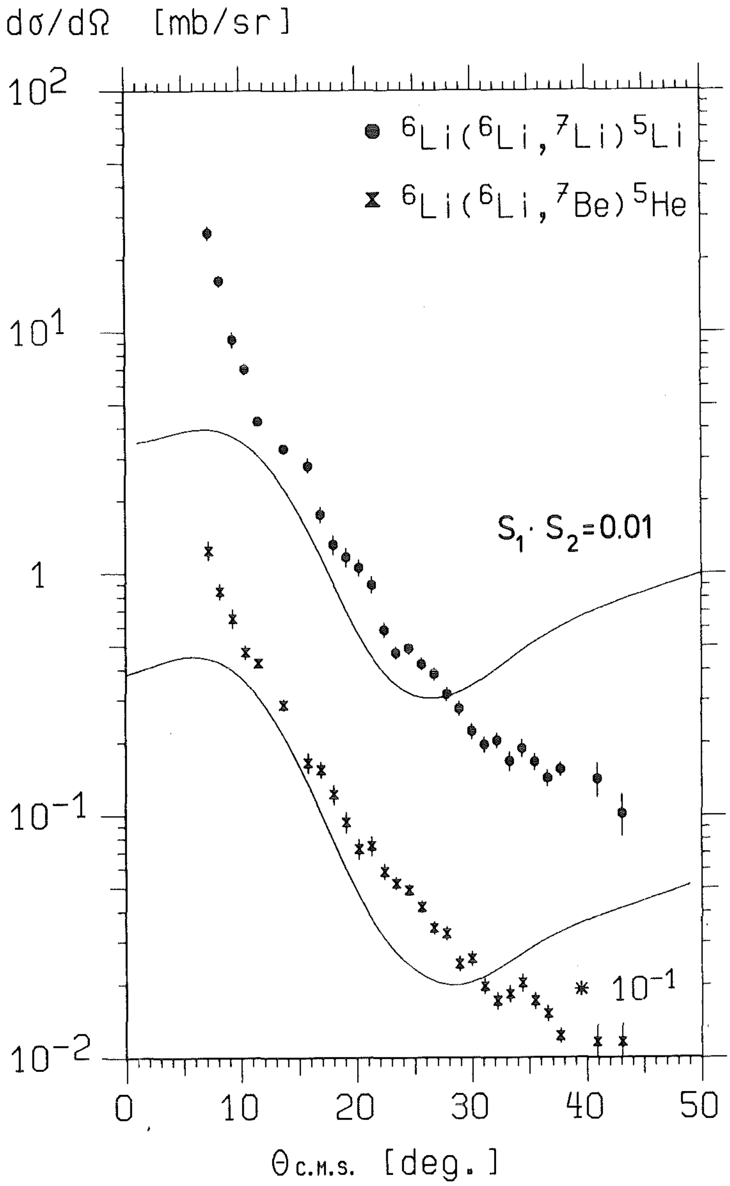

Fig. 2
Experimental cross sections for single nucleon transfer reactions when bombarding ^{6}Li by 156 MeV ^{6}Li ions. The solid curves are results of FR-DWBA calculations, representing typical misfits requiring unreasonable values of the spectroscopic factors, if the distorted waves in the outgoing channels are generated by the ^{6}Li + ^{6}Li elastic scattering optical potential [4].

1.8 ± 0.2 mb for the proton pick up $^{6}Li(^{6}Li,^{7}Be)^{5}He_{gr}$. The total cross section values summed over all excitation energies (including the continuum parts of the spectra) are found to be ca. 10 mb.

3. Basic theoretical features

When discussing the general features of the studied nucleon-pick up reactions with their interaction

$$V_{Li-Li} = V_{Li+Core} + V_{Li+p} \quad ,$$

the core-interaction is usually ignored, as in the DWBA reaction model elastic effects of $V_{Li+Core}$ are largely absorbed by the distorted waves, while in a plane-waves approximation (PWBA) the core is considered just as a spectator. This is, of course, not correct in general, because the interaction of the projectile with the particular core acts as absorption when studying the interaction of a specific participant. From this reason, any PWBA reaction model suffers from the inability to reproduce absolute values of the cross sections. However, a PWBA approach may well account for some global features of the differential cross sections as far as they are determined by the matching of the internal momentum distributions to inherent kinematical conditions, i.e. by the dependence on the momentum transfer $\vec{q}$ and on the momentum distribution of the transferred particles [10].

Being more specific and considering the proton pick up reaction $^{6}Li(^{6}Li,^{7}Be)^{5}He$ e.g., the PWBA transition amplitude may be written [11] by two integral factors.

$$\begin{aligned} T_{PWBA} \;\propto & \int d\vec{r}_{pHe}\; e^{-i\vec{q}\,\vec{r}_{pHe}}\, \psi(\vec{r}_{pHe}) \\ & * \int d\vec{r}_{Lip}\; \phi^{*}_{^{7}Be}(\vec{r}_{Lip})\; V(\vec{r}_{Lip})\; e^{i\vec{K}\cdot\vec{r}_{Lip}} \end{aligned} \qquad (3.1)$$

with the coordinates defined in Fig. 3

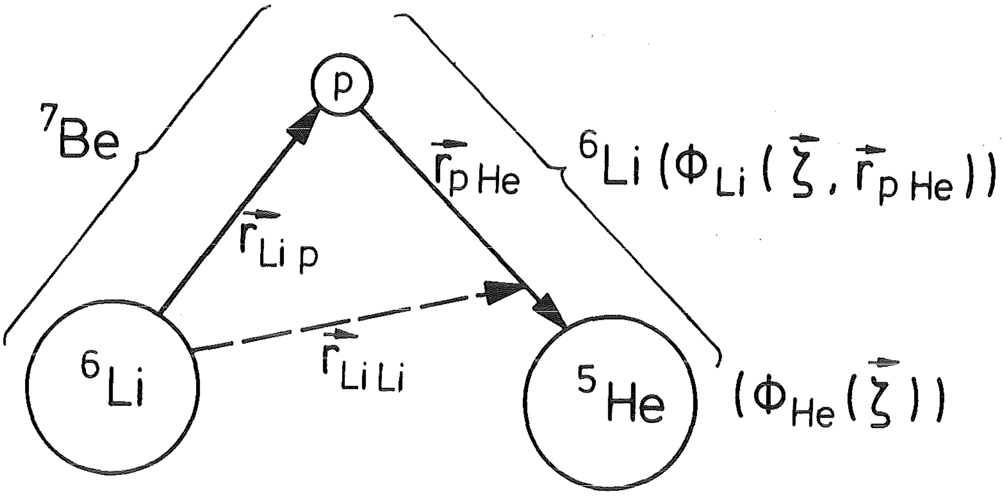

Fig. 3 Coordinates of the single proton pick up reaction

and

$$\vec{q} = \vec{k}_{^7\mathrm{Be}} - \frac{M_{\mathrm{He}}}{M_{\mathrm{Li}}} \vec{k}_{\mathrm{Li}} \tag{3.2a}$$

$$\vec{K} = \vec{k}_{^6\mathrm{Li}} - \frac{M_{\mathrm{Li}}}{M_{\mathrm{Be}}} \vec{k}_{^7\mathrm{Be}} \tag{3.2b}$$

The overlap integral of the initial and final "target" states

$$\Psi(\vec{r}_{\mathrm{pHe}}) = \int d\ \xi_{\mathrm{He}}(\vec{\xi})\ \phi_{\mathrm{Li}}(\vec{\xi},\vec{r}_{\mathrm{pHe}})\ d\vec{\xi} \tag{3.3}$$

describes the amplitude of finding a proton bound in the ^{5}He core (usually specified more in detail by a fractional parentage expansion). Thus, the first integral factor $\Psi(q)$ in the T_{PWBA} amplitude (3.1) represents the probability of finding a proton in the ("target") ^{6}Li with momentum $\vec{q}$.

The second factor [10]

$$\begin{aligned} G(K) &= \langle \phi_{^7\mathrm{Li}}(\vec{r}_{\mathrm{Lip}}) | V(\vec{r}_{\mathrm{Lip}}) |\ e^{i\,\vec{K}\cdot\vec{r}_{\mathrm{Lip}}} \rangle \\ &= \int dk \langle \phi_{^7\mathrm{Li}}(\vec{r}\,'_{\mathrm{Lip}}) |\ e^{i\,\vec{k}\vec{r}\,'_{\mathrm{Lip}}} \rangle \langle e^{i\,\vec{k}\vec{r}\,'_{\mathrm{Lip}}} | V(r_{\mathrm{Lip}}) | e^{i\,\vec{k}\vec{r}_{\mathrm{Lip}}} \rangle \end{aligned} \tag{3.4}$$

is the amplitude of scattering of the projectile (^{6}Li) and the bound proton, having the initial momentum $\vec{K}$ into a state with a relative momentum k, folded with the momentum distribution of the transferred proton bound in the ejectile (^{7}Be). The quantity G(K) can be evaluated [11] introducing explicitely the bound state wave function of the bound proton in the ejectile

$$G(K) = -\frac{\hbar^2}{2\mu_{Lip}}(K^2+\alpha^2)\int \phi^*_{^7Li}(\vec{r}_{Lip})\, e^{i\vec{K}\vec{r}_{Lip}}\, d\vec{r}_{Lip} \qquad (3.5)$$

where $-\varepsilon_{Be} = \hbar^2\alpha^2/2\mu_{Lip}$ is the binding energy in the ejectile.

When evaluating the quantity G(K) for the particular cases $(^7Be, ^7Li)$, a relatively weak K dependence of G(K) is noticed (which would lead, extremely simplified, to the zero-range approximation). Thus, the shape of the differential cross sections seems to be dominantly determined by the first integral factor in eq.(3.1), i.e. by the momentum distribution of the pick up proton in the target nucleus. Fig. 4 compares the differential cross sections of the $^6Li(^6Li,^7Li)^5Li$ and $^6Li(^6Li,^7Be)^5He$ reactions at the same momentum transfer q with corresponding neutron and proton transfer $^6Li(p,d)^5Li$ [2] and $^6Li(n,d)^5He$ [3] reactions. In fact, there appear conspicuous empirical similarities in the q-dependence, and in addition relative small differences in the magnitude, revealing, first of all, a similar reaction mechanism. For the case of $^6Li(^6Li,^7Be)^5He$ the shapes of the PWBA cross section and of $|\tilde{\psi}(q)|^2$

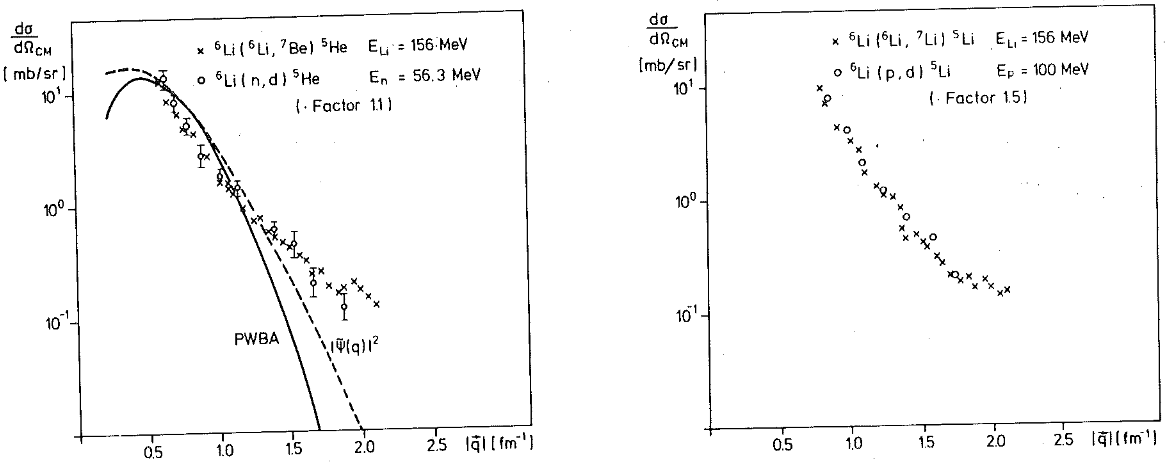

Fig. 4 Momentum transfer dependence of neutron and proton transfer reactions from ^6Li

are shown in Fig. 4 (in arbitrary units). Apart from the question of the absolute magnitude of the cross sections, strongly affected by the absorption, the comparison with data emphasizes the necessity of a proper account for the distortions and of finite range effects.

4. DWBA analysis and results

The Finite-Range DWBA calculations were carried out using the computer code LOLA [12], slightly modified in order to take correctly into account the identity of the interacting spin-one particles in the incident channel [13,14]. In addition, a search routine has been included, adjusting a selected set of parameter values by the χ^2/F-minimum criterion.

We basically assume that the considered reactions proceed via a 1p nucleon pick up from the ^{6}Li ground state, for which both $1p_{3/2}$ and $1p_{1/2}$ orbitals are theoretically expected to be present [15]. In the actual calculations we considered pure $p_{3/2}$ nucleon transfers since the $p_{1/2}$ and $p_{3/2}$ wave functions are fairly similar and as the spectroscopic details are of less importance for the aspect underlying this analysis. The wave functions of a single $p_{3/2}$ - shell nucleon, bound in the ^{5}Li, ^{6}Li and ^{5}He core, were calculated with Saxon-Woods shapes of the single-particle bound state potentials. The geometrical parameters of these binding potentials were chosen (see table 1) in the same way as by Li et al. [2]. The depths V_o of the central parts were adjusted in order to give appropriate bindings energies. The values of V_o and of the binding energies, given in table 1, refer to the $p_{3/2}$ orbitals.

The spectroscopic factors $S_1 \times S_2$ have been derived from theoretical results given by Cohen and Kurath [15], consistent with experimental results [3]. They amount in both cases for the $p_{3/2}$ pick up to $S_1 \times S_2 = 0.0914$.

The distorted waves in the incident ^{6}Li+^{6}Li channel have been generated by the optical potential deduced by extensive experimental elastic scattering studies at $E_{Li} = 156$ MeV [4]. It has been shown that a spin-orbit potential is not significant in the elastic ^{6}Li+^{6}Li scattering, so that such a term in the optical poten-

Nucleus = Core + Nucleon	$-V_o(p_{3/2})$ (MeV)	r_{ov}^* (fm)	a_v (fm)	$-V_{so}$ (MeV)	r_{oso}^* (fm)	a_{so} (fm)	Binding energy (MeV)
$^6Li_{gr} = {}^5Li_{gr} + n$	50.5	1.45	0.65	8.3	1.45	0.65	7.15
$^7Li_{gr} = {}^6Li_{gr} + n$	52.6	1.45	0.65	13.0	1.45	0.65	5.66
$^6Li_{gr} = {}^5He_{gr} + p$	54.0	1.45	0.65	8.3	1.45	0.65	4.59
$^7Be_{ge} = {}^6Li_{gr} + p$	50.5	1.45	0.65	13.0	1.45	0.65	5.60

*) $R_i = r_{oi}\ A_{core}^{1/3}$ $R_c = 1.25 \cdot A_{core}^{1/3}$ (fm)

Table 1 Parameters of the single-nucleon bound state potentials [2] (Central part: Saxon-Woods shape - Spin-orbit: Thomas-form [2])

tials has been neglected furtheron in the entrance and in the outgoing channels as well. In particular, we adopt a (real) squared Saxon-Woods shaped potential, resulting from a best-fit of the elastic $^6Li+^6Li$ data, without admitting a spin-orbit interaction, but with volume and surface absorption terms (set C in table 1 of ref. 4). The same general form has been used for the optical potentials acting in the exit channels. However, while the $^6Li+^6Li$ potential in the ingoing channel has been kept fixed, the parameters for outgoing channels have been varied and adjusted in order to get a best-fit for the data with values of the spectroscopic factors, which approach otherwise well established values (theoretically deduced and consistent with available experimental information [2]).

As indicated by the calculated cross sections shown in Fig. 2, a reasonable description of the data cannot be achieved, if the distorted waves in the exit channels are generated by the same (or only slightly different) optical potential as in the incident channel. In fact, such a feature has been already reported and complained in the studies of the $^6Li(p,d)^5Li$ and $^6Li(n,d)^5He$ reactions [1,3].

Fig. 5 compares the experimental data with the best-fit theoretical cross sections resulting from the adjustment of the ($^7Li+^5Li$) and ($^7Be+^5He$) optical potentials, in particular of the

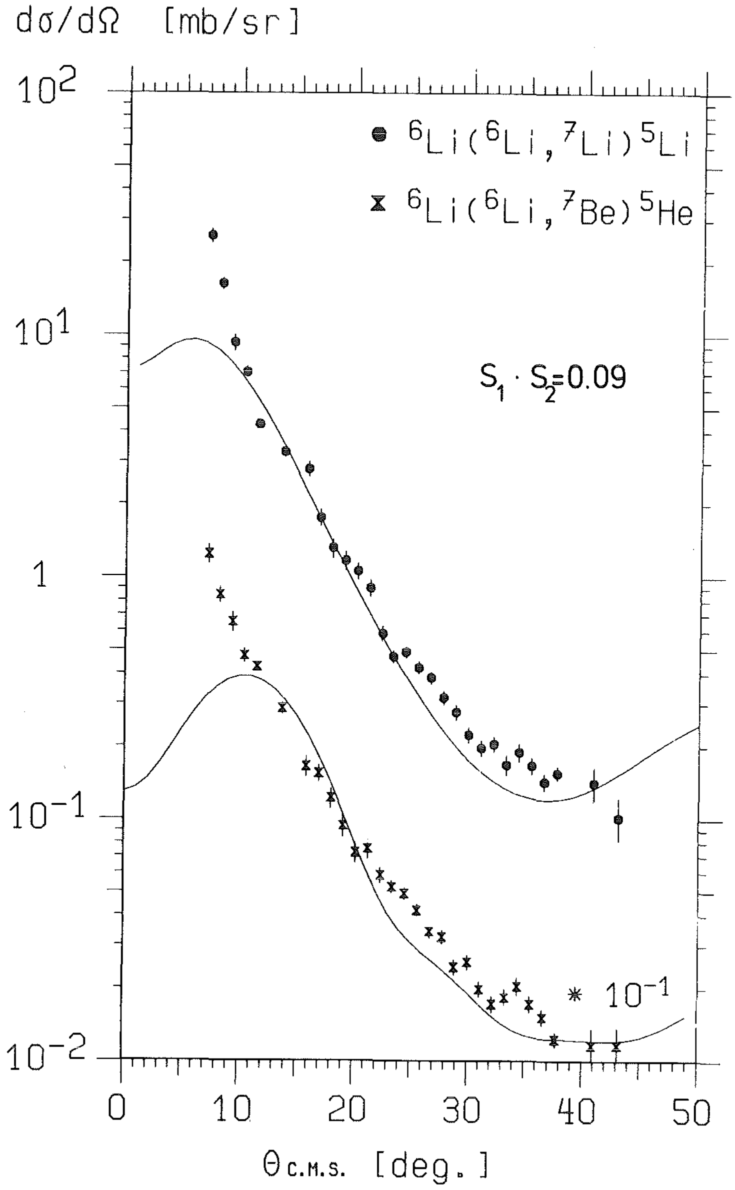

Fig. 5 Results of the FR-DWBA analyses of the $^6Li(^6Li,^7Li)^5Li_{gr}$ - and $^6Li(^6Li,^7Be)^5He_{gr}$ transfer cross sections with values of the spectroscopic factors being in agreement with independent information.

values of the real part and the strength of the absorption (see table 2). Although the theoretical description appears to be certainly not perfect (especially at forward angles), the experimental cross sections are resonably well reproduced, however with significant changes in V_o and in the absorption strength $W(W_o,W_s)$ as compared to the entrance channel.

Channel	$-V_o$ (MeV)	r_v (fm)	a_v (fm)	$-W_o$ (MeV)	r_w (MeV)	a_w (fm)	$-W_s$ (MeV)	r_s (fm)	a_s (fm)	S_1xS_2
^{6}Li+^{6}Li	73.3	2.16	1.13	1.1	3.57	0.43	10.7	2.10	0.58	
^{7}Li+^{5}Li	113.3	1.21	0.67	4.08	3.57	0.43	17.4	2.10	0.58	0.09
^{7}Be+^{5}He	132.7	2.13	1.07	1.33	3.57	0.43	17.4	2.10	0.58	0.09

Tab. 2 Optical potentials of the incident and exit channels
The real part is a squared Saxon-Woods form

$$U_R(r)=V_o(1+\exp((r-r_v\cdot A^{1/3})/a_v))^{-2},$$

the volume absorption is of the Saxon-Woods form, while the surface absorption is parametrized

$$U_S(r)=4i\ W_s\ a_s\ d/dr(1+\exp((r-r_sA^{1/3})/a_s)^{-1}$$

Fig. 6 presents calculated cross sections with some particular parameter values, arbitrarily altered by ± 20 % and keeping the other fixed with the best-fit values. They provide a feeling about the sensitivity of the cross sections to the exit-channel optical potentials and demonstrate the significance of the observed effects.

5. Concluding remarks

The experimental differential cross sections for the single nucleon transfer reactions ^{6}Li(^{6}Li,^{7}Li)^{5}Li$_{gr}$ and ^{6}Li(^{6}Li,^{7}Be)^{5}He$_{gr}$ have been measured at E_{Li} = 156 MeV and analysed on the basis of a conventional FR-DWBA approach, looking for some global information on the interaction in the exit channels. In contrast to the general expectation [16] that the optical potentials in the incident and exit channels should not considerably differ for similar systems, the considered cases, involving light and unstable nuclei (^{5}Li,^{5}He), require significant differences between the ^{6}Li+^{6}Li, ^{7}Li+^{5}Li and ^{7}Be+^{5}He optical potentials used to describe the data.

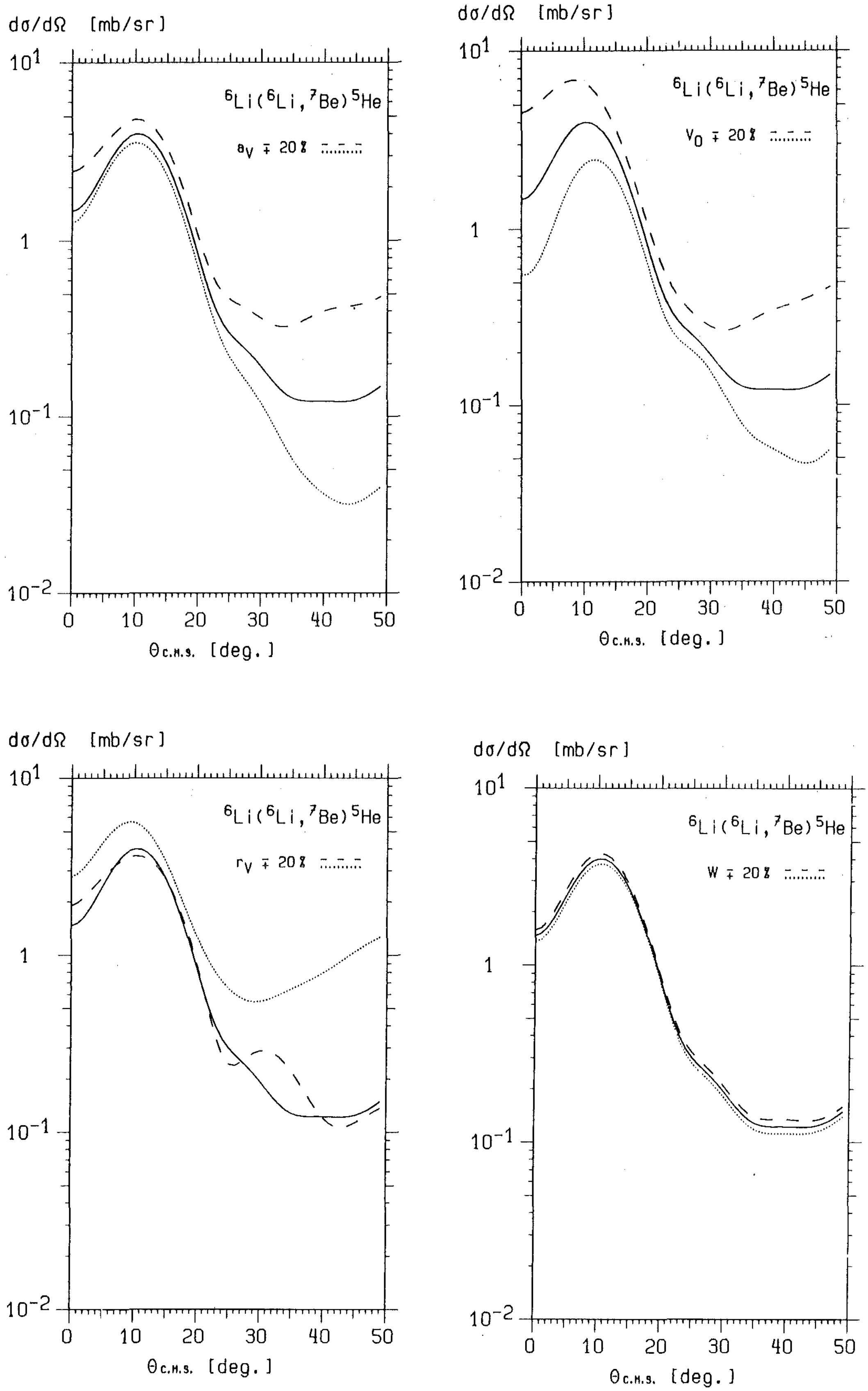

Fig. 6a-d Theoretical ^{6}Li(^{6}Li,^{7}Be)^{5}He$_{gr}$ cross sections calculated on the basis of the FR-DWBA demonstrating the sensitivity on various optical potential parameters.

In 1964 P. Hodgson commented [16] on such an indirect approach, exploring the interaction potentials of unstable or excited nuclear systems, with emphasizing *"when reaction theory is further advanced"*. In fact, the discussed effects arise with the application of a first order conventional DWBA procedure, explicitely omitting higher order processes. Such processes contribute most likely to reactions between light nuclei [17,18] and may account for the obvious remaining deficiencies in describing the experimental data at all, even after the adjustment of the distorting potentials. The investigation of the question whether two-step processes in the elastic exit channel interaction [18] are just absorbed by the effects observed with the first order DWBA, is of further interest. But it needs a more elaborate and complicated description of the reaction mechanism, adequately accounting for the specific nature of decaying nuclear systems interacting with the ejectiles.

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References

1. L.A. Kull, Phys. Rev. 163 (1967) 1066
2. T.Y. Li and S.K. Mark, Nucl. Phys. A 123 (1969) 147
3. F.P. Brady, N.S.P. King, B.E. Bonner, M.W. McNaughton, J.C. Wang and William W. True, Phys. Rev. C16 (1977) 31
4. S. Micek, Z. Majka, H. Rebel, H.J. Gils and H. Klewe-Nebenius, Nucl. Phys. A 435 (1985) 621
5. D.R. Brown, J. Halpern, J.R. Calarco, P.A. Russo, D.L. Hendrie and H. Homeyer, Phys. Rev. C14 (1976) 896
6. Y. Sakuragi, M. Kamimura, S. Micek, H. Rebel and H.J. Gils, Z. Phys. A (in press)
7. J. Cook, H.J. Gils, H. Rebel, Z. Majka and H. Klewe-Nebenius, Nucl. Phys. A 388 (1982) 173
8. F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. A 227 (1974) 1 and references therein.
9. E.L. Haase, W.N. Wang and M.A. Fawzi, Nucl. Phys. A 172 (1978) 81
10. G.F. Chew and M.L. Goldberger, Phys. Rev. 77 (1950) 470
11. Daphne F. Jackson, Nuclear Reactions (Methuen & Co., London 1970) p. 188
12. R.M. de Vries, Phys. Rev. C8 (1973) 951
13. M.L. Goldberger and K.M. Watson, Collision Theory (New York: Wiley, 1964)
14. L. Jarczyk, B. Kamys, A. Magiera, A. Strzałkowski, A. Szczurek, K. Bodek, M. Hugi, J. Lang, R. Müller and E. Ungricht, J. Phys. G: Nucl. Phys. 11 (1985) 843
15. S. Cohen and D. Kurath, Nucl. Phys. A 101 (1961) 1
16. P.E. Hodgson, Compt. Rend. Congrès Internat. Physique Nucl., ed. P. Guggenberger (Paris 1964) p. 288
17. K. Bodek, M. Hugi, J. Lang, R. Müller, A. Schiltz, J. Sromicki, E. Ungricht, L. Jarczyk and A. Strzałkowski, Phys. Lett. 92B (1980) 79
18. B. Kamys, L. Jarczyk, Z. Rudy, A. Strzałkowski, H.H. Wolter, J. Lang, R. Müller and J. Sromicki, Nucl. Phys. A 406 (1983) 193

APPENDIX

Reaction Cross Sections (CM system)

E_{Li} = 156 MeV

$^{6}Li(^{6}Li,{}^{7}Li)^{5}Li_{gr.}$

THETA degree	SIGMA mb/sr	DSIGMA mb/sr
7.2	25.75	1.5708
8.2	16.32	0.8650
9.3	9.32	0.6990
10.4	7.03	0.3585
11.5	4.27	0.1495
13.7	3.28	0.1542
15.8	2.79	0.1981
16.9	1.756	0.1264
18.0	1.315	0.1197
19.1	1.165	0.1037
20.2	1.057	0.0814
21.3	0.897	0.0718
22.4	0.585	0.0415
23.4	0.469	0.0267
24.5	0.4898	0.0260
25.6	0.4215	0.0232
26.7	0.3833	0.0215
27.8	0.3168	0.0200
28.9	0.2761	0.0185
30.0	0.2222	0.0162
31.1	0.1964	0.0143
32.2	0.2039	0.0145
33.3	0.1675	0.0152
34.4	0.1888	0.0159
35.5	0.1661	0.0128
36.6	0.1425	0.0108
37.7	0.1546	0.0096
40.9	0.1413	0.0220
43.1	0.1015	0.0199

$^{6}Li(^{6}Li,{}^{7}Be)^{5}He_{gr.}$

THETA degree	SIGMA mb/sr	DSIGMA mb/sr
7.2	12.47	1.0974
8.2	8.45	0.6253
9.3	6.52	0.5803
10.4	4.74	0.2986
11.5	4.258	0.1490
13.7	2.865	0.1461
15.8	1.654	0.1538
16.9	1.545	0.1190
18.0	1.223	0.1150
19.1	0.939	0.0930
20.2	0.728	0.0677
21.3	0.755	0.0687
22.4	0.587	0.0417
23.4	0.524	0.0283
24.5	0.492	0.0261
25.6	0.420	0.0231
26.7	0.343	0.0202
27.8	0.326	0.0202
28.9	0.2447	0.0174
30.0	0.2560	0.0177
31.1	0.1979	0.0142
32.2	0.1720	0.0134
33.3	0.1834	0.0141
34.4	0.2040	0.0165
35.5	0.1720	0.0131
36.6	0.1520	0.0112
37.7	0.1230	0.0086
40.9	0.1160	0.0197
43.1	0.1150	0.0212