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EXACT-FINITE-RANGE DWBA ANALYSIS OF $^{12}\text{C}(\vec{^6\text{Li}}, \alpha)^{14}\text{N}$ REACTION AT $E(^6\text{Li}) = 20$ MeV

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Résumé. — Nous présentons une analyse DWBA des pouvoirs d'analyse observés dans la réaction $^{12}\text{C}(\vec{^6\text{Li}}, \alpha)^{14}\text{N}$ étudiée à Heidelberg à l'aide d'une source de ^6Li vectoriellement polarisée. Nous avons concentré notre étude sur les trois états 1^+ de ^{14}N : fondamental, 6,20 MeV et 9,70 MeV, ceux-ci étant particulièrement aptes à une description en termes d'un transfert direct de deuteron.

Abstract. — We have performed EFR-DWBA calculations of the analysing powers observed in the $^{12}\text{C}(\vec{^6\text{Li}}, \alpha)^{14}\text{N}$ reaction with the vector polarized ^6Li source of Heidelberg. We have focused our analysis on the three 1^+ states : ground, 6.20 MeV and 9.70 MeV states of the ^{14}N nucleus which are particularly relevant for a deuteron cluster direct transfer.

Recently M. Makowska-Rzeszutko *et al.* ⁽¹⁾ (see ref. [1]) have measured the analysing powers observed in the $^{12}\text{C}(\vec{^6\text{Li}}, \alpha)^{14}\text{N}$ reaction at $E(^6\text{Li}) = 20$ MeV using the vector polarized ^6Li beam installed at the Heidelberg EN-Tandem [2]. Table I gives the transitions investigated by these authors and the dominant configurations of the ^{14}N residual nucleus states predicted by the shell model analysis of W. True [4]. Using these theoretical predictions and also the ^{14}N states already observed by K. Meier-Ewert *et al.* [5] we have focused our analysis on the three 1^+ states : g.s., 6.20 MeV and 9.70 MeV which are the most relevant for a deuteron-cluster direct transfer in a $(^6\text{Li}, \alpha)$ reaction. R. L. White *et al.* [6, 7] have already shown the evidence for the direct nature of this reaction at $E(^6\text{Li}) = 33$ MeV. In this way we have tried to analyse the analysing powers of M. Makowska-Rzeszutko *et al.* in the frame of the exact-finite-range distorted-wave-Born-approximation (EFR-DWBA) formalism developed by T. Tamura [10] which takes into account exactly the recoil and finite range effects. In this way we have modified the SATURN-MARS-1 Codes [11] of T. Tamura and K. S. Low in order to include the spin-orbit distortions in the optical waves and also to extract the polarization observables from the transition matrix. Table II gives the optical parameters we

TABLE I
 ^{14}N excited states observed by M. Makowska-Rzeszutko *et al.* ⁽¹⁾ in the $^{12}\text{C}(\vec{^6\text{Li}}, \alpha)^{14}\text{N}$ reaction at $E(^6\text{Li}) = 20$ MeV. The dominant configurations are given by W. True [2].

Energy (MeV)	J^π, T	Dominant configurations
—	—	—
0	$1^+, 0$	$p_{1/2}^2$
3.95	$1^+, 0$	core excited
4.91	$0^-, 0$	$p_{1/2} s_{1/2}$
5.11	$2^-, 0$	$p_{1/2} d_{5/2}$
5.69	$1^-, 0$	$p_{1/2} s_{1/2}$
5.83	$3^-, 0$	$p_{1/2} d_{5/2}$
6.20	$1^+, 0$	$s_{1/2}^2$
6.44	$3^+, 0$	$s_{1/2} d_{5/2}$
7.03	$2^+, 0$	core excited
7.97	$2^-, 0$	$p_{1/2} d_{3/2}$
8.49	(4^-)	—
8.96/8.98	$5^+/2^+$	unresolved
9.13	$2^+, 1$	core excited
9.39	2^-	—
9.70	$1^+, 0$	$d_{5/2}^2$
10.06/10.10	?	—
10.81	4^+	—

⁽¹⁾ MAKOWSKA-RZESZUTKO, M., EGELHOF, P., KASSEN, D., STEFFENS, E., WEISS, W., FICK, D., DREVES, W., KUBO, K.-I. and SUZUKI, T., private communication.

use in this work ; for the ^6Li channel we have two sets (denoted A and B) which are the result of a recent analysis we have made [8] of the ^6Li elastic scattering

TABLE II

Optical parameters of the entrance and exit channels. All the depths are in MeV ; the radii and the diffusenesses are in fm. The radii have the form $R = r_0 A_T^{1/3}$

	V	r_0	a	W_{vol}	r_0	a	V_{LS}	r_0	a	r_{oc}
$^6\text{Li} + ^{12}\text{C}$	(A) 71.1	1.954	0.689	8.62	2.504	0.114	18.37	1.243	0.476	1.35
	(B) 71.1	1.954	0.689	8.62	2.504	0.114	14.62	1.476	0.293	1.35
$\alpha + ^{14}\text{N}$	54.87	1.748	0.569	5.17	1.748	0.569	—	—	—	1.2

of W. Weiss *et al.* [3]; for the α channel we have used optical parameters at 19.2 MeV taken from C. M. Perey and F. G. Perey's table [9]. The cluster-direct-transfer calculations we have made assume that ^{14}N is a ^{12}C closed-shell core plus a bound deuteron. The deuteron is assumed to be in a 1S internal state and the α particle and deuteron in ^6Li have only 2S relative motion (the 1S relative state will be discussed later on). These bound state Woods-Saxon parameters and the cluster configurations, calculated from W. True [4] with the relation

$$\sum_{i=1}^2 [2(n_i - 1) + l_i] = 2(N - 1) + L,$$

are taken from R. L. White *et al.* [6, 7] and are given in the table III.

TABLE III

Bound state parameters and assumed cluster configurations. The energies are in MeV ; the radii and the diffusenesses are in fm. The radii have the form $R = r_0 A_T^{1/3}$.

		r_0	a	E_s	N	L
^{14}N	g.s.	1 ⁺	1.94	0.65	10.27	1 2
	6.20 MeV	1 ⁺	1.94	0.65	4.07	3 0
	9.70 MeV	1 ⁺	1.94	0.65	0.57	2 2
^6Li	g.s.	1 ⁺	2.15	0.65	1.47	2 0

Figure 1 displays the results we have obtained for the ^{14}N 1⁺ states : g.s., 6.20 MeV and 9.70 MeV. The upper part of this figure shows the difference between two sets A and B of optical parameters for the entrance channel. Main difference concerns the analysing power of the ^6Li scattering on ^{12}C which is described better with B than A set. This difference is weak for the 6.20 MeV state and quite large for ground state, the A-set giving the best result. We have also tried to assume a 1S state for the α -d relative motion in ^6Li . The results of these calculations are given on the lower part of the figure 1 and they confirm that the 2S relative motion for the ^6Li wave function seems to be more physical than the 1S one. Moreover such a 2S relative

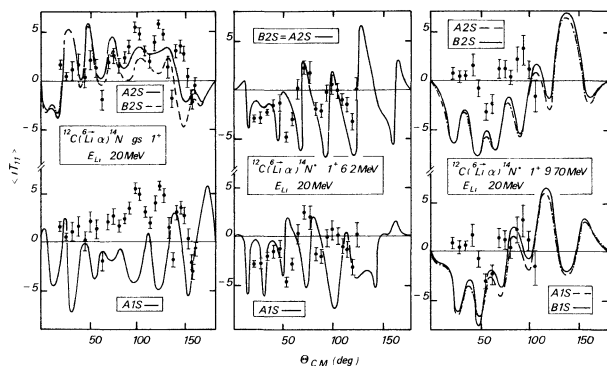


FIG. 1. — Angular distributions of analysing powers $\langle iT_{11} \rangle$ for the $^{12}\text{C}(^6\text{Li}, \alpha)^{14}\text{N}$ reaction for the three ^{14}N 1⁺ states : g.s., 6.20 MeV and 9.70 MeV. A (or B) denotes the ^6Li optical parameter set used while 2S (or 1S) denotes the relative motion state used for the description of $^6\text{Li}(\alpha + d)$.

state is predicted first by the shell-model and also when antisymmetrization is included in a ^6Li cluster model [12, 13]. The use of a 2S relative state is not confirmed by our results concerning the 1⁺ 9.70 MeV state but it must be noted that the agreement between our calculation and the experimental data is not so good especially at forward angles.

Our EFR-DWBA analysis of the analysing powers observed in the $^{12}\text{C}(^6\text{Li}, \alpha)^{14}\text{N}$ reaction at $E(^6\text{Li}) = 20$ MeV gives a good justification of the description of this mechanism by a deuteron-cluster direct-transfer. The higher order terms seem here to be negligible, while at $E(^6\text{Li}) = 22.8$ MeV we can observe a strong contribution of two-step process [14]. This is also the case in the $^{16}\text{O}(^6\text{Li}, \alpha)^{18}\text{F}$ reaction at $E(^6\text{Li}) = 34$ MeV where the exchange effects seem to be important [15].

Further investigations concerning this $^{12}\text{C}(^6\text{Li}, \alpha)^{14}\text{N}$ reaction at $E(^6\text{Li}) = 20$ MeV are being carried out especially concerning the description of all transitions observed by M. Makowska-Rzeszutko *et al.* (1) in terms of a two-nucleon transfer treatment.

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