THE SUCCESS OF THE DISTORTED WAVE METHOD AT VERY HIGH INCIDENT ENERGY

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THE SUCCESS OF THE DISTORTED WAVE METHOD AT VERY HIGH INCIDENT ENERGY

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Résumé - Les réactions de transfert direct d'un proton et d'un neutron in-
duites par un faisceau de ^{16}O de 793 MeV bombardant une cible de ^{208}Pb sont
largement expliquées par deux règles de sélection contenues dans le formalis-
me de la Méthode des ondes distordues.

Abstract - The one-proton and one-neutron direct surface transfer reactions
induced by 793 MeV ^{16}O incident energy beam bombarding a ^{208}Pb target nu-
cleus, are widely explained by two selection rules contained in the Distorted
Wave Method formalism.

One-nucleon transfer reaction induced by a 793 MeV ^{16}O beam bombarding a ^{208}Pb tar-
get has been studied at the GANIL facility using an energy-loss magnetic spectrome-
ter in order to evidence two selection rules concerning single-particle state popu-
lations for various spins $j_f = \ell_f \pm 1/2$. The first selection rule tells us : as the
incident energy increases, the strongly excited states are the ones having a large
orbital angular momentum ℓ_f (ref./1/). This is due to the increase of angular momen-
tum mismatch between the entrance and exit grazing partial waves as the incident
energy increases. Then large transfer angular momentum is needed in order to assure
the proper balance between grazing wave angular momenta. The second selection rule
says that starting, in the projectile, from an initial single particle state of spin
$j_i = \ell_i \pm 1/2$ the favored final single-particle state has also a $j_f = \ell_f \pm 1/2$ spin,
i.e. no intrinsic spin flip during the transfer process. In the present measurement
of ^{208}Pb(^{16}O,^{15}N)^{209}Bi and ^{208}Pb(^{16}O,^{15}O)^{209}Pb reactions, the strongly excited final
states will be $j_f = \ell_f - 1/2$ since the initial single particle state has a 1p1/2
configuration in the ^{16}O projectile. This selection rule is explained by the schema-
tic diagram of Fig. 1 : the fact that the transferred nucleon has, in addition to its
initial intrinsic nucleon velocity, the velocity of the projectile, makes, it can be
captured by the target only if the algebraic sum of these two speeds matches best
the final intrinsic nucleon velocity in the residual nucleus. Calculations based on
the one-step Distorted Wave Born Approximation (DWBA) has to contain naturally these
two high incident energy selection rules.

The Fig. 2 shows the energy spectrum of the ^{208}Pb(^{16}O,^{15}N) ^{209}Bi one-proton transfer
reaction. The energy resolution is 215 keV FWHM. As at low incident energy only the
single particle states are populated. We can see, immediately from the second se-
lection rule that the 2f5/2 state is more strongly excited than the 2f7/2 one of
same orbital angular momentum $\ell_f = 3$. The 1h9/2 level, and $\ell_f = 5$ state, is also

$$j_{i<} = 1p1/2 = l_i - 1/2$$

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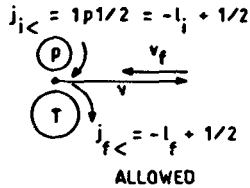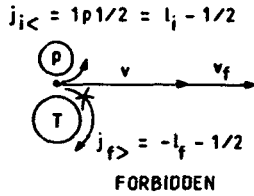$$j_{i<} = 1p1/2 = -l_i + 1/2$$

$$j_{f<} = -l_f + 1/2$$

ALLOWED

Fig. 1

strongly populated. The 1i13/2 state population is favored by the first selection rule since it involves a large $l_f = 6$ final orbital momentum but it is also inhibited by the second selection rule since it has a $j_f = l_f + 1/2$ final spin. For these two contradictory reasons, it has turned out that the 1i13/2-state cross section is smaller than the ground-state one. Let us quote that the mismatch between the entrance and outgoing grazing waves is 8ℏ.

Angular distributions have been measured between 0° and 6° and a one-step DWBA analysis has been performed with the code PTOLEMY /3/. The form factor parameters were taken from ref./2/. The optical model parameters were obtained by interpolation between a 1503 MeV ^{16}O incident energy set /4/ and a 312 MeV set /2/. These parameters have the following values : V=W=50 MeV, r_0 = 1.105 fm, r_i = 1.085 fm and a_0 = a_i = 0.750 fm. They

$^{208}Pb(^{16}O, ^{15}N)^{209}Bi$

$E_{^{16}O}$ = 793 MeV

3.°< θ_{lab} < 4.75°

g.s.
1h 9/2⁻

0.896 MeV
2f 7/2⁻
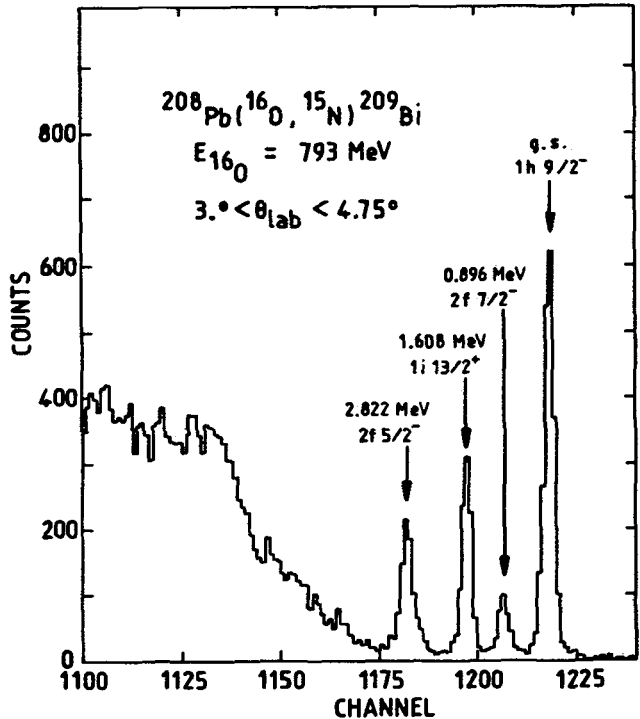
1.608 MeV
1i 13/2⁺

2.822 MeV
2f 5/2⁻

Fig. 2

correspond to a strong absorptive potential. This DWBA analysis reproduces quite well the relative intensities of all the single-particle state transitions as it can be judged from the spectroscopic factors listed in Table I.

Table I

One-proton spectroscopic factors

State	E* (MeV)	$(^{16}O,^{15}N)$ 312 MeV	$(^{16}O,^{15}N)$ 793 MeV	$(^3He,d)$ 20.3 MeV	Theory[a]
$1h9/2^-$	g.s.	0.95	0.95	0.95	0.95
$2f7/2^-$	0.896	0.81	0.89	0.63	0.85
$1i13/2^+$	1.608	0.73	0.80	0.45	0.70
$2f5/2^-$	2.822	0.72	0.77	0.71	0.66

a) All spectroscopic factors are normalized on the g.s. theoretical value (see ref./5/).

In Fig. 3 are presented the energy spectra of $^{208}Pb(^{16}O,^{15}O)^{209}Pb$ one-neutron transfer reaction. Only single-particle states are populated. According to the second selection rule the 2g7/2 state is more strongly populated than the 2g9/2 ground state, both are $\ell_f = 4$ transitions. The most strongly excited state is the 1i11/2 level which has an $\ell_f = 6$ orbital momentum and is a $j_f=\ell_f-1/2$ state. The two selection rules favor this direct transfer reaction. The 1j15/2 state is strongly favored by the first selection rule, $\ell_f = 7$ compared to a grazing wave angular momentum mismatch of 10ℏ. But on the other hand population to this state is inhibited by the second selection rule : $j_f = \ell_f + 1/2$.

The one-neutron spectroscopic factors of Table II are the results of the same DWBA analysis than the one performed for the one-proton transfer reaction. The agreement is quite reasonable and shows once more that the one-step DWBA calculation is able to reproduce fairly well the relative intensities governed by these two selection rules for high incident energy.
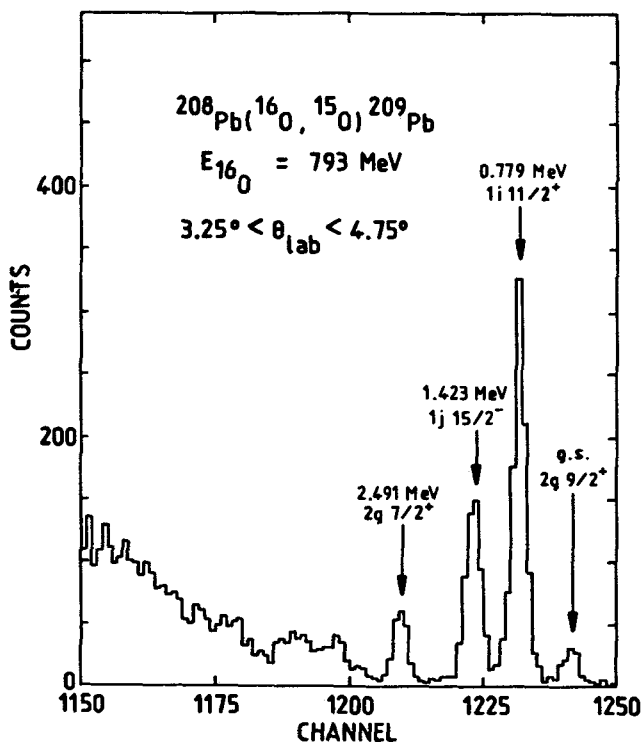

Fig. 3

From the absolute cross section estimate and the success of these two selection rules it can be inferred that the upper part of the transfer reaction energy domain has been reached and corresponds to twice the Fermi energy.

Table II

One-neutron spectroscopic factors

State	E^* (MeV)	$(^{16}O, ^{15}O)$ 312 MeV	$(^{16}O, ^{15}O)$ 793 MeV	(d,p) 20.0 MeV	Theory[a]
$2g9/2^+$	g.s.	0.89	0.89	0.89	0.89
$1i11/2^+$	0.779	0.88	0.53	0.92	0.96
$1j15/2-$	1.423	0.88	0.54	0.62	0.62
$2g7/2^+$	2.491	1.39	0.67	1.13	0.84

a) All spectroscopic factors are normalized on
the g.s. theoretical value see ref./5/.

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