University of Groningen

The $^{197}\text{Au}(\text{d}, ^3\text{He}) ^{196}\text{Pt}$ reaction and the supersymmetry scheme

Verges, M; Berrier-Ronsin, G; Rotbard, G; Vernotte, J; Langevin-Joliot, H; Gerlic, E; Van De Wiele, J; Guillot, J; van der Werf, SY

Published in:
Physics Letters B

DOI:
[10.1016/0370-2693\(81\)90339-7](https://doi.org/10.1016/0370-2693(81)90339-7)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
1981

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Verges, M., Berrier-Ronsin, G., Rotbard, G., Vernotte, J., Langevin-Joliot, H., Gerlic, E., Van De Wiele, J., Guillot, J., & van der Werf, SY. (1981). The $^{197}\text{Au}(\text{d}, ^3\text{He}) ^{196}\text{Pt}$ reaction and the supersymmetry scheme. *Physics Letters B*, 107(5), 349-352. [https://doi.org/10.1016/0370-2693\(81\)90339-7](https://doi.org/10.1016/0370-2693(81)90339-7)

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

THE $^{197}\text{Au}(\text{d}, ^3\text{He})^{196}\text{Pt}$ REACTION AND THE SUPERSYMMETRY SCHEME

M. VERGNES, G. BERRIER-RONSIN, G. ROTBARD, J. VERNOTTE,
H. LANGEVIN-JOLIOT, E. GERLIC, J. VAN DE WIELE and J. GUILLOT

Institut de Physique Nucléaire, B.P. No. 1, 91406 Orsay, France

and

S.Y. VAN DER WERF

Kernfysisch Versneller Instituut, University of Groningen, Groningen, The Netherlands

Received 7 October 1981

The $^{197}\text{Au}(\text{d}, ^3\text{He})^{196}\text{Pt}$ reaction has been studied at $E_d = 108$ MeV. An important breakdown of the selection rules of the supersymmetry scheme is observed for the 2_2^+ level. The generally strong excitation of the 2_2^+ level by transfer reactions in the Pt region leads to question the validity of the supersymmetry scheme at least for this level.

In the Interacting Boson Model (IBA) describing [1] the collective degrees of freedom of even-even nuclei, three dynamical symmetries, each corresponding to a chain of subgroups of SU(6), have been recognized. The Pt nuclei, particularly ^{196}Pt , appear to be well described [2] by the O(6) limit. The Interacting Boson-Fermion Model (IBFA), where a fermion is coupled to an even-even boson core, appears to reproduce reasonably many experimental results for odd- A nuclei [3,4].

Going one step further towards a unified picture, Iachello has recently suggested [5] that dynamical supersymmetries might be present in the spectra of complex nuclei. The supersymmetry is defined as a situation in which the bosonic (even-even nuclei) and fermionic (odd- A nuclei) spectra can be simultaneously classified by a complete set of group theoretical labels, the energies being given as a function of these labels by a common expression.

Of course, the supersymmetry (as well as the ordinary symmetries of TBA) is not claimed to be a general property of nuclei, but on the contrary can only occur in very special cases, when certain terms of the hamiltonian dominate the others. In the first case proposed [5], the even-even nucleus is supposed to be correctly described by the O(6) limit,

the odd particle in the odd- A nucleus being allowed to occupy only the $j^\pi = 3/2^+$ orbital. This supersymmetry model has been applied to several nuclei in the Pt region and has been generally found [4-6] quite successful in reproducing the energies and $B(E2)$ values. The selection rules for single-particle transfer reactions [6], $\Delta\sigma = \pm\frac{1}{2}$, $\Delta\tau = \pm\frac{1}{2}$ have been found to be obeyed [7] in the reactions $^{194}\text{Pt} \rightarrow ^{193}\text{Ir}$ and $^{192}\text{Os} \rightarrow ^{193}\text{Ir}$. However, an important breaking was shown [8] in the $^{193}\text{Ir} \rightarrow ^{194}\text{Pt}$ reaction, where the transition to the $J^\pi = 2_2^+$ level, forbidden by the supersymmetry selection rules, was observed to be very strong.

In order to see if this very strong population of the 2_2^+ level was an exception or not, it was decided to try another couple of nuclei. Because ^{196}Pt is considered [2] to be the best O(6) nucleus, the reaction $^{197}\text{Au}(\text{d}, ^3\text{He})^{196}\text{Pt}$ was selected for this test. This choice was strengthened by the recent conclusion [9] that, on the basis of energies and $B(E2)$, the couple $^{196}\text{Pt}-^{197}\text{Au}$ appears as one of the best cases for the existence of supersymmetry in nuclei.

The experiment was performed at 108 MeV, using the analyzed deuteron beam of the Orsay synchrotron, with several gold targets of known thicknesses (between 1.0 and 5.6 mg/cm²). The emitted

Fig. 1. Spectrum of ^3He particles emitted at $\theta_{\text{lab}} = 4^\circ$ in the $^{197}\text{Au}(d, ^3\text{He})^{196}\text{Pt}$ reaction at 108 MeV.

^3He particles were analyzed by the "Montpellier" spectrometer and detected by a system [10] of two position sensitive gas chambers followed by two plastic scintillators. The solid angle of the spectrometer was 0.21 msr, with an opening in the reaction plane of 0.5° . The resolution of 130 keV (full width at half maximum), mainly due to the beam, permitted to separate correctly the first peaks in the spectrum (see fig. 1) corresponding to the ground state, 2_1^+ and 2_2^+ levels of ^{196}Pt , and to give reliable limits for the cross sections of the higher-lying 0_2^+ , 3_1^+ and 4_1^+ levels. Levels above 1.2 MeV could not be separated and shall not be discussed.

Absolute cross sections were determined directly, knowing the solid angle of the spectrometer and the thickness of the targets. The resulting angular distributions are compared in fig. 2a to DWBA calculations performed using standard optical potentials [11]. It can be seen that the three angular distributions have similar shapes, well fitted by $l = 2$ DWBA calculations. The g.s. $\rightarrow$ g.s. transition is necessarily a pure $l = 2$, $d_{3/2}$ transfer and the extracted spectroscopic factor, $C^2S = 0.24$, is in good agreement with the value, $C^2S = 0.263$, previously determined [12] in the $^{196}\text{Pt}(^3\text{He}, d)^{197}\text{Au}$ reaction. For the 2_1^+ and 2_2^+ levels, the angular momentum selection rules would also permit $l = 0$ and $l = 4$ transfer. The DWBA calculations for pure $l = 0$, $l = 2$ and $l = 4$ transfer are shown in fig. 2b. From these curves it is possible to derive calculated angular distributions for mixed $l = 2 + l$

Fig. 2. (a) Experimental angular distributions for the $0_{\text{g.s.}}^+$, 2_1^+ and 2_2^+ levels of ^{196}Pt . These distributions have very similar shapes and are well fitted by $l = 2$, $d_{3/2}$ DWBA calculations (continuous curves) using the optical potentials of ref. [11]. (b) Comparison of the cross sections and shapes of the DWBA angular distributions calculated for $l = 0$, $l = 2$ and $l = 4$, with an identical spectroscopic factor $C^2S = 1$.

$= 0$ transitions, the shape being a function of the ratio $R(0/2) = C^2S(l=0)/C^2S(l=2)$. Similar curves can be derived for mixed $l = 2 + 4$ transitions, the shape being a function of the ratio $R(4/2)$. A careful comparison of these curves with the angular distributions of fig. 2a permits to conclude, for the 2_1^+ and 2_2^+ levels, that both $R(0/2)$ and $R(4/2)$ are smaller

Table 1

Comparison of relative experimental spectroscopic factors for the $^{197}\text{Au}(\text{d}, ^3\text{He})^{196}\text{Pt}$ reaction to the predictions of the supersymmetry model.

J^π	$E_{\text{exp.}}$ (keV)	$E_{\text{th.}}$ (keV) a)	$C^2S_{\text{exp.}}$ ($l = 2$) b)	$C^2S_{\text{supersym.}}$ c)	Class. c)
$0_{\text{g.s.}}^+$	0	0	100 d)	100 d)	Allowed
2_1^+	356	286	88	167	Allowed
2_2^+	689	562	60	0	Forbidden, $\Delta\tau = 3/2$
4_1^+	877	800	≤ 15	0	Forbidden, $\Delta\tau = 3/2$ e)
3_1^+	1015	1032	≤ 15	0	Forbidden, $\Delta\tau = 5/2$
0_2^+	1135	828	≤ 10	0	Forbidden, $\Delta\tau = 5/2$

a) Energies calculated using eq. (7) of ref. [5] and the parameters $A = 243$ keV, $B = 276$ keV, $C = 17$ keV given by Vervier in ref. [9].

b) All transitions, except that corresponding to the 4_1^+ level, are assumed to be $l = 2, d_{3/2}$. For a $d_{5/2}$ transition the spectroscopic factor would be: $C^2S(d_{5/2}) = 0.75 C^2S(d_{3/2})$.

c) From ref. [6]. d) Normalized.

e) This transition is forbidden, not only because it breaks the selection rule $\Delta\tau = 1/2$, but also because the only possible type of transfer in the model: $l = 2, d_{3/2}$, is forbidden in this case by the angular momentum selection rules.

than 30%, and that the $l = 2$ transfer is largely dominant in cross section such that the $l = 2$ spectroscopic factors can be safely determined (error below 12%) assuming as for the ground state a pure $l = 2, d_{3/2}$ transfer. These conclusions are confirmed by an independent analysis using, instead of DWBA calculations, the experimental angular distributions determined [13] in the $^{208}\text{Pb}(\text{d}, ^3\text{He})^{207}\text{Tl}$ reaction at 108 MeV, for the $J^\pi = 1/2^+$ (g.s), $3/2^+$ (350 keV) and $7/2^+$ (3480 keV) levels of ^{207}Tl .

The relative $l = 2$ spectroscopic factors are compared in table 1 to the predictions resulting from the supersymmetry selection rules (only $l = 2, d_{3/2}$ transitions are possible in this model).

It is clear from table 1 that, even in the carefully chosen case of the $^{197}\text{Au} \rightarrow ^{196}\text{Pt}$ reaction (where, as pointed out before, the supersymmetry scheme is reasonably founded [2] and appears to acceptably describe the energies and $B(E2)$ values [9]) the selection rules for single-particle transfer reactions are broken for the 2_2^+ level of ^{196}Pt . Indeed, this appears to be rather a rule than an exception and in all the cases studied so far the 2_2^+ level of the final even-even nucleus is strongly populated as compared to the 2_1^+ level: 117% in ^{194}Pt [8], 68% in ^{196}Pt (pres-

ent work), 32% in ^{192}Os [14]; the ratio also appears large in ^{198}Hg [15] although no precise figure has been given. The inability of the model to account for the large population of the 2_2^+ level could result either from the use of a too simple operator in deriving the single-particle transfer selection rules (the supersymmetry scheme itself being correct) or from the fact that the 2_2^+ level is not correctly described in the supersymmetry scheme (and perhaps, therefore, in the $O(6)$ limit of IBA). Calculations of the transfer strengths in a more classical scheme, where the even-even and odd nuclei would be described respectively by the IBA and IBFA models, with different types of single-particle transfer operators including the one used to derive the supersymmetry selection rules, are clearly needed in order to precise the origin of the observed breaking.

To summarize, the general breakdown of the selection rules observed for the 2_2^+ levels of the even-even nuclei in the Pt region appears at this stage as an important difficulty for the supersymmetry model. We feel that it should be clearly understood and explained before one can really conclude that the supersymmetry scheme applies reasonably to this nuclear region.

References

- [1] F. Iachello, ed., *Interacting bosons in nuclear physics* (Plenum, New York, 1979), and references therein.
- [2] J.A. Cizewski et al., *Phys. Rev. Lett.* **40** (1978) 167.
- [3] F. Iachello and O. Scholten, *Phys. Rev. Lett.* **43** (1979) 679.
- [4] F. Iachello, ed., *Interacting bose-fermi systems in nuclei* (Plenum, New York, 1981), and references therein.
- [5] F. Iachello, *Phys. Rev. Lett.* **44** (1980) 772.
- [6] A.B. Balentekin, I. Bars and F. Iachello, to be published; F. Iachello and S. Kuyucak, to be published.
- [7] J.A. Cizewski, in: *Interacting bose-fermi systems in nuclei*, ed. F. Iachello (Plenum, New York, 1981); Y. Ywasaki et al., *Phys. Rev. C* **23** (1981) 1477; R.H. Price, D.G. Burke and M.W. Johns, *Nucl. Phys. A* **176** (1971) 338.
- [8] M. Vergnes et al., *Phys. Rev. Lett.* **46** (1981) 584.
- [9] J. Vervier, *Phys. Lett.* **100B** (1981) 383 and private communications; J. Vervier, R. Holzmann, R.V.F. Janssens, M. Loiselet and M.A. van Hove, to be published.
- [10] A. Willis et al., *Nucl. Phys. A* **344** (1980) 137.
- [11] W.W. Daehnick, J.D. Childs and Z. Vrcelj, *Phys. Rev. C* **21** (1980) 2253; E.F. Gibson et al., *Phys. Rev.* **155** (1967) 1194.
- [12] M.L. Munger and R.J. Peterson, *Nucl. Phys. A* **303** (1978) 199.
- [13] H. Langevin-Joliot, E. Gerlic, J. Van de Wiele and J. Guillot, to be published.
- [14] R.D. Bagnell et al., *Phys. Rev. C* **20** (1979) 42.
- [15] M.L. Munger, Technical Progress Report, Colorado University, Boulder, Nov. '73–Nov. '74, p. 35.