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TEST OF SUPERSYMMETRY IN THE $^{193}Ir \rightarrow ^{194}Pt$ PROTON STRIPPING REACTIONS

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A breakdown of the selection rules of the supersymmetry model is observed for the population of the 0_2^+ and 2_2^+ levels of ^{194}Pt in the $^{193}Ir \to {}^{194}Pt$ proton stripping reactions performed using the Orsay and Mc Master University tandem accelerators. The existence of other violations in the neighbouring nuclei leads to believe that we are seeing the limitations of the supersymmetry scheme itself, at least for particle transfer reactions.

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It was recently suggested[1] that dynamical supersymmetries might be present in the spectra of complex nuclei. A dynamical supersymmetry is defined as a situation in which the states of both bosons (even A) and fermions (odd-A) systems can be simultaneously classified by a complete set of group-theoretical labels, their energies being given, as a function of these labels, by a common expression.

In the Interacting Boson Model (IBA 1) the collective degrees of freedom of even nuclei are described as interacting S and D bosons around an inert core. Three natural dynamical symmetries, corresponding to situations where certain terms of the Hamiltonian dominate the others, have emerged : SU(3), close to the axial rotor, SU(5), close to the anharmonic vibrator and O(6), somewhat similar to the γ-unstable rotor. It has been found[2] that the Platinum nuclei (particularly ^{196}Pt) are well described by the O(6) limit. Recently the model was extended to the odd-A nuclei by adding a fermion to the bosons (IBFA). Iachello[1] was able, in a particular case, to find a group accomodating both the bosons and the fermion : the group Spin (6) including an O(6) representation describing the bosons and a spinor representation describing a fermion with $j = 3/2$. The model based on this group representation has been applied succesfully[1] to the level schemes in the ideal case of the even Pt and odd Ir nuclei.

The levels of these nuclei can be labelled by the spin-parity value and by 2 principal quantum numbers σ and τ ($\sigma = \sigma_1$, $\tau = \tau_1$ of ref. 1. Examples of such labels are given in fig. 1, 2 and 3 of ref. 1). The model gives[3] selection rules for electromagnetic transitions and single particle transfer reactions. In odd-A Gold nuclei the electromagnetic transitions expected from the model to be forbidden were found[4] to be at least strongly inhibited. For particle transfer reactions, considering the simplest transfer operator, the transitions are allowed only if they obey the selection rules[3]

$$\Delta\sigma = \pm 1/2$$
$$\Delta\tau = \pm 1/2$$

These predictions have been tested[5] through the study of the proton pick-up reaction Pt(t,α)Ir. The selection rules (and more precise intensity rules[3] as well) for the population of the $J^\pi = 3/2^+$ levels are obeyed in the $^{194}Pt \rightarrow {}^{193}Ir$ case, but the agreement is getting worse when going towards the heavier Ir isotopes. The different pattern observed[6] for the population of the same $J^\pi = 3/2^+$ levels in the reaction $^{192}Os(^3He,d)^{193}Ir$ is also very nicely explained by the above selection rules. In both cases the transitions classified as forbidden are very weakly populated : less than 8 % of the allowed ground state population. It should however be remarked that even in the $^{194}Pt(t,\alpha)^{193}Ir$ reaction, where the relative populations of the $J^\pi = 3/2^+$ levels are correctly predicted by the model, the population of the lowest $J^\pi = 1/2^+$ level, forbiden in the supersymmetry scheme, seems to be appreciable.

Another test of the selection rules is provided by the proton stripping reactions $^{193}Ir \rightarrow {}^{194}Pt$. In this case the selection rules forbid the population of the excited 0^+ levels and only the $0^+_{g.s}$ of ^{194}Pt should be populated. For the 2^+ levels, the population of the 2^+_1 is allowed, the population of the 2^+_2 is forbidden.

The reaction $^{193}Ir(^3He,d)^{194}Pt$ was performed at 36 MeV using the Orsay MP tandem accelerator and the split pole spectrometer, on an enriched (98.7 %) ^{193}Ir target of thickness $\approx$ 50 $\mu g/cm^2$. The counting rate was very low and spectra were taken at only 3 angles (θ_{lab} = 10°, 17°, 38°). Two spectra were also taken with the Mc Master University tandem and split pole spectrometer : one at 25.5 MeV and θ_{lab} = 50° for the $^{193}Ir(^3He,d)^{194}Pt$ reaction, the other at 27 MeV and θ_{lab} = 60° for the $^{193}Ir(\alpha,t)^{194}Pt$ reaction. The cross sections extracted from these different spectra were in all cases corrected for the non negligible kinematic variation with excitation energy, using DWBA calculations[7] with appropriate standard optical potentials. These corrected experimental relative cross sections are compared in Table 1 to the predictions of the supersymmetry model. It is clear that the results strongly disagree with predictions, the important population of the forbidden 0_2^+ and 2_2^+ levels being particularly striking. Indeed the two 2^+ levels are about equally populated although one transition is allowed and the other is forbidden.

A first explanation would be that the mechanism of the reactions might not be purely direct. The good agreement between data at different energies and with different reactions is however an indication that two-step processes do not play a dominant role in the population of the 0_2^+ and 2_2^+ levels. This conclusion is strengthened by the fact that, in inelastic scattering experiments[8], the 2_2^+ level is negligibly populated as compared to the 2_1^+. In view of the success of the model in the case of the selective population of $J^\pi = 3/2^+$ levels of ^{193}Ir, starting from its even neighbours, it seems that the difficulties cannot be attributed to the particle transfer operator but are related to the nature of the ^{194}Pt excited levels or to the supersymmetry scheme itself. The simplest explanation in the present case would be that, even though the ground state and several other levels of ^{194}Pt can be reasonnably described by the O(6) limit of IBA 1, the 0_2^+ and 2_2^+ levels cannot. However, another example of violation ($\sigma(2_2^+)$, forbidden/$\sigma(0^+_{g.s})$, allowed $\approx$ 40 %), similar but not as striking as the one observed in the present work, may be found in previously published data[9] for the reaction $^{193}Ir(t,\alpha)^{192}Os$ and we have pointed out the appreciable population of the first $J^{\pi} = 1/2^+$ level in the $^{194}Pt(t,\alpha)^{193}Ir$ reaction. A similar very appreciable population of the low-lying $J^{\pi} = 1/2^+$ level has been observed[10] in the $^{194}Pt(^3He,d)^{195}Au$ reaction. With the number of significant violations we can now list (i.e several transitions in different reactions, each supposedly forbidden but found to have 30 to 60 % of the allowed ground state strength) we are perhaps seeing the limitations of the supersymmetry description of the ^{192}Os, ^{193}Ir, ^{194}Pt, ^{195}Au, multiplet, at least as far as predictions for single nucleon transfer are concerned.

The present paper shows, in transfer reactions, the first evidence of an important breaking of the supersymmetry proposed by Iachello[1]. In view of the interest of the problem it should stimulate other experimental and theoretical works in order to determine the limit of validity of the supersymmetry model and to better understand the Pt isotopes which still appear as very intriguing nuclei, among the most interesting to study and the most difficult to describe correctly.

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Table 1

Comparison of experimental cross sections with the supersymmetry model selection rules

$E_{exc.}$ (keV)	J^{π}	Experimental cross sections[a]				Selection rules
		(^{3}He,d) 36 MeV	(^{3}He,d) 25.5 MeV	(α,t) 27 MeV	Average results	
0.	$0^+_{g.s}$	100[b]	100[b]	100[b]	100[b]	Allowed
328	2^+_1	65	59	56	60 ± 5	Allowed
623	2^+_2	75	64	70	70 ± 5	Forbidden
1270	0^+_2	45	28	33	35 ± 10	Forbidden
1479	0^+_3	15[c]			15 ± 5	Forbidden
1547	0^+_4	$\lesssim$ 7	$\lesssim$ 7		$\lesssim$ 7	Forbidden

a) See ref. 7.

b) Normalized

c) A rough estimate of the strength of the 0^+ component has been obtained by a mixed ℓ analysis of the "angular distribution" corresponding to the well known close doublet 0^+ (1479 keV), 7^- (1485 keV).