SYSTEMATICS OF SOME BETA-TRANSITIONS

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ABSTRACT

0^+ excited states of even-even nuclei can arise in several ways. In order to throw some light on the mechanism of excitation of these states, the log (ft) values for beta-transitions to the 0^+ excited state and the 0^+ ground state of even-even nuclei have been compared. In this analysis both allowed and forbidden beta-transitions have been considered. This survey is similar to that of beta-transitions by M. Sakai. Results of the present analysis are presented and compared to that of Sakai.

A. INTRODUCTION

ENOUGH experimental data on 0^+ excited states in even-even nuclei exist at the present time, that it may be justifiable to attempt to make a systematic analysis. These states offer the possibility of distinguishing various nuclear models and the mechanism of the excitation of these states. In this hope all the available data on 0^+ excited states of even-even nuclei are collected and their properties enumerated. In all the cases of even-even nuclei considered in the present analysis, the 0^+ excited states occur as second and higher excited states, except in the case of Zr^{90}.

The ratio of the energy of the 0^+ excited state to that of the first 2^+ excited state indicates a possible classification into three types:

(1) Pair-excitation: Can arise as particle excitations in closed shell or sub-shell nuclei.

(2) Phonon-excitation: Can arise as vibrational states of spherical nuclei, *i.e.*, two phonon states 0^+, 2^+, 4^+ triplet depending upon anharmonicity terms.

(3) Beta-vibration in strongly deformed nuclei. At this stage one may resort to Reiner's[1] criterion to distinguish two phonon vibrations from Beta-vibrations, wherever the EO conversion electrons have been detected.

At the moment two models exist that can be applied with reasonable understanding for the description of the 0^+ excited states in nuclei, *viz.*, the individual particle model[2] and the collective model.[3] In support of the application of the collective model, I. Marklund *et al.*[4] have shown some possible low frequency collective excitations of non-spherical nuclei. These nuclei may exhibit quadrupole vibrations about their cylindrical equilibrium configuration (Gamma-vibrations) or about their elliptical equilibrium (Beta-vibrations). The 0^+ excited level is most characteristic in the Beta-vibration bend.

Many attempts have been made to assign the origin of these 0^+ excited states. Recently Davydov and Fellippov[5] showed that these levels can be explained as members of excitation band of an asymmetric rotor. These 0^+ excited states in medium-weight even nuclei have been understood as vibrational states. The latter understanding is mainly based upon the radiation properties of gamma-rays emitted from the first and the second 2^+ excited state. To add to all this understanding Kraushaar and Goldhaber[6] showed the presence of anomalous selection rules in gamma-transitions which suggested phonon-excitation as mentioned earlier.

With all these considerations in mind M. Sakai[7] investigated some kind of hindrance phenomena in Beta-transitions. In this analysis, he considered the comparative life times of allowed transitions from 1^+, 2^+ and 3^+ parent nuclei to the ground state, first 2^+ state and the second excited 2^+ state of even-even nuclei. His study revealed some kind of retardation phenomena in all these transitions and there is a passing remark as regards 0^+ excited state in a few cases. Thus, in order to throw some light on the mechanism of 0^+ excited states, we have considered the data regarding the even-even nuclei, where the 0^+ excited state exist. In this analysis both the allowed and forbidden beta-transitions from the same state of the parent nuclei to the ground state, first 2^+ excited state and 0^+ excited state of daughter nuclei have been considered. The data comprehend both the so-called vibrational and rotational regions.

B. COMPILATION OF THE AVAILABLE DATA AND RESULTS

The experimental log (*ft*) values of both allowed and forbidden beta-transitions from the same state of the parent nucleus to the 0^+ ground state, first 2^+ excited state and the 0^+ excited state of the daughter nucleus are collected from the publications available. The compilation is presented in Table I. In the first column the parent nucleus and the daughter nucleus are listed. The second, third and the fourth columns concern with the various characteristics of the above-mentioned states in daughter nucleus. Where-ever the log (*ft*) values are not available, these are calculated from the per-

TABLE I

	1		2		3			4			5	6
No.	Parent Nucleus	Daughter Nucleus	Transition to 0^+ ground state	Log (ft)	Transition to first 2^+ excited state	Excitation energy (Mev.)	Log (ft)	Transition to 0^+ excited state	Excitation energy (Mev.)	Log (ft)	Position of 0^+excited state	Reference
1	$_{5}B^{12}_{7}$	$_{6}C^{12}_{6}$	$1^+\to 0^+$	3·8	$1^+\to 2^+$	4·43	5·0	$1^+\to 0^+$	7·65	3·9	2nd	*a*
2	$_{31}Ga^{70}_{39}$	$_{32}Ge^{70}_{38}$	$1^+\to 0^+$	5·1	$1^+\to 2^+$	1·04	5·7	$1^+\to 0^+$	1·21	5·3	2nd	*b*
3	$_{39}Y^{90}_{51}$	$_{40}Zn^{90}_{50}$	$2^-\to 0^+$	8·5	..	..	..	$2^-\to 0^+$	1·73	9·3	1st	*a*
4	$_{45}Rh^{104}_{59}$	$_{46}Pd^{104}_{58}$	$1^+\to 0^+$	5·5	$1^+\to 2^+$	0·556	5·9	$1^+\to 0^+$	1·05	(6·0)	2nd	*a*
5	$_{45}Rh^{106}_{61}$	$_{46}Pd^{106}_{60}$	$1^+\to 0^+$	5·2	$1^+\to 2^+$	0·513	5·7	$1^+\to 0^+$	1·147	5·2	3rd	*b*
6	$_{45}Ag^{108}_{63}$	$_{46}Pd^{108}_{62}$	$1^+\to 0^+$	4·8	$1^+\to 2^+$	0·48	5·9	$1^+\to 0^+$	1·08	4·9	3rd	*a*
7	$_{63}Eu^{152m}_{89}$	$_{64}Gd^{152}_{88}$	$0^-\to 0^+$	7·5	$0^-\to 2^+$	0·344	8·7	$0^-\to 0^+$	0·615	10·0	2nd	*c*
8	$_{61}Eu^{152m}_{91}$	$_{62}Sm^{152}_{90}$	$0^-\to 0^+$	8·65	$0^-\to 2^+$	2·122	8·6	$0^-\to 0^+$	0·685	8·0	2nd	*c*
9	$_{67}Ho^{166}_{99}$	$_{68}Er^{166}_{98}$	$0^-\to 0^+$	8·1	$0^-\to 2^+$	0·080	8·0	$0^-\to 0^+$	1·06	7·5	3rd	*c*
10	$_{73}Ta^{178}_{105}$	$_{72}Hf^{178}_{106}$	$1^+\to 0^+$	7·0	$1^+\to 2^+$	0·093	7·1	$1^+\to 0^+$	1·197	7·3	3rd	*d*
11	$_{75}Re^{188}_{113}$	$_{76}Os^{188}_{112}$	$1^-\to 0^+$	8·1	$1^-\to 2^+$	0·155	8·6	$1^-\to 0^+$	1·086	9·2	3rd	*c*
12	$_{77}Ir^{194}_{117}$	$_{78}Pt^{194}_{116}$	$1^-\to 0^+$	8·2	$1^-\to 2^+$	0·328	8·6	$1^-\to 0^+$	1·265	7·8	3rd	*c*
13	$_{91}Pa^{234}_{143}$	$_{92}U^{234}_{142}$	$(1^-)\to 0^+$	7·0	$(1^-)\to 2^+$	0·093	7·1	$(1^-)\to 0^+$	1·197	7·3	3rd	*e*

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c. Marklund, I., Nooijen, B. V. and Grabowski, Z., *ibid.*, 1960, **15**, 533.
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e. Wood, G. T., *ibid.*, 1960, **119**, 2004.

centage decay, partial half-life and Feenberg and Trigg's[8] curves. All these calculated log (*ft*) values are indicated by the underlined daughter nucleus. In case the assignment is not sure, the character is put in parentheses. The Fifth column indicates the position of the 0^+ excited state. The reference are listed in column six. From Table I, the following inferences can be obtained.

(*a*) 0^+ *ground state and* 0^+ *excited state*

Nuclei: ${}_{5}B_{7}{}^{12}$, ${}_{31}Ga_{39}{}^{70}$, ${}_{45}Rh_{61}{}^{106}$, ${}_{45}Ag_{63}{}^{108}$, ${}_{73}Ta_{105}{}^{178}$ *and* ${}_{91}Pa_{143}{}^{234}$

These states having the same log (*ft*) values, except for the small differences indicate similar configuration. Although these log (*ft*) values tend to be equal, the log (*ft*) values to the 0^+ excited state seem to be consistently somewhat higher.

(*b*) 0^+ *ground state and first* 2^+ *excited state*

Nuclei: ${}_{73}Ta_{105}{}^{178}$ and ${}_{91}Pa_{143}{}^{234}$

In these cases the log (*ft*) values to the 0^+ ground state and first 2^+ state are the same.

Again the log (*ft*) values for the 2^+ state are consistently larger.

In the other cases log (*ft*) of 2^+ state appears to be very much larger than the 0^+ ground state value.

(*c*) 0^+ *excited state and first* 2^+ *excited state*

Nuclei: ${}_{73}Ta_{105}{}^{178}$ and ${}_{91}Pa_{143}{}^{234}$

In these cases the log (*ft*) values are same.

The general trend is that the 2^+ excited state has larger log (*ft*) value than the ground state.

The case of ${}_{45}Rh_{59}{}^{104}$ appears to be anomalous. The nuclei ${}_{63}Eu_{89}{}^{152m}$ and ${}_{63}Eu_{89}{}^{152m}$ provide an interesting example of transition to the deformed region. Note that there is an inversion in the trend in log (*ft*) values. For the other deformed nuclei the log (*ft*) values show a large difference with the exception of ${}_{73}Ta_{105}{}^{178}$, ${}_{91}Pa_{143}{}^{234}$.

C. CONCLUSION

The classification of excited 0^+ states purely on the basis of the energy ratios is rather ambiguous, whereas an analysis based upon the trends of the log (*ft*) values seems to be more meaningful.

The present analysis has pointed to interesting interrelationships for the log (*ft*) values, which may be hopefully correlated with the excitation mechanism.

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