ANALYSIS OF SOME ALLOWED BETA-TRANSITIONS

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Abstract

Sakai's method of analysing log *ft* values has been extended to higher excited states in even-even nuclei. Within the context of the rather limited data an enhancement in the matrix element is observed for transitions to $2''^{+}$, $2'''^{+}$ and $4'^{+}$ and $4''^{+}$ levels.

1. Introduction

Log *ft*, an experimentally obtainable quantity, is a measure of the inverse square of the nuclear matrix element M, where M is defined as $M = \int \psi_f^{*} H \psi_i$. ψ_f and ψ_i are the wavefunctions of the final and initial states in the beta decay respectively. The nuclear matrix element is a measure of the overlap of the initial and final state wavefunctions. A large value of *ft* corresponds to a small value of the nuclear matrix element. The matrix element can be computed theoretically if one has a knowledge of the wavefunctions ψ_f and ψ_i. In the cases where ψ_f and ψ_i are not known, the matrix element can be computed by determining the log *ft* values experimentally.

The low excited states in medium-weight even-even nuclei have been understood as vibrational states. Sakai[1] considers log *ft* values for beta-transitions from a common parent level to the different excited levels of the even-even daughter nucleus. He finds that the log *ft* value for the second excited $2'^{+}$ state is greater than that for the first excited 2^{+} state. This difference in log *ft* values is known as hindrance and he has calculated the hindrance factor $\triangle_{21} \log ft$ for each case.

In the present study we have extended Sakai's method of analysis to higher 2^{+} levels and other excited states such as 4^{+}, to which allowed beta-transitions take place, in order to see if there is a similar hindrance.

2. Analysis of Data

Table I represents our attempt in this direction. Not only the transitions from a common parent level to different excited levels of the daughter

TABLE I

	Parent nucleus	Daughter nucleus	Transition type	log *ft*
1.	${}_{11}\mathrm{Na}_{13}{}^{24}$	${}_{12}\mathrm{Mg}_{12}{}^{24}$	$\underline{4}^+-4^+$ (4·122)	6·2
2.	${}_{15}\mathrm{P}_{19}{}^{34}$	${}_{16}\mathrm{S}_{18}{}^{34a}$	$(1^+)-2^+$ (2·127)	4·7
			$(1^+)-2''^+$ (4·000)	4·9
	${}_{17}\mathrm{Cl}_{17}{}^{34}$	${}_{16}\mathrm{S}_{18}{}^{34}$	$(3^+)-2'^+$ (3·220)	4·8
3.	${}_{23}\mathrm{V}_{25}{}^{48}$	${}_{22}\mathrm{Ti}_{26}{}^{48}$	$(4^+)-4^+$ (2·300)	5·7
			$(4^+)-4'^+$ (3·240)	6·7
4.	${}_{25}\mathrm{Mn}_{31}{}^{56}$	${}_{26}\mathrm{Fe}_{30}{}^{56b}$	$\underline{3}^+-2^+$ (0·850)	7·0
			$\underline{3}^+-2'^+$ (2·660)	5·7
			$\underline{3}^+-2''^+$ (2·950)	5·4
			$\underline{3}^+-2'''^+$ (3·370)	5·1
			$\underline{3}^+-4^+$ (2·080)	>9·0
	${}_{27}\mathrm{Co}_{29}{}^{56}$	${}_{26}\mathrm{Fe}_{30}{}^{56b}$	$\underline{4}^+-4'^+$ (4·100)	6·1
			$\underline{4}^+-(3'^+)$ (3·840)	6·4
			$\underline{4}^+-3^+$ (3·450)	6·8
			$\underline{4}^+-(5^+)$ (3·120)	7·3
			$\underline{4}^+-4^+$ (2·080)	8·7
5.	${}_{29}\mathrm{Cu}_{31}{}^{60}$	${}_{28}\mathrm{Ni}_{32}{}^{60a}$	$\underline{2}^+-2^+$ (1·333)	7·4
			$\underline{2}^+-(2'^+)$ (2·158)	6·4
			$\underline{2}^+-(2''^+)$ (3·130)	5·3
	${}_{27}\mathrm{Co}_{33}{}^{60}$	${}_{28}\mathrm{Ni}_{32}{}^{60}$	$\underline{5}^+-4^+$ (2·505)	7·6
			$(2^+)-2^+$ (1·333)	7·2
6.	${}_{47}\mathrm{Ag}_{57}{}^{104}$	${}_{46}\mathrm{Pd}_{58}{}^{104c}$	$\underline{2}^+-2^+$ (0·555)	5·3
			$\underline{2}^+-(2'^+)$ (1·340)	⩾5·4
			$\underline{2}^+-(2''^+)$ (1·810)	5·7
			$\underline{5}^+-4^+$ (2·090)	5·2
			$\underline{5}^+-4'^+$ (2·200)	5·1
			$\underline{5}^+-4''^+$ (2·270)	5·0

TABLE I (*Contd.*)

	Parent nucleus	Daughter nucleus	Transition type	log *ft*
	${}_{45}Rh_{59}{}^{104}$	${}_{46}Pd_{58}{}^{104d}$	$5^+—4'^+$ (2·26)	4·7
			$5^+—(4^+)$ (2·09)	5·5
7.	${}_{49}In_{65}{}^{114}$	${}_{48}Cd_{66}{}^{114}$	$\underline{5}^+—(4^+)$ (1·280)	7·6
8.	${}_{49}In_{67}{}^{116}$	${}_{50}Sn_{66}{}^{116e}$	$1^+—2^+$ (1·270)	5·7
			$1^+—2''^+$ (2·200)	5·7
			$1^+—2'^+$ (2·090)	>7·4
9.	${}_{53}I_{79}{}^{132}$	${}_{54}Xe_{78}{}^{132}$	$\underline{4}^+—(4^+)$ (1·450)	7·4
			$\underline{4}^+—(4'^+)$ (1·980)	6·9
			$\underline{4}^+—(4''^+)$ (2·410)	6·4
10.	${}_{77}Ir_{115}{}^{192}$	${}_{78}Pt_{114}{}^{192}$	$(4^+)—(4^+)$ (0·785)	8·5
			$(4^+)—(4'^+)$ (0·921)	8·3

(*a*) Dzhelepov, B. S. and Peker, L. K., *Decay Schemes of Radioactive Nuclei,* Pergamon Press (London), 1961.

(*b*) Petterson, B. G., Hamilton, J. H. and Thun, J. E., *Nuclear Phy.*, 1961, **22**, 131.

(*c*) Girgis, R. K., *Thesis,* Amsterdam, 1959, p. 64.

(*d*) Wien, K., *Ann. Physik,* 1963, **10**, 281.

(*e*) Fettweis, P. and Vervier, J., *Physics Letters,* 1962, **3**, 36.

All other data are taken from Strominger, D., Hollander, J. M. and Seaborg, G. T. (Reference 2, of the text).

nucleus, but also the transitions from different parent levels to the common daughter level are considered. The log *ft* values are calculated from the branching percentage[2] if they are not already given and are listed in the last column of Table I. The first and second columns represent the parent and the daughter nuclei respectively. In the third column the transition types are listed and the energy (in Mev) of the excited states of the daughter nuclei is given in brackets. Wherever the spins are not known definitely, they are put in parentheses.

3. CONCLUSIONS

From a study of Table I the following conclusions can be drawn:

1. $\log ft\,(2'') < \log ft\,(2')$
   $\log ft\,(2''') < \log ft\,(2'')$

S-34 is an exceptional case.

2. It can be remarked that in five out of six cases $\log ft\,(4') < \log ft\,(4)$. In only one case (Ti-48) the situation is reversed, that is $\log ft\,(4) < \log ft\,(4')$. It is also observed that $\log ft\,(4'') < \log ft\,(4')$ in the case of Xe-132 and Pd-104.

Within the context of Table I we notice an enhancement to the $2''^{+}$ (third excited 2 state), $2'''^{+}$ (fourth excited 2 spin state), $4'^{+}$ (second 4 spin state) and $4''^{+}$ (third excited 4 state) states, which is in direct contrast with the hindrance phenomena observed by Sakai[1] for $2'$ (second excited 2^{+} level) levels.

4. THEORETICAL REMARKS

Both the hindrance and enhancement phenomena can be qualitatively related to the excitation mechanism of the various excited levels. An attempt to understand these features in a quantitative fashion has been recently made by Sakai and Yoshida[3] from the point of view of the pairing correlation theory. This approach seems to be of some promise.

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6. REFERENCES

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2. Strominger, D., Hollander, J. M. and Seaborg, G. T.	*Reviews Mod. Phys.*, 1958, **30**, 585.
3. Sakai, M. and Yoshida, S.	*Report No.* 49, June 1963, Institute for Nuclear Study, Japan.