Indian J. Phys **44**, 198–203 (1970)

E_2 transition probabilities in even nuclei

M S RAJPUT AND A. AUGUSTHY

Department of Physics, Aligarh Muslim University
Aligarh (U.P.), India

(*Received* 19 *December* 1969—*Revised* 31 *March* 1970)

E_2 transition probabilities for $2^+ \rightarrow 0^+$ ground state transitions of even-even deformed nuclei have been calculated using Daveydov and Rostovsky (DR) estimates. The predictions of this model have been compared with the experimental data. From this comparison, it has been found that the DR estimates are closer to the experimental rates. The variations of the ratios $\frac{B(E_2)\text{exp}}{B(E_2)\text{DR}}$ and $\frac{B(E_2)\text{exp}}{B(E_2)\text{SP}}$ with nonaxiality parameter 'γ_0' of Davydov and Filippov theory which is a measure of the degree of departure from the axial symmetry, have been studied.

INTRODUCTION

Systematics of E_2 transition probabilities for $2^+ \rightarrow 0^+$ ground state transitions in even-even deformed nuclei in the mass region $150 \leqslant A \leqslant 200$ and $A > 230$ have been studied by several authors. No definite correlation has been found between the experimental and theoretical transition probabilities Several attempts by Alder *et al* (1956), Coleman (1957), McGowan & Stelson (1961), Curie (1962), Rajput & Sehgal (1967), Schwarzchild (1966) and Rajput (1970) have been made to explain the fastness of these transitions. The various models proposed to explain the fastness of these transitions have confirmed their collective behaviour. The most generally used single particle model predictions have shown that the experimental transition probabilities are larger by a factor ranging from 30 to 300 in the above mass region In this work we have studied the variations of the ratios of experimental transition probabilities to those theoretically calculated on the basis of the single particle, (Blatt & Weiskopf 1952) as well as the nonaxial collective models (Davydov & Rostovsky 1964), with the nonaxiality parameter γ_0 of Davydov and Filippov theory (1958). Davydov and Fillippov have suggested a model for deformed nuclei in which they assume that the rotation of the nucleus takes place without change of the intrinsic state. The equilibrium shape of the nucleus is like a triaxial ellipsoid and is determined by the two parameters β_0 and γ_0, where β_0 is the deformation parameter and γ_0 is the nonaxiality parameter. When there is a deviation from axial symmetry, it lowers one of the principal moments of inertia and increases the other The nucleus rotates about the axis with the largest moment of inertia.

Davydov and Rostovsky (1964) have treated the problem of collective excitations by taking into account the interactions of rotations with β and γ vibrations. The excited states generated in rotation due to the quadrupole vibrations of the nuclear surface are called γ vibrations. When the nucleus passes into the excited states, the shape of the nucleus changes. This increase in deformation increases the moment of inertia and hence causes the centrifugal stretching. Such vibrations are called β-vibrations.

Calculation of Transition Probabilities

Davydov and Rostovsky (1964) have derived the expressions for the E_2 transition probabilities from one collective state to the other in terms of the usual parameters of DF theory (Davydov & Fillippov 1958)). The reduced transition probability for E_2 transitions from the ground state to the first 2^+ state of ground state rotational band is given by,

$$B(E_2, 0^+ \rightarrow 2^+) = \frac{5e^2Q_0^2}{16\pi}\left(1-\frac{1}{S}\right)\left(1-\frac{2S}{3q^2}\right)^2 \quad \ldots \quad (1)$$

where

$$Q_0 = \frac{3ZR_0^2\beta_0}{\sqrt{5\pi}} \quad \ldots \quad (2) \qquad S = \frac{\epsilon_{22}}{\epsilon_{20}} \quad \ldots \quad (3)$$

$$q = \frac{\epsilon_{0\beta}}{\epsilon_{20}} \quad \ldots \quad (4) \quad \text{and} \quad R_0 = 1.2\times 10^{-13}\times A^{1/3}\ \text{cm} \quad \ldots \quad (5)$$

Here ϵ_{20} is the energy of 2^+ state of ground state rotational band, ϵ_{22} the energy of 2^+ state of the γ-vibrational band and $\epsilon_{0\beta}$ is the energy of 0^+ state of the β-vibrational band. β_0 is the deformation parameter. The effective values of these parameters have been calculated from the experimentally measured energy levels. The equilibrium deformations β_0 used in the calculations were taken from the work of Bes & Szymanski (1961) corrected by Marshack & Rasmussen (1963). Their values were obtained using Nilson levels and including pairing correlations and are in good agreement with experimental ones. Using these relations the transition probabilities have been calculated in 26 cases. The single particle reduced transition probabilities $B(E_2, 0^+ \rightarrow 2^+)_{SP}$ have been calculated using the relation

$$B(E_2, 0^+ \rightarrow 2^+) = 0.31 A^{4/3}\ e^2 \times 10^{-52}\ \text{cm}^4 \quad \ldots \quad (6)$$

The experimental transition probabilities have been compiled from Nuclear Data (1965). In some cases, the transition probabilities have been calculated from $T_{\frac{1}{2}}$ measurements where direct measurements are not available.

Results and Discussion

Table 1 gives the values of the parameters used in the calculations. The column 7 gives the values of transiion probabilities calculated using equation 1. We define the factors F_{DR} and F_{SP} as follows :

$$F_{DR} = \frac{B(E_2)\ \exp}{B(E_2) DR}$$

$$F_{SP} = \frac{B(E_2)\ \exp}{B(E_2) SP}$$

Alder *et al* (1956) studied the systematics of E_2 transition probabilities and pointed out that the interactions of the rotational and vibrational bands are responsible for the enhancement of these probabilities. Nathan & Nilson (1965) further emphasized the occurrence of collective vibrations and their relation with shell structure. The ratio $\frac{B(E_2)\ \exp}{B(E_2) SP}$ being always greater than 1, confirms the fact that the first 2^+ states are largely collective Several attempts (Alder *et al* 1956, Coleman 1957, McGowan & Stelson 1961 and Curie 1962) have been made to explain the collective behaviour of these transitions No definite correlation was found between the experimental data and the proposed systematics. Rajput & Sehgal (1967) found that the enhancement factors of the E_2 transitions for 2^+ to 0^+ state decreases gradually with the increase in the value of non-axiality parameter γ_0 of Davydov & Fillippov (1958) theory. Davydov & Rostovsky (1964) have reviewed the DF theory and calculated the transition probabilities taking into account fully the collective excitations of all types.

Experimental values of transition probabilities are compared with Davydov & Rostovsky (1964) and single particle estimates (Blatt & Weisskopf 1952). The theoretical values calculated using DR theory are closer to the experimental values than the single particle values Thus indicates the superiority of DR estimates over the single particle estimates.

Further interesting information is obtained when the factors F_{DR} and F_S plotted against the nonaxiality parameter γ_0 of DF theory. It was reported earlier by Rajput & Sehgal (1967) that the factor F_{SP} decreases gradually with increase in value of the nonaxiality parameter. But in this work we have observed that the factor F_{DR} increases slowly with the increase in the value of the nonaxiality parameter. The variations of F_{DR} and F_{SP} with nonaxiality parameter γ_0 are shown in figure 1. From this figure it is clear that the DR estimates are better approximations than the SP estimates; the two factors follow completely different trends. The variation of the factor F_{DR} with neutron number is shown in figure 2. The factor increases as the magic number is approached and again decreases as we go away from the magic number.

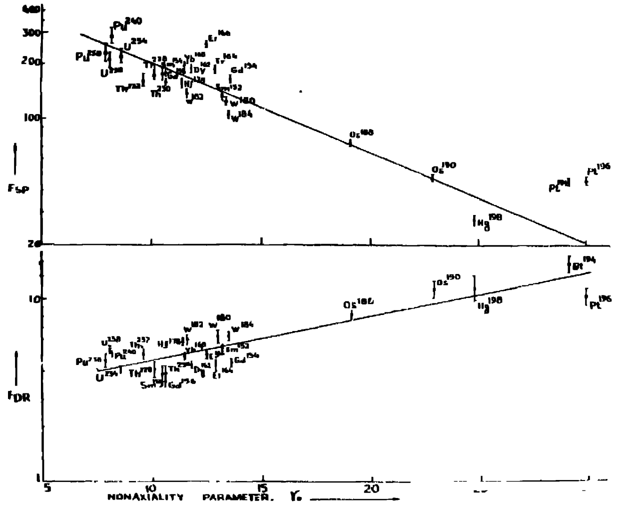

Figure 1. Variation of F_{DR} and F_{SP} with nonaxiality parameter γ_0

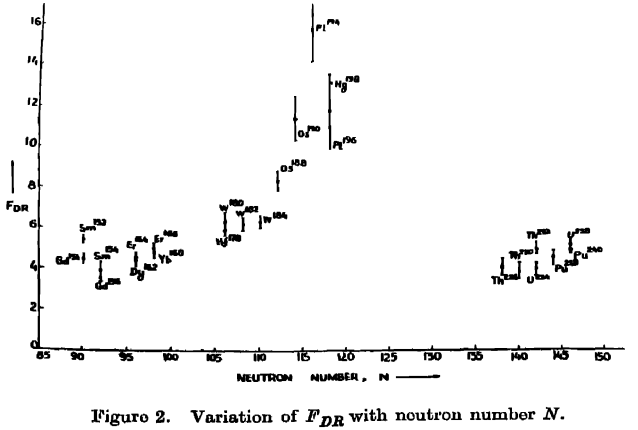

Figure 2. Variation of F_{DR} with neutron number N.

Table 1

Nucleus	Energy of of first 2^+ level (Mev)	S	q	β_0	$B(E_2)$ exp $e^2 \times 10^{-48}$ cm^4	$B(E_2)$ cal $e^2 \times 10^{-48}$ cm^4	F_{DR}	F_{SP}	γ_0
Sm^{152}	0 122	8.90	5.60	0 34	3 40± 12	0 629	5.40±.20	133±8	13.2
Sm^{154}	0.084	14 45	13.73	0 34	4.61±.20	1.161	3.90±.38	177±12	10.5
Gd^{154}	0 123	8.10	5.52	0 33	3 68±.20	0822	4 48± 22	167±4	13.6
Gd^{156}	0 089	13.00	11.40	0 33	4 68±.20	1 134	3 51± 15	181±4	10 6
Dy^{162}	0 081	10 96	12 71	0 31	5.06± 15	1 152	4.39±.13	190±9	11.8
Er^{164}	0.092	9.40	13.56	0.30	5 20± 35	1.171	4.44±.26	188±9	12 9
Er^{166}	0.081	9 78	18 17	0.29	5.78±.20	1 152	5 02± 18	246±7	12.5
Yb^{168}	0 088	11 21	13 62	0.28	5 43±.25	1.122	4 84±.22	196±9	11 5
Hf^{178}	0.093	12.12	12 80	0 22	4 57± 20	0.770	5 93±.26	158±6	11.4
W^{180}	0.104	7.91	8.77	0 21	4 39± 33	0 700	6 26± 50	125±5	13 4
W^{182}	0 100	12 22	11 38	0.20	4.15±.20	0.673	6.17±.30	138±7	11.6
W^{184}	0.111	8 14	21 00	0 18	3 66± 15	0 585	6.26± 26	103±4	13 5
Os^{188}	0.155	4.08	11 40	0 14	2 75± 15	0 332	8.29± 46	75±3	19.1
Os^{190}	0.187	2 98	18.00	0 12	2.55±.25	0.224	11 36±1.11	48±7	22.9
Pt^{194}	0.316	1.89	3.85	0 11	1 94±.20	0 123	15.83±1 63	46±7	29.2
Pt^{196}	0.356	1.91	6 20	0 10	1.27±.13	0.116	10.94±1.10	46±5	30.0
Hg^{198}	0.412	2.64	4 00	0.08	1.03±.10	0 088	11 77±1.76	28±4	24 8
Th^{228}	0.058	15.30	14.40	0.22	7 12± 75	1 734	4.11±.43	17±12	10.1
Th^{230}	0.053	13 00	11 90	0.24	7 90±.8	2 098	3.85±.39	165±4	10.6
Th^{232}	0 050	15 80	14.50	0.24	9.70±.5	1 942	5.00±.26	164±14	9.6
U^{234}	0.044	19.40	18 52	0.25	10 00±0.8	2.525	3.96±.32	221±21	8.6
U^{238}	0.045	23.80	22 20	0 24	12 60±0.6	2.427	5.19± 25	211±21	8.1
Pu^{238}	0.044	23 20	21 30	0.24	11.50±0 9	2.520	4 57±.37	234±25	7.9
Pu^{240}	0.044	23 70	20.00	0.24	12.70±0.4	2.526	5.03±.15	287±25	8 2

ACKNOWLEDGEMENT

The authors are very thankful to Dr. M. L. Sehgal for helpful discussions and encouragement. They are also thankful to Prof. Rais Ahmed for his interest in this work, and to the Council of Scientific and Industrial Research, New Delhi, for financial assistance.

REFERENCES

Alder K., Bhor A., Huus T., Mottelson B. & Winther A. 1956 *Rev. Mod. Phys.* **28** 432.
Bes D. R. & Szymanski Z. 1961 *Nuclear Physics* **28**, 42.
Blatt J. M & Weisskopf V. F. 1952 *Theoretical Nuclear Physics* John Wiley & Sons, New York
Coleman C F. 1957 *Nuclear Physics* **7**, 488.
Curie W M 1962 *Nuclear Physics* **32**, 574
Davydov A S & Rostovksy V. S. 1964 *Nuclear Physics* **60**, 529
Davydov A S & Filippov G F 1958 *Nuclear Physics* **8**, 237
Grodzins L. 1962 *Physics letters* **2**, 88
Funk E G., Prask H. J. & Mihelich J. W. 1966 *Phy Rev.* **141**, 1200.
Marshalek E R. & Rasmussen J O. 1963 *Nuclear Physics* **43**, 438
McGowan F. K & Stelson P H 1961 *Phys. Rev.* **132**, 1274
Nathan O & Nilson S. G. 1965 *α-β-γ-ray Spectroscopy*. Edited by K Siegbahn. N. H. Publ. Co., Amsterdam.
Nuclear Data 1965. Academic Press. New York.
Rajput M. S & Sehgal M. L 1967 *J Phy Soc. Japan* **23**, 917
Rajput M S. 1970 *Nuovo Cimento* **66A**, 343.
Schwartzchild A. 1966 *Phys. Rev.* **141**, 1214.