$2^- \rightarrow 2^+$ BETA TRANSITION OF ^{42}K

B. MALLIKARJUNA RAO, C. NARASIMHA RAO, P. MALLIKHARJUNA RAO, RAJAN MATHEWS AND K. VENKATA REDDY

Laboratories for Nuclear Research, Andhra University, Visakhapatnam 530 003

ABSTRACT

A Siegbahn-Slatis intermediate image magnetic coincidence spectrometer has been used to study the spectral shape of the non-unique first-forbidden beta transition in ^{42}K. The beta with an end-point energy of 2000 keV follows the spin sequence $2^- \rightarrow 2^+$ and has been studied in coincidence with the 1520 keV gamma that follows it. The shape has been fitted with a correction factor of the form $C(W) = k\ (1 + aW + b/W + cW^2)$ with $a = -0{\cdot}11 \pm 0{\cdot}060$, $b = 0{\cdot}701 \pm 0{\cdot}192$ and $c = 0{\cdot}012 \pm 0{\cdot}072$. The results of the present investigation are discussed from a suitable nuclear model interpretation point of view.

INTRODUCTION

THE decay scheme[1] of ^{42}K is well established. The outermost beta following the spin sequence $2^- \rightarrow 0^+$ with an end-point energy of 3520 keV is a first-forbidden unique transition[2]. The first inner beta component of present interest is a $2^- \rightarrow 2^+$ non-unique first-forbidden transition. Beta transitions with $\Delta J = 0$ like the $2^- \rightarrow 2^+$ transition in the case of ^{42}K are governed by all the six matrix element parameters. It is difficult to find unique solutions for these transitions in spite of accurate measurements of the beta decay observables. To add to this discrepancies in the measurements of various observables, persist because of the different experimental methods adopted by various authors. And as such measurements and re-measurements of the various beta decay observables governing the $2^- \rightarrow 2^+$ transitions are widely found in literature by the various groups of researchers using different instruments. This has prompted the authors to re-investigate the spectrum shape of the $2^- \rightarrow 2^+$ transition in ^{42}K with present set-up which yields accurate results.

The $2^- \rightarrow 2^+$ component of the present interest has a ξ-value $\left(\frac{\alpha Z}{2R}\right) \approx 6{\cdot}8$ which is not much greater than the end-point energy W_0 ($\approx 4\ m_0 c^2$ units) thus suggesting the non-applicability of ξ-approximation to this case. There have been several investigations on this $(2^- \rightarrow 2^+)$ inner beta of ^{42}K. Koertz[3] using a coincidence magnetic spectrometer and later Pohm *et al.*[4], using singles spectrometer independently reported an allowed shape in the energy region 0·5 to 1·97 MeV, within statistical fluctuations. This is in contradiction with high log *ft* value and the small value of (compared to W_0). Andre *et al.*[5], using a Siegbahn–Slatis intermediate-image coincidence spectrometer and Daniel *et al.*[6], using a Heidelberg intermediate-image coincidence spectrometer report a considerable deviation from the allowed shape. They performed the shape factor analysis and fitted the data to a correction factor of the form $(C(W) = k\ (1 + aW + b/W + cW^2)$. The value of the constants *a*, *b* and *c* reported in the above two works differ from each other. It is, therefore, felt worthwhile to undertake a systematic investigation of this beta transition in ^{42}K using the present standadised set-up.

EXPERIMENTAL DETAILS

The radioactive material was produced by neutron irradiation of the enriched ^{41}K (99·49%) procured from ORNL, Tennessee, in the CIRUS reactor of BARC, Bombay. The radioactive material was obtained as a chloride in dilute HCl solution. The source was received in three consignments for the present experimentation. Uniform sources were prepared on thin aluminised mylar backing by vacuum evaporation. In general the source thicknesses for coincidence experiments ranged from 100–120 μgm/cm^2 and that of singles spectra from 30–60 μgm/cm^2. The sources were all of 2 mm diameter. The total time taken for each run was restricted to 8 hours to reduce the decay correction.

A Siegbahn–Slatis β-ray spectrometer is used to investigate the beta spectrum. The optimisation of the spectrometer for precision analysis of beta spectra and elimination of back scattering effects, etc., have been described elsewhere[7-9]. The details of the modifications, optimisation of the spectrometer for coincidence studies and its operation have been described elsewhere[10-12].

An overall test of the equipment was obtained from a measurement of the coincidence spectrum of the 960 keV β group in ^{198}Au, under conditions similar to those used in the ^{42}K experiment. The shape factor plot was fitted to a linear correction factor of the form $C(W) = k\ (1 + aW)$ with $a = (-0{\cdot}025 \pm 0{\cdot}008)\ (m_0 c^2)^{-1}$ and the end-point energy of the beta is 962 ± 2 keV. This

result is found to be in excellent agreement with the earlier reported works[13-16].

The coincidence spectrum was recorded by scanning the beta spectrum in coincidence with the 1520 keV gamma rays. The resolving time of the coincidence unit was set at 24 ns. The 1·52 MeV gammas were accepted in a window of 30% of the photopeak in the gamma channel. All spectra were roughly scanned in steps of 50 keV in the energy range 200 to 1850 keV. For each run about 3,000 counts were collected at the maximum of the beta continuum. The observed count rate was corrected for (*i*) chance rate, (*ii*) finite spectrometer resolution, (*iii*) back-scattering, (*iv*) coincidence efficiency and (*v*) beta-gamma angular correlation anisotropy.

The shape of this transition was also analysed from the singles experiment. The singles spectrum was recorded in the range 0·200 to 3·5 MeV in steps of 60 keV. The outer beta with a spin change (ΔJ) equal to 2 is unique firstforbidden transition and has been analysed[2] fitting the spectrum to a correction factor for the form

$$C(U) = (q^2 + 9\,L_1/L_0)\ (1 - a\,W).$$

The shape of the inner beta component was constructed by eliminating the influence of the outer beta by the subtraction method.

The spectra were analysed by standard procedures described earlier[7-9]. Figure 1 shows the F.K.

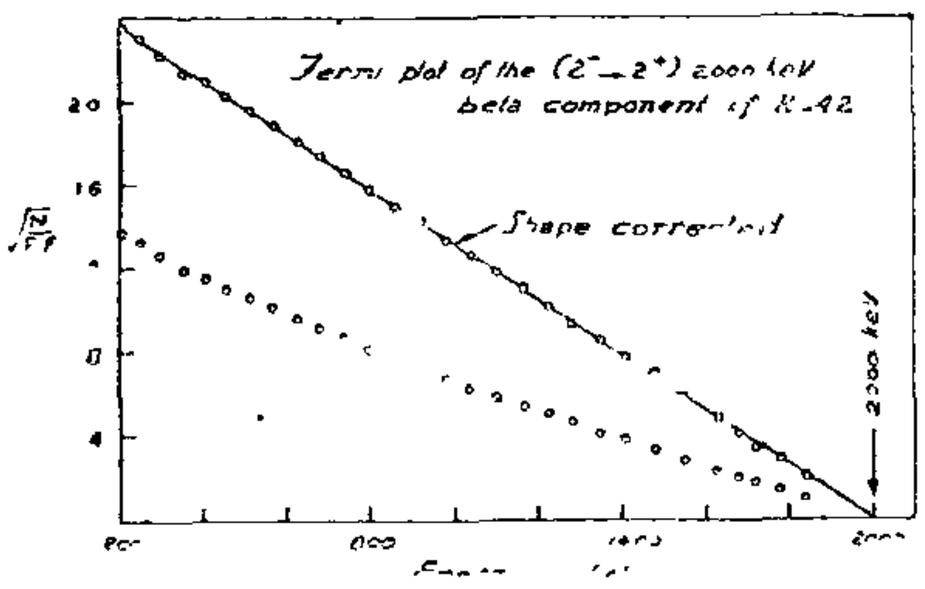

FIG. 1. Fermi plot of K-42 bata spectrum in coincidence with the 1520 keV gamma-ray.

plot of the coincidence spectrum. The correct end-point energy was judged from the behaviour of the shape factor curves when W_0, the end-point energy, is varied in steps of 2 keV. The experimental shape factor was weighted least-square fitted to a shape correction factor of the form $C(W) = k(1 + aW + b/W + cW^2)$ and is represented by the dashed line in Fig. 2, for the data corresponding to the run No. 2. The results due to the three coincidence runs and the singles run are summarised in Table I. From Table II, it can be seen that the present results concerning the values of end-point energy are in substantial agreement with those of Andre[5].

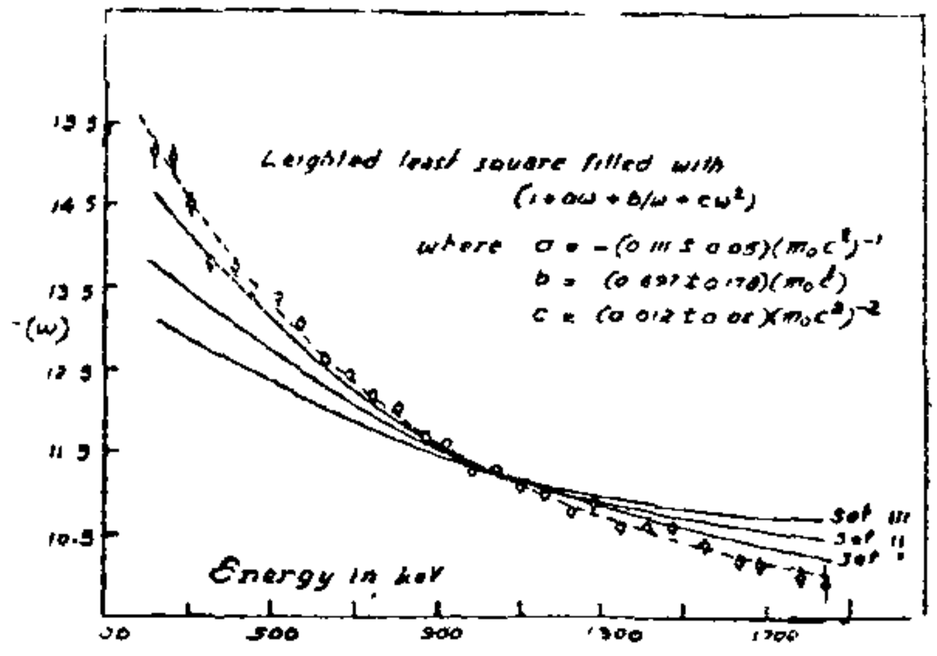

FIG. 2. Shape-factor of ^{42}K (2000 keV). The experimental points are fitted with $c(W) = k(1 + aW + b/W + cW^2)$ by weighted least squares. The three solid lines represent the theoretical estimates from the matrix elements sets due to Vema Reddy *et al.*

DISCUSSION

First-forbidden transitions with no spin change are in general too involved to facilitate a matrix element analysis as these transitions are caused by as many as six matrix elements. However, it is interesting to note that most of these transitions exhibit the characteristics of an allowed beta transition and can be well described by the ξ-approximation or the so-called 'quasi-allowed approximation'. This is not surprising as a cancellation effect is not likely to take place simultaneously in both V and Y. As can be seen from shell model, a reduction in Y by an accidental cancellation is also highly improbable, except in the case where λ_1, in equation $Y = -C_v \xi (/_{CVC} - 1 - 1\,2\,\lambda_1) \int \vec{ir}$, is about 1. The large spectrum shape deviation (of the order of 35%) as found in the present work and also the large beta-gamma anisotropy concerning the $2^- \rightarrow 2^+$ beta transition in ^{42}K besides a high log *ft* value show the breakdown of ξ-approximation in this case. Also, the condition for ξ-approximation, namely, $\xi \gg (W_0 - 1)$ is not satisfied inasmuch as that the ratio of $(W_0 - 1)/\xi \approx 0{\cdot}6$ for this transition. Thus, this transition can only be classified as one that deviates from ξ-approximation[17] and this deviation may perhaps be due to an accidental cancellation in Y or V or due to a selection rule effect. Vema Reddy *et al.*[18] have evaluated, using Simms[19] accurate formalism, the six matrix element parameters associated with this transition in ^{42}K with their beta-gamma angular correlation results coupled to the shape factor due to the present

TABLE I

Results of the beta shape factor analysis of the $2^- \rightarrow 2^+$ beta in ^{42}K

Run No.		E_0 (keV)	Shape factor $C(W) = k(1 + aW + b/W + cW^2)$		
			$a\,(m_0c^2)^{-1}$	$b\,(m_0c^2)$	$c\,(m_0c^2)^{-2}$
Coincidence	1	2001±2	−0·111±0·06	0·701±0·192	0·012±0·072
	2	2000±2	−0·111±0·05	0·697±0·178	0·012±0·061
	3	2003±2	−0·114±0·05	0·662±0·182	0·012±0·063
Singles	1	1995±2	−0·324±0·023	1·270±0·088	0·035±0·002

TABLE II

Comparison of the end-point energy and the shape correction factor constants due to different authors for the 2 MeV transition of ^{42}K

Author	E_0 (keV)	$C(W) = k(1 + aW + b/W + cW^2)$		
		$a\,(m_0c^2)^{-1}$	$b\,(m_0c^2)$	$c\,(m_0c^2)^{-2}$
Pohm[4]	1980	$0 \leq a \leq 0{\cdot}1$	..	..
Andre[5]	2000	−0·12±0·04	0·67±0·06	0·013±0·008
Daniel[6]	2000	−0·15±0·026	0·81±0·47	−0·020±0·030
Present work	2000	−0·11±0·05	0·70±0·178	0·012±0·061

TABLE III

Matrix element parameter sets reported by Vema Reddy et al.[6], *consistent with the present shape measurements*

	Y	V	x	u	w	z	λ	Λ_{CVC}
Set I	0·440	2·28	−2·56	−4·28	−2·70	1·00	0·25	3·10
Set II	0·500	2·28	−2·56	−4·18	−2·70	1·00	0·32	3·03
Set III	0·378	2·20	−2·35	−3·82	−1·60	1·00	0 29	3·06

investigation and the circular polarisation results due to De Saitignon[20]. Figure 2 shows the shape predicted by three sets due to this analysis and the corresponding values are tabulated in Table III. From Fig. 2 it can be seen that the shape predicted by Set 1 is in good agreement with the present measurement. On examining the various values of the parameters, especially the value of Y which is reduced by one order of magnitude when compared to other matrix element parameters one can only conclude that there is a significant suppression in the magnitude of Y which could be due to an accidental cancellation and this is in clear agreement with the conclusion we arrived at earlier when we considered the applicability of ξ-approximation to the present behaviour of the beta spectral shape.

Applicability of Nuclear Models to the $2^- \rightarrow 2^+$ Transition.—^{42}K is an odd-odd nucleus with 19 protons and 23 neutrons decaying *via* beta decay to the even-even daughter nucleus ^{42}Ca, with 20 protons and 22 neutrons. In the shell description the parent state can be given as $1f_{7/2}$ while the daughter state as $1d_{3/2}$, a neutron transforming into a proton. In a transition of this kind where $\Delta J = 2$, only the rank 2 matrix element $\int B_{ij}$ should be different from zero and the shape exhibited by such a transition should be of the unique first-forbidden type. But, this is not true in the present case, when one examines the shape factor plot of

the beta spectrum and also the values of the nuclear matrix element parameters due to the analysis of Verma Reddy *et al.*[18] inasmuch as the rank zero and one matrix elements make significant contributions to this transition. From this it may be concluded that the 2^- and 2^+ states of ^{42}K and ^{42}Ca respectively cannot be represented as pure shell model states. Andre *et al.*[5], suggested an admixture of $2\,p_{3/2}$ in the parent state. Then, the transition may follow the spin sequence $2\,p_{3/2} \rightarrow 1\,d_{3/2}$. In this case where $\Delta J = 0$, all the six matrix element belonging to rank 0, 1 and 2 govern the beta transition. Following this an attempt is made to compute the matrix element ratios x/z, u/z and w/z employing the expressions of Rose and Osborn[21]. The values thus obtained are given below.

$$x/z = -0{\cdot}2976,\ u/z = -1.4140 \text{ and}$$
$$w/z = -1{\cdot}3691.$$

A comparison of these values with the experimentally derived ones given in Table III, shows that even this description based on an admixture of configurations does not give a correct picturisation of the involved parent state. Hess[22] suggests another alternative to explain these matrix element parameters by introducing a deformed component both in the parent and the daughter states. This requires, the vanishing of rank one matrix elements. From the present solutions of matrix element parameters, it can be seen that these matrix elements are different from zero. Thus the suggestion of Hess also appears to be not true for the present case. From a model point of view both the parent and the daughter states are not well understood. Finally one can only conclude that a theoretical investigation of the present involved state from several angles would be highly useful in explaining the present trend of this 2·0 MeV transition in ^{42}K.

1. *Nuclear Data Sheets,* 1974, A214.
2. Narasimha Rao, C., Mallikarjuna Rao, B., Mallikharjuna Rao, P. and Venkata Reddy, K., *Phys. Rev. C,* April, 1975, 11, 735.
3. Koertz, Schwarchild, Gold, and Wu, *Phys. Rev.,* 1954, 95, 612.
4. Pohm, A. V., Waddell, R. C. and Jenson, E. N., *Ibid.,* 1956, 101, 1315.
5. Andre, S. and Depommier, P., *Compt. Rend.,* 1964, 259, 1102.
6. Daniel, H., Schmitt, H. and Springer, K., *Kolloquim Uber Betazerfall u Schwache Wechselwirkung,* Max Plant Institut fur Kern–Physik, Heidelberg, 1965, p. 225.
7. Nagarajan, T. and Venkata Reddy, K., *Nucl. Inst. Meth.,* 1969, 66, 77.
8. — and —, *Phys. Rev.,* 1969, 178, 1968.
9. — and —, *Nucl. Instr. Meth.,* 1970, 80, 217.
10. Mallikarjuna Rao, B., *Ph.D. Thesis,* Andhra University, Waltair, 1975 (Unpublished).
11. —, Narasimha Rao, C., Mallikharjuna Rao, P. and Venkata Reddy, K., Communicated to *Nucl. Instr. Meth.*
12. Ravindranath, M., Narasimha Rao, C. and Venkata Reddy, K., *Nucl. Phys. and Solid State Phys. Symp.,* Bombay, 1972, 14 B, 511.
13. Keeler, W. J and Connor, R. D., *Nucl. Phys.,* 1965, 61, 513.
14. Lewin W. H., Van Nooyen, B., Van Eijk, C. W E. and Wapstra, A. H., *Ibid.,* 1963, 48, 159.
15. Paul, H., *Ibid.,* 1965, 72, 326.
16. Van Krugten, H., *Thesis,* Univ. of Tech. Delft, 1967 (Unpublished).
17. Kotan, T. and Ross, M., *Phys. Rev. Lett.,* 1958, 1 (4), 140.
18. Verma Reddy, B., *Ph.D. Thesis,* Andhra University, Waltair, 1974.
19. Simms, P. C., *Phys. Rev.,* 1965, 138 B, 784.
20. Saitignon, P. De., Chabre, M. and Depommier, P., *Compt. Rend.,* 1964, 258, 884.
21. Rose, M. E. and Osborn, R. S., *Phys Rev,* 1954, 93, 4326.
22. Hess, R., *Helv. Phys. Acta,* 1968, 41, 77.

SYNTHESIS OF GLABRANINE, 5, 7-DIHYDROXY-6-PRENYL-FLAVANONE AND 5-HYDROXY-7-METHOXY-6-PRENYL FLAVANONE

V. P. MANCHANDA, A. K. BATTA, P. L. KHANNA AND R. N. KHANNA*

Department of Chemistry, Delhi University, Delhi-7

ABSTRACT

An unambiguous synthesis of glabranine (I), 5, 7-dihydroxy-6-prenyl flavanone (II) and 5-hydroxy-7-methoxy-6-prenyl flavanone (III) have been carried out starting from phloroglucinol and cinnamoyl chloride. Syntheses of two chromeno-flavanones have also been reported.

GLABRANINE (I) m.p. 154–55° was isolated from *Glycyrrhiza glabra*[1] and has been assigned the structure, 8-C-prenyl-5, 7-dihydroxy-flavanone from its spectral studies. Recently an isomer of Glabranine, 5, 7-dihydroxy-6-prenyl flavanone (II) and the methyl ether (III) have also been isolated from Derris Rariflora[2] and the structures established based on spectral data. They have now been synthesised and the properties of the synthetic compounds have been found to be in complete agreement with those reported in the literature.

* All correspondence should be addressed to R. N. Khanna.