SHAPE FACTOR ANALYSIS OF THE 690 keV BETA TRANSITION IN ^{111}Ag

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ABSTRACT

The earlier shape measurements on the 690 keV beta transition of ^{111}Ag are inconsistent with each other. So a thoroughly tested Siegbahn-Slatis coincidence beta ray spectrometer is used to study the shape of the above transition and the shape factor is fitted with a form $C(W) = k(1 + aW)$ where $a = (0{\cdot}0879 \pm 0{\cdot}0188)\ (m_0 c^2)^{-1}$. The results are discussed from a suitable model interpretation point of view.

INTRODUCTION

THE beta decay of ^{111}Ag is of particular interest both from the spectrum shape measurement and the nuclear model interpretation point of view. The presence of four betas with end point energies 1044, 793, 690 and 414 keV are well established[1,2,3]. Robinson *et al.*[2] employing a 4π anthracene spectrometer studied the shape of the 690 keV beta and reported a large deviation in the spectrum shape from linearity. Hamilton *et al.*[4] and later Seshagiri Rao *et al*[5] independently studied the beta-gamma angular correlation coefficient of the 690 keV beta in coincidence with the 342 keV gamma that followed it and reported the coefficients to be nearly independent of energy. Later Lehmann[6], employing a Siegbahn-Slatis coincidence beta-ray spectrometer reported the spectrum shape to be statistical in nature in complete contradiction with the earlier results due to Robinson *et al.* More recently Nagarajan *et al.*[7], employing an intermediate image spectrometer, confirmd the results of Lehmann. However, Nagarajan *et al.* employed a singles spectrometer and hence the shape analysis of the 690 keV beta, which was constructed after subtraction of two outer betas, involves large errors. Moreover the end point energy E_0 of the beta reported by Nagarajan *et al.* (*viz.* 695 keV) differs from the value reported by Lehmann, by as much as 10 keV.

Delabaye *et al.*[8] calculated matrix elements of this transition based on both extreme single particle model and experimental observables such as spectrum shape, beta gamma correlation and beta-circularly polarised gamma correlation. The matrix elements obtained from single particle model were unable to predict the shape deviation measured by Robinson *et al.* Seshagiri Rao analysed the matrix elements by relaxing the spectrum shape measurement of Robinson and Langer. He obtained the matrix elements of magnitude consistent with ξ-approximation where $\xi = aZ/2R$. In fact the criterion for ξ-approximation $\xi >> W_0 - 1$ is well satisfied in this case ($\xi \sim 10$, $W_0 = 2{\cdot}3$). Thus it was felt that a remeasurement of the shape of the 690 keV transition would be interesting inasmuch as it clearst he discrepancies that exist in the earlier measurements and that it would also throw much light on the structure of the 343 keV level in ^{111}Cd.

EXPERIMENTAL DETAILS AND RESULTS

Carrier free ^{111}Ag isotope was obtained from BARC, Bombay. The decay scheme of ^{111}Ag is shown in Fig. 1. 2 mm diameter sources were prepared on thin mylar foils and the source thickness was found to be $\sim 150\ \mu g/cm^2$.

A Siegbahn-Slatis beta-ray spectrometer modified for beta-gamma coincidence studies was employed in the present investigation. The details of the modification and optimisation of the spectrometer for coincidence studies are described elsewhere[9,10].

The coincidence spectrum was recorded by scanning the beta spectrum in coincidence with the 342 keV gamma ray. The resolving time of the coincidence unit was set at 24 ns. The observed countrate was corrected for (i) chance rate, (ii) finite spectrometer resolution, (iii) back scattering and (iv) coincidence efficiency. Correction for beta-gamma angular correlation anisotropy was not applied as the reported anisotropy[5] is negligible. All the spectra were analysed with the Fermi functions of Bhalla and Rose[11] and screening corrections due to Buhring[12]. The method of analysis is described elsewhere[13]. The end point energy was determined from the behaviour of the shape factor curves, when E_0 the end point is varied around the true end point energy.

Figure 1 shows the Fermi-Kurie plot of the coincidence spectrum. The experimental shape factor was weighted least square fitted to a correction factor of the form $C(W) = k(1 + aW)$ and is shown by the solid line in Fig. 2. The values of 'a' for different runs are shown in Table I.

TABLE I

Run	Energy in keV	$a\ (m_0 c^2)^{-1}$
1	697±2	$-0{\cdot}0894 \pm 0{\cdot}0324$
2	696±2	$-0{\cdot}0836 \pm 0{\cdot}0312$
3	697±2	$-0{\cdot}0915 \pm 0{\cdot}0343$

Discussion

^{111}Ag is a spherical odd-proton nucleus ($Z = 47$) which decays to ^{111}Cd. The neutron and proton configurations of ^{111}Ag are $50 + (2d_{5/2})^6\ (1g_{7/2})^8\ (3s_{1/2})^2$ and $28 + (2p_{3/2})^4\ (1f_{5/2})^6\ (2p_{1/2})^1\ (1g_{7/2})^8$ respectively. The initial and final configurations of the outermost beta with an end point energy of 1035 keV can be written as

$$[(\nu s_{1/2})_{J_1}{}^2 = 0\ \pi P_{1/2}]_{J'=1/2}$$

and

$$[(\pi P_{1/2})_{J_2}{}^2 = 0\ \nu_{1/2}]_{J=1/2}$$

respectively.

Thus the daughter nucleus ^{111}Cd, where the odd neutron is in an $s_{1/2}$ orbital presents a good case for the applicability of the core excitation model due to de—Shalit[14].

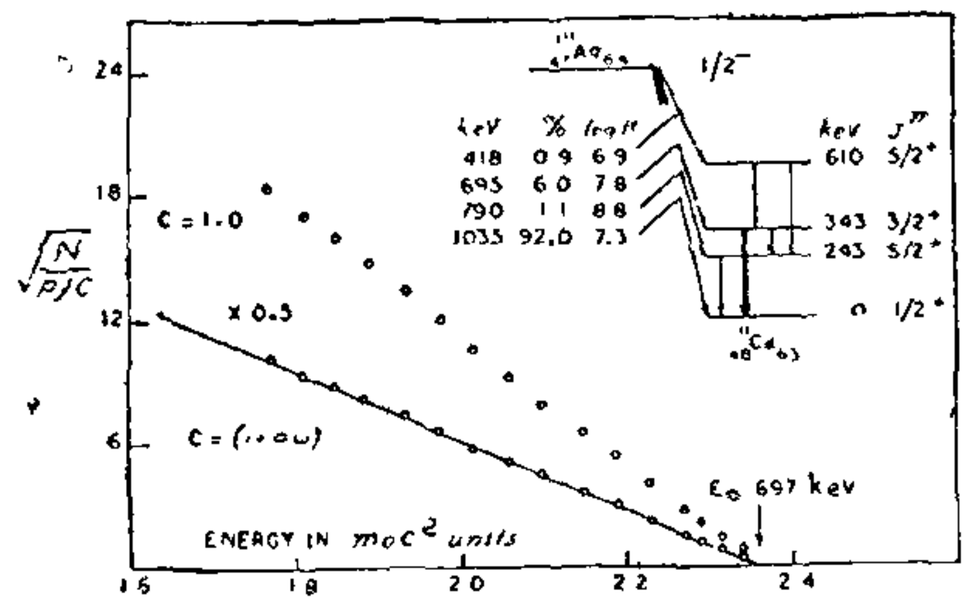

FIG. 1. The Fermi-Kurie plot of the 697 keV beta in the decay of ^{111}Ag measured in coincidence with the 343 keV gamma.

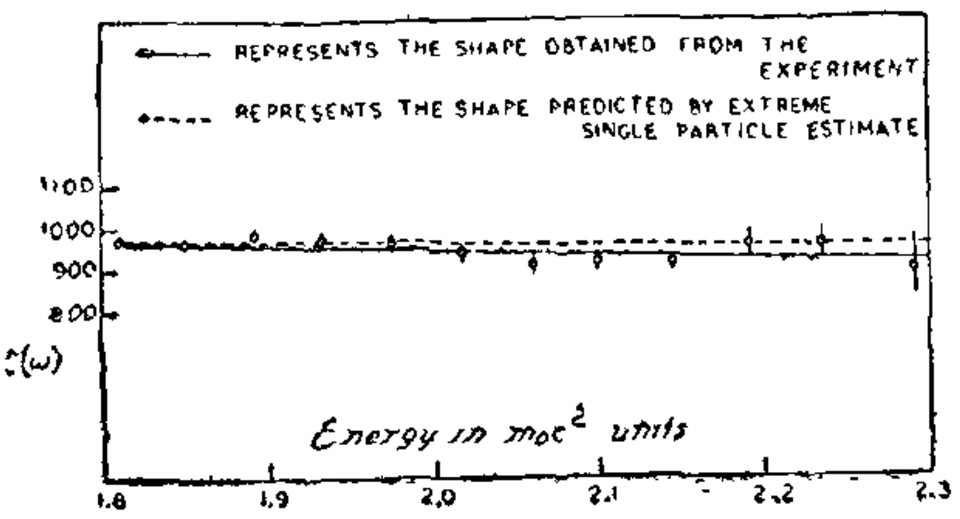

FIG. 2. Comparison of experimental and theoretical shapes of the 697 keV beta transition in ^{111}Ag.

The Nuclear matrix elements (NMEs) evaluated by both Delabaye *et al.* and Seshagiri Rao show that the normal matrix elements are reduced in size and are comparable to the B_{ij} matrix element. According to the ξ-approximation, the normal matrix elements dominate the transition and their magnitudes consequently should be larger than that of the B_{ij} matrix element. On the other hand if the modified B_{ij}-approximation is applicable, the reduction of the normal matrix elements must be so as to reduce them to magnitudes smaller than the B_{ij} matrix element. However, relative magnitude of the matrix elements obtained by Delabaye *et al.* and Seshagiri Rao clearly indicates that none of these two extreme cases can be applied to the present beta transition. The cause of the reduction, however, cannot be inferred from the present experimental results inasmuch as the 'J-selection rule' is not violated and the 'K-selection rule' cannot be invoked in view of the fact that ^{111}Cd is a spherical nucleus.

Delabaye *et al.* in their attempt to study the structure of the 340 keV state assumed a wave function of the type:

$$|J,\ M\rangle = a\,|d_{\frac{1}{2}};\ J = j,\ M\rangle + \beta\,|s_{1/2},\ J_c = 2;\ J,\ M\rangle,$$

in which, the first part corresponds to the single particle excitation and the second part corresponds to the core-excitation. The first part of the wave function is assumed to be due to the excitation of the partice into the *d*-orbit. The later part of the wave function corresponds to the retention of the particle in the $s_{1/2}$ orbit and exciting the core to the first phonon vibrational state. The relative amplitudes of these wave functions are denoted by α and β. Their analysis, however, showed that the values of matrix elements were not sensitive to the magnitudes of α and β. A pure de-Shalit type of core-excitation is, however, seldom encountered. Recently Rama Murty *et al.*[15] studied the states of ^{111}Cd using the intermediate coupling model and described the $3/2^+$ state by the following wave function:

$$|3/2^+\rangle = 0{\cdot}61\ \ |0\ 3/2\ 3/2\rangle - 0{\cdot}53\ |2\ 1/2\ \ 3/2\rangle + 0{\cdot}34\ |2\ 3/2\ 3/2\rangle - 0{\cdot}42\ |2\ 5/2\ 3/2\rangle + 0{\cdot}20\ |2\ 7/2\ 3/2\rangle$$

and with this description all the electromagnetic properties of this state were satisfactorily explained. In the above wave function the contribution of the single particle wave function $|0\ 3/2\ 3/2\rangle$ is 36%. The present shape data are consistent with the single particle nature of the state involved. Noting that the contribution of the $|0\ 3/2\ 3/2\rangle$ in the wave function obtained by Rama Murty *et al.* is the maximum (36%), it may be concluded that the present shape data are also consistent with the wave function of Rama Murty *et al.* Alternatively, it may be possible to view the 343 keV state as arising from angular momentum coupling. The nucleus $^{111}_{48}Cd_{63}$ is of odd neutron type with 13 neutrons in excess of 50 (which complete the first four major shells), having the orbitals $d_{5/2}$, $g_{7/2}$, $s_{1/2}$, $d_{3/2}$, $d_{5/2}$ and $h_{11/2}$ for their occupation. Several possible configurations are available in which a spin 3/2 could occur. A detailed study of these configurations may throw some light on the structure of the 343 keV state which may account for the reduction in the size of the normal matrix elements. The present shape factor analysis is well in agreement with

the shape predicted by the matrix elements calculated by Delabaye *et al.* on the basis of extreme single particle model as shown in Fig. 2.

Conclusions

(1) The present experimental results regarding the shape of the 693 keV beta transition show a small deviation from the exact allowed shape reported by Lehmann, which is within the ξ-approximation. This might be due to the incorrect choice of the end point energy on the part of Lehmann.

(2) The present shape is consistent with the shape predicted by the matrix elements calculated from extreme single particle model.

1. Johansson, S., *Phys. Rev.*, 1950, **79**, 896.
2. Robinson, R. S. and Langer, L. M., *Ibid.*, 1958, **112**, 481.
3. Sastry, V. V. G., Lakshmirarayana, V. and Jnanananda, S., *Nucl. Phys.*, 1964, **56**, 140
4. Hamilton, J. H., Pottersson, B. G. and Hollander, J. M., *Arkiv Fysik*, 1960, **18**, 273.
5. Seshagiri Rao, V., *Ph.D. Thesis*, Andhra University, Waltair, 1967.
6. Lehmann, J., *Nucl. Phys.*, 1967, **A 98**, 273.
7. Nagarajan, T., Ravindranath, M. and Venkata Reddy, K., *Phys. Rev.*, 1971, **C 3**, 254.
8. Delabaye, M., Deutsch, J. P. and Lipnik, P., *Nucl. Phys.*, 1966, **80**, 385.
9. Ravindranath, M., Narasimha Rao, C. and Venkata Reddy, K., *Nucl. Phys. and Solid State Phys. (India)*, 1972, **14 B**, 511.
10. Seshi Reddy, T., *Ph.D. Thesis*, Andhra University, Waltair, 1976.
11. Bhalla, C. P. and Rose, M. E., *ORNL Report*, 1962, No. 3207.
12. Buhring, W., *Nucl. Phys.*, 1965, **61**, 110.
13. Nagarajan, T. and Venkata Reddy, K., *Nucl. Instr. and Meth.*, 1970, **80**, 217.
14. de-Shalit, A. and Talmi, T., *Nuclear Shell Theory*, Academic Press, Inc., New York, 1963.
15. Rama Murty, V. V., Rama Rao, M. T. and Lakshminarayana, V., *Phys. Rev.*, 1970, **C1**, 1498.

SYNTHESIS OF SOME BENZOTHIAZOLYL HYDRAZONES

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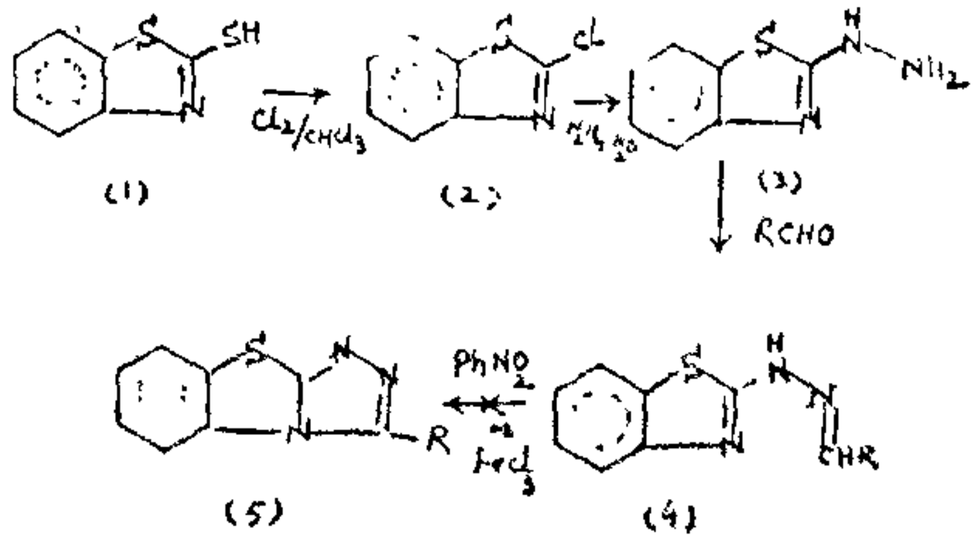
ALTHOUGH a large amount of work has been carried out on 1, 2, 4 triazoles, very little information is availabe on *s*-triazolo (3, 4-*b*) benzothiazoles possessing various functional groups. This gap may perhaps be due to non-availability of efficient methods for the synthesis of starting material. The method for the synthesis of this system involving the use of hydrazine has been discussed earlier by various workers[1,2]. Hydrazino benzothiazole is generally prepared from 2 mercapto[3] or 2-chloro benzothiazole by the action of hydrazine hydrate. The reaction was carried out with varying concentrations of hydrazine hydrate for different durations. There is no significant improvement in the yield. The reported chloro compound obtained from mercapto benzothiazole and sulfur monochloride was formed only in low yields. Heterocyclic thiols on oxidative chlorination are generally known to yield sulfonyl chlorides and this method finds a general use for the synthesis of the corresponding sulfonamides[4,5].

Hence the use of gaseous chlorine was investigated under mild condition. The conditions of reactions were so adjusted that the variation of both the time of reaction and the chloroform: water ratio in the suspending medium was possible. When gaseous chlorine was bubbled through mercapto benzothiazole suspended in chloroform and water it was noticed that the product after 50 to 60 min was indeed a 2-chloro benzothiazole. The chloro compound thus obtained was converted into the hydrazino compound in 72-75% yield. In this particular case reaction of chloro derivative with hydrazino, proceeded well to give good yields in contrast to some reports where the conversion of halo heterocycle to the corresponding hydrazine, proceeded with poor yields[6]; excessive heating with hydrazine[7] resulted in the decomposition of the mixed heterocycles, possessing sulfur and nitrogen. With excess of hydrazine for a period of 40 minutes, the yield is better than that reported by Veltman[8].



In the hope of obtaining biologically active compounds, hydrazino benzothiazole was condensed with various aldehydes. Cyclization of these hydrazones through nitrobenzene did not proceed and the oxidation with ferric chloride did not give satisfactory results. These were cyclized by bromine in acetic