DECAY OF Eu^{155}

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INTRODUCTION

EUROPIUM^{155} is known[1] to decay to Gadolinium^{155} with half life about 1·7 years. There are three decay schemes proposed recently, one by Dubey *et al.*,[2] the other by Juliano[3] and the third by Bisi and Zappa.[4] The last two decay schemes are similar except that there is one more level at 117 kev. to explain new transitions observed by them. There is considerable disagreement about spin and parity assignments to these levels and also about the β-groups. Since Gd^{155} is an odd A nucleus in the region of nuclei where large deformation is known to be present, it would be interesting to know more about these nuclear levels. This isotope was reinvestigated using intermediate image Siegbahn-Slätis β-ray spectrometer adapted for β-$\bar{e}$-coincidence measurements. The conversion line spectrum of this isotope has not been studied so far using this technique.

OBSERVATIONS

The source was obtained by irradiating in Oak Ridge Pile, a sample of Sm^{154}, enriched to 99·1%. The other activity produced was due to Eu^{156} which decays to Gd^{156} with half life of 15 days. About a year had elapsed before the observations on Eu^{155} were started. There was thus no possibility of Eu^{156} being present in appreciable amount. Other impurity that was observed was Eu^{154}. Contribution due to Eu^{154} could easily be established by coincidence measurements as shown later.

(*a*) The spectrometer was adjusted for resolution 2·7% as tested with Cs^{137} source of 3 mm. diameter. Eu^{155} source was prepared by evaporating a drop of solution on a thin plastic film made conducting by aquadaq. Insuline was used for getting uniform sources. The β-particle detector on the focussing side was a thin anthracene crystal covered with 150 μgm./cm.^{2} thick aluminium foil as a reflector, and mounted on a perspex light guide, 9″ long and 1″ diameter, which passes through the pole piece of the spectrometer. EM.I. photomultiplier tube 6260 type was used. Pulses from the anode were fed to the amplifier and discriminator and to the recorder. The low energy response was tested with K and L lines of 84 kev. transition in the decay of Tm^{170}. Performance of this scintillation detector was tested by studying different well-known isotopes (*e.g.*, Co^{60}, Tm^{170}, Ce^{144} and Eu^{152}). One finds only three distinct peaks superposed on very intense background due to β-continuum. These conversion lines have been identified as due to 86 kev. (K_1 L_1) and 105 kev. (K_2 L_2) transitions. An estimate of relative intensities of these lines based on such a spectrum would be in great error. From the spectrum it appears that there is a high energy β-group which extends up to about 1,800 kev. Fermi analysis showed the presence of two main high energy β-groups, $\beta_a \simeq$ 1,800 kev. and $\beta_b \simeq$ 830 kev. which were attributed to Eu^{154}. Fermi analysis of low energy β-spectrum after subtracting above-mentioned high energy β-groups reveals the other β-groups as follows:—

β-Groups	Energy	Intensity	log (ft.)
β_1 ..	245 ± 5 kev.	20%	8·1
β_2 ..	182 ± 5 kev.	22%	7·7
β_3 ..	145 ± 5 kev.	58%	7·1

E. L. Church[3] finds the following β-groups: $\beta_1 = 250$; $\beta_2 = 190$; $\beta_3 = 160$ and $\beta_4 = 150$ kev. It has not been possible to resolve the last two β-groups.

(*b*) A plastic scintillator $\frac{1}{8}''$ thick, $\frac{3}{4}''$ diameter was kept behind the source for detecting the β-particles. Discriminator level was kept sufficiently low to admit the pulses due to low energy electrons also. Pulses from the discriminator, on both sides, were fed to a coincidence unit with resolution, 0·25 μsec. Performance of the coincidence unit was tested with a Tm^{170} source. Only K and L conversion peaks due to 84 kev. transition were observed in coincidence with β-rays and the background due to the β-spectrum was completely suppressed.

Figure 1 shows the conversion electron spectrum in coincidence with β-rays in the decay of Eu^{155}. This spectrum reveals several conversion lines. They have been identified as due to γ_1 (86 ± 2 kev.); γ_2 (104 ± 2 kev.); γ_3 (31 ± 2 kev.); γ_4 (38 ± 2 kev.) and γ_a (120 ± 2 kev.). The interpretation of the lines observed is given in Table I.

The transition energies given in the last column are mean values obtained in different runs. Our observation confirms the presence of γ-rays of about 30 kev. and 39 kev. energy reported by Bisi for the first time from his γ-γ coincidence observations. The γ-ray of energy 60 kev. reported by

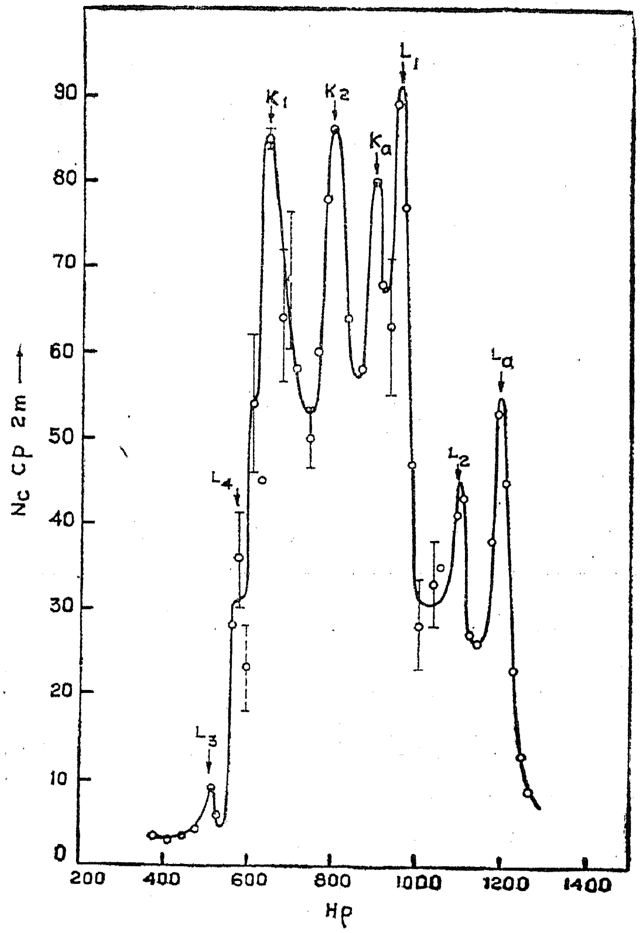

FIG. 1. Conversion electron spectrum in coincidence with β-rays, for Eu^{155}.

TABLE I

Line energy		Identity	Energy of the transition
23 kev.	..	L_3	31 $\pm$ 2 kev. (γ_3)
28·5 kev.	..	L_4	38 $\pm$ 2 kev. (γ_4)
36·5 kev.	..	K_1	86 $\pm$ 2 kev. (γ_1)
54 kev.	..	K_2	104 $\pm$ 2 kev. (γ_2)
68·5 kev.	..	K_a	120 $\pm$ 2 kev. (γ_a)
77 kev.	..	L_1	..
97·5 kev.	..	L_2	..
114 kev.	..	L_a	..

others[1, 3, 5] has not been resolved. L-shell conversion line energy of this transition is 51·63 kev. which overlaps the K-conversion line energy of 104 kev. transition at 53·7 kev. The K-shell conversion line due to 60 kev. transition and L-conversion line due to 18 kev. transition reported by some others[1, 3, 5] are too low in energy to be detected in the present arrangement. Another weak transition of energy 45 kev. has been reported by Boehm but not by others. However, it was not possible to observe it here since its L-conversion line falls very close to the K-conversion line of 86 kev. transition. Since the reported conversion line intensity of this transition is only about 5% that of 86 kev. transition its contribution in estimating K/L + M ratio for 86 kev. transition has been neglected, this being within the statistical errors. Using the theoretical value for L/M ratio (M. E. Rose[6]) the ratio K/L was calculated to be $2{\cdot}6 \pm 0{\cdot}6$.

Since a weak high energy β-group was observed in the β-spectrum and which was attributed to Eu^{154} impurity it was necessary to find if there are any conversion lines observed belonging to Eu^{154}. By adjusting the discriminator level, low energy β-groups were cut off and conversion line spectrum in coincidence with high energy β-rays was studied in the same region. Only two conversion lines (Ka and La, Fig. 2) were observed. These two

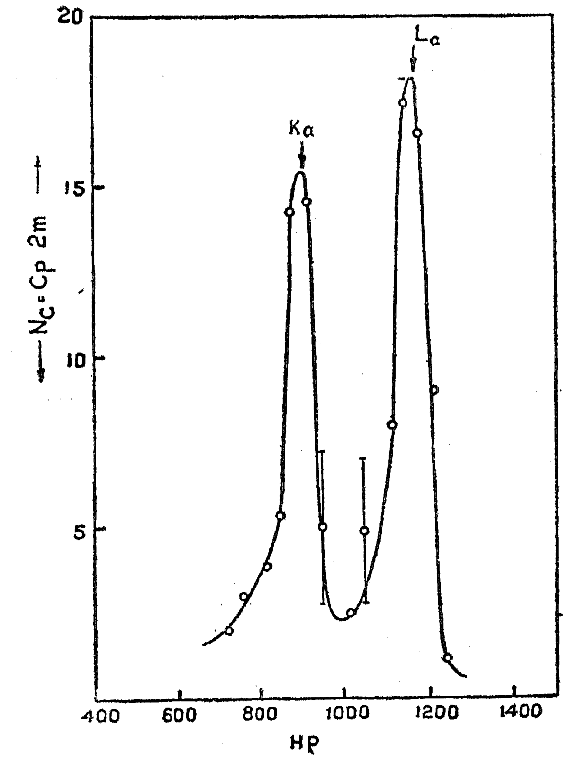

FIG. 2. Conversion electron spectrum in coincidence with high energy β-rays.

lines were interpreted as due to 122 kev. transition in the decay of Eu^{154}. The K/L ratio for this transition was found to be about 1·0 which is in agreement with the value reported by other observers.[7] This reveals the usefulness of this technique.

RESULTS AND DISCUSSION

From the internal conversion spectrum taken in coincidence with β-particles the K/L ratio was determined for the 86 and 104 kev. transitions as $2 \cdot 6 \pm 0 \cdot 6$ and < 6 respectively. Only the upper limit has been given for 104 kev. transition because the contribution of L-line of 60 kev. transition could not be determined. Rutledge[8] finds K/L ratio for the 86 kev. transition as 8 whereas Lee and Katz find it to be ~ 4. Lee and Katz[9] observe another transition of energy about 130 kev. The K-line of this transition falls very close to the L-line of 86 kev. transition. These could not be resolved in our spectrometer. This can result in giving a lower value for K/L ratio for the 86 kev. transition. But Church and Goldhaber[10] pointed out that 130 kev. γ-ray may be due to Eu^{156} impurity which was however not present appreciably in our sample. Comparing the K/L ratio with the theoretical values (Table II) corrected for finite nuclear size it is concluded that this is $E_2 + M_1$ transition, whereas 104 kev. transition may be $(E_1 + M_2)$ or $(E_2 + M_1)$ transition.

TABLE II

Transition	Theoretical K/L ratio				Experiment
Energy	E_1	E_2	M_1	M_2	K/L
86 kev. ..	6·7	0·8	7·9	3·3	$2 \cdot 6 \pm 0 \cdot 6$
104 kev. ..	6·92	1·06	7·6	3·7	< 6

Juliano observes $L_I : L_{II} : L_{III}$ from visual intensity measurement with high resolution spectrograph as medium: very medium: weak medium and he concludes that 86 kev. transition is E_1 type. Our value for K/L ratio favours $E_2 + M_1$ type of transition. Based on these observations as well as those of others a new decay scheme for Eu^{155} is proposed (Fig. 3). This decay scheme is similar to the one proposed by Bisi in which a new level at 117 kev. is assumed to explain 87 kev. and 30 kev. transition in cascade.

There is no arrangement about the spin assignments made by different workers. The spin of the ground state of Gd^{155} has been measured by Jenkins

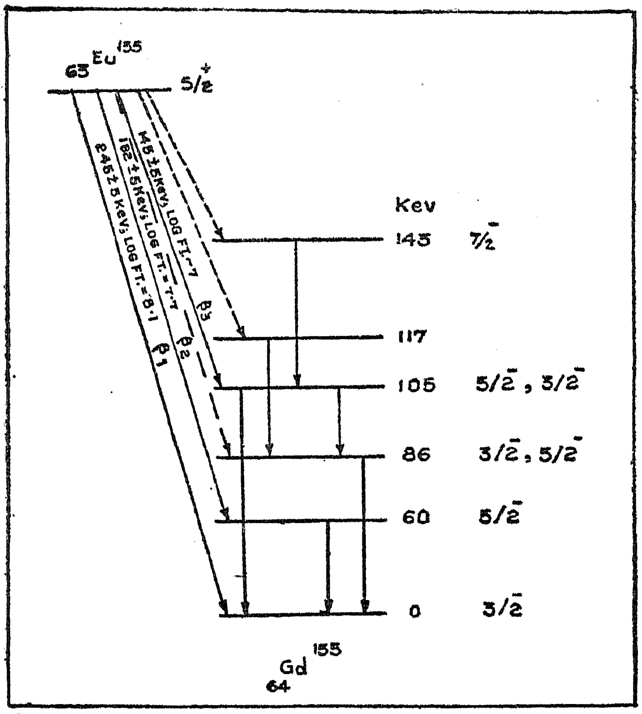

FIG. 3. Decay scheme of Eu[155].

and Speck[11] as 3/2 and by Murakawa[12] as $\geqslant 5/2$. Dubey and others assign $7/2^-$ for the ground state, $9/2^-$ for the 18 kev. state and $5/2^-$ for the 102 kev. state to get a better spin sequence on the basis of the shell model. Accordingly 84 kev. is mainly E_2 type and 104 kev. transition is $E_2 + M_1$ type, which is in agreement with our observations. The ground state ($3/2^-$), 60 kev. ($5/2^-$) and 144 kev. ($7/2^-$) states are known to belong to one rotational level.[13] It is not possible to make definite spin assignment to all the other states. Assignment of spin $3/2^-$ or $5/2^-$ to 86 kev. level and $5/2^-$ or $3/2^-$ to 105 kev. level has been made on the basis of our experimental observations of K/L ratio and log *ft* values. Spins $3/2^+$ for 86 kev. level and $5/2^+$ for 105 kev. level have been assigned by Juliano. This would mean the 145 kev. β-transition ($5/2^+ \rightarrow 5/2^+$) is of allowed type. But log *ft* value is about 7·1 which favours 1st forbidden type of β-transition ($5/2^+ \rightarrow 5/2^-$) in agreement with our assignment.

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SUMMARY

Decay of Eu[155] has been studied using intermediate image β-ray spectrometer, modified to make β-$\bar{e}$ and β-γ coincidence measurements.

The following β-groups have been observed: 245 kev., 182 kev. and 145 kev. K/L ratio for 86 kev. transition is found to be $\sim 2 \cdot 6$. A decay scheme has been proposed.

REFERENCES

1. Stromiger, D., Hollander, J. M. and Seaborg, G. T. .. *Rev. Mod. Phys.*, 1958, **30**, Part II.
2. Dubey, V. S., Mandeville, C.E. and Rothman, M.A. .. *Phys. Rev.*, 1956, **103**, 1430.
3. Juliano, J. O. .. *Univ. California Radiation Lab. J. Rept. U.C.R.L.*–3733.
4. Bisi, A. and Zappa, L. .. *Nucl. Phys.*, 1958, **6**, 252.
5. Boehm, F. and Hateh, E. N. *Bull. Am. Phys. Soc.*, 1957, **2** (4), 231 W_3.
6. Rose, M. E. .. *Table of Internal Conversion Coefficients*, North-Holland Publishing Co., Amsterdam, 1958.
7. Cork, J. M., Brice, M. K. Helmer, R. G. and Sarason, D. E. *Phys. Rev.*, 1957, **107**, 1621.
8. Rutledge, W. C., Cork, J. M. and Burson, S. B. *Ibid.*, 1952, **86**, 775.
9. Lee, M. R. and Katz, R. .. *Ibid.*, 1954, **93**, 155.
10. Church, E. L. and Goldhaber, M. *Ibid.*, 1954, **95**, 626 A.
11. Speck, D. R. and Jenkins, F. A. *Ibid.*, 1956, **101**, 1725.
12. Murakawa, K. .. *Ibid.*, 1954, **96**, 1544.
13. Heydenburg, N. P. and Temmer, G. M. *Ibid.*, 1956, **104**, 981.

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