DIRECTIONAL CORRELATION STUDY OF GAMMA CASCADES IN THE DECAY OF Sb^{124}.

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ABSTRACT. The decay scheme of Sb^{124} is studied and the gamma-gamma directional correlation measurements are carried out for few cascades. On the basis of the experimental data on directional correlations, the spin assignments are made for the 603, 1326, 1964, 2313, 2688 keV excited levels of Te^{124}. Multipole assignments are made for 989, 1362 keV transitions.

INTRODUCTION

The disintegration of 60 day Sb^{124} leads to a complex spectrum. Beta emission of Sb^{124} results in the formation of Te^{124} in different excited states. The beta spectrum has been thoroughly analysed by various investigators using absorption methods and magnetic analysers. The spin assignments for the levels have been investigated by directional correlation studies by several workers. There are however, other levels in addition to the levels mentioned above which have not been studied by angular correlation method. In the present investigation angular correlation study has been undertaken for all the possible gamma cascades.

EXPERIMENTAL TECHNIQUE

A fast slow triple coincidence scintillation spectrometer having a time resolution of 30 nano seconds is designed and constructed. The head assembly consists of NaI(Tl) scintillator coupled to Dumont 6292 photomultipliers, a fast amplifier and an emitter follower. The power to the photomultipliers is supplied from a well regulated negative high tension unit. This arrangement permits direct coupling of the photomultiplier anode to the input of the fast amplifier, which has a band width of over 60 megacycles per second. The output pulse from the cathode follower has a fast rise (better than 0.01 microsecond) a flat top and long trailing edge suitable for clipping by the shorted delay technique. The standard Bell Graham and Petch coincidence circuit is used with reversal of diode connections since the pulses encountered are negative. The triple coincidence circuit is an additive type cathode follower having a resolving time of two microseconds. Compton graded inverted cone type of shields are used around the scintillators in order to eliminate crystal to crystal scattering effects and other interfering effects. The energy resolution of each spectrometer is found to be 8.5% for the 662 KeV gamma rays of Cs^{137}.

A cylindrical perspex container having a cavity of 4mm diameter and 10mm depth with a wall thickness of 0.25mm is used as source holder. This source container is mounted vertically at the intersection of the axes of the two detectors and about 5 cm from the crystals. The spectrometer is initially tested for angular correlation measurements using the standard cascade of Ni^{60} and found to be quite satisfactory for correlation measurements.

RRSULTS

The gamma spectrum is recorded employing a weak source of Sb^{124} in 2π geometry. The intensity versus the pulse height is plotted for the signles spectrum as shown in Figs. 1 and 2, for the regions of low and high energies. An analysis

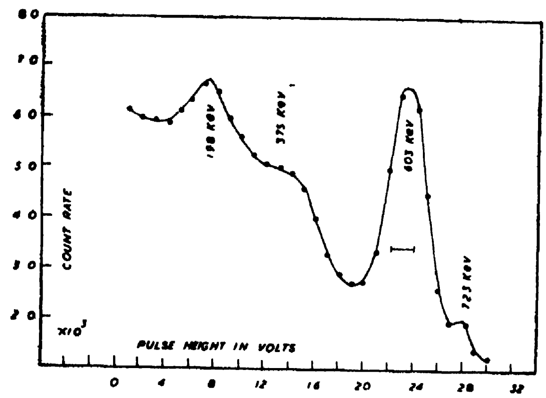

Fig. 1. Singles spectrum of Sb^{24} (low energy region)

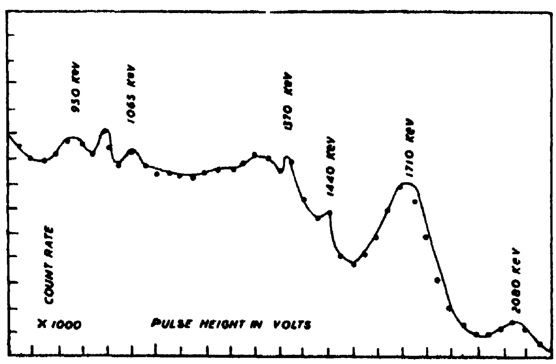

Fig. 2. Singles spectrum of Sb^{24} (high energy region)

of these spectra show the presence of gamma transitions with energies 198, 375, 603, 723, 950, 989, 1065, 1370, 1440, 1710, and 2085KeV.The strong peak observed at 198KeV is due to the gamma photons scattered backwards. At the high energy side there are indications of faint peaks with energies of 950 and 1440 KeV and the remaining peaks are well resolved and prominent. The 603 KeV gamma component is found to be the most intense of all the radiations indicating that this radiation is emitted as result of the transition from the first excited state to the ground state of Te^{124}.

In the present investigation coincidences are observed by focussing one of the channels to a prominent peak and scanning the other channel through the entire energy spectrum. The two counters are so fixed as to subtend an angle of 90° between them in order to minimise the crystal to crystal scattering. Similarly coincidences are observed by focussing the fixed channel to all the prominent peaks and the experiment is repeated. The coincidence curves are shown in Figs. 3. to 6.

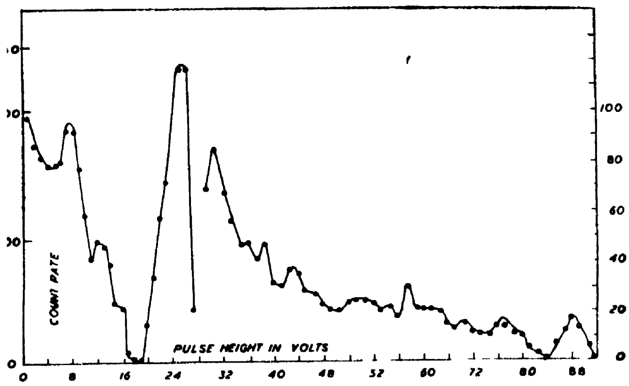

Fig. 3. Coincidence spectrum with 603 KeV gamma component.

The component with an energy 603KeV is in coincidence with the gamma rays of energies 2085, 1710, 1362, 989, 723, 603 and 200 KeV. The 989 KeV component is in coincidence with components of energies 603 and 1362 KeV. The well resolved component with an energy of 1710 KeV prominently coincides with the 603 KeV component and less prominently with 723 KeV component. The 2085 KeV gamma component is only in coincidence with 603 KeV component. While observing all these coincidences the gates of the two channel are so adjusted as to eliminate the possibility of the interference of any strong peak on the adjacent weak component. On the basis of the coincidence data obtained in the present investigation a level scheme is drawn as shown in Fig. 11.

The gamma-gamma directional correlation study for the 2085–603 KeV, 1710–603 KeV, 1362-603 KeV and 989-723 KeV cascades are studied in order to assign spins for some levels and multipolarities for some of the transitions in the decay of Sb^{124}. In the present case only those cascades in which the radiations are well resolved with a considerable number of coincidences are taken into

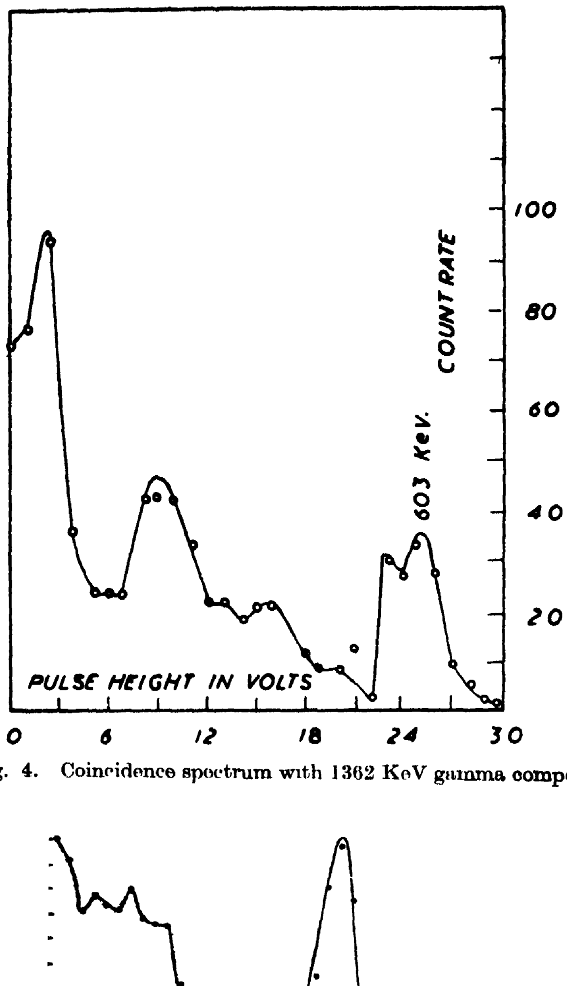

Fig. 4. Coincidence spectrum with 1362 KeV gamma component

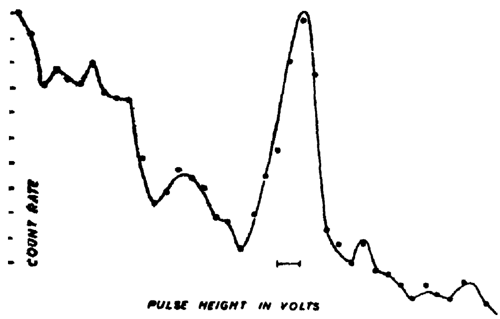

Fig. 5. Coincidence spectrum with 1710 KeV gamma component.

consideration. In these observations care is taken to see that the source is intense and is vertically mounted. It is centered within 0.5% variation of the count rate. A reasonable number of coincidences are collected in each observation until the statistics are found to be satisfactory. These coincidences are corrected for accidental coincidences and the resulting data are used to evaluate the correlation coefficients A2 and A4 employing White's analytical method of analysis (White,

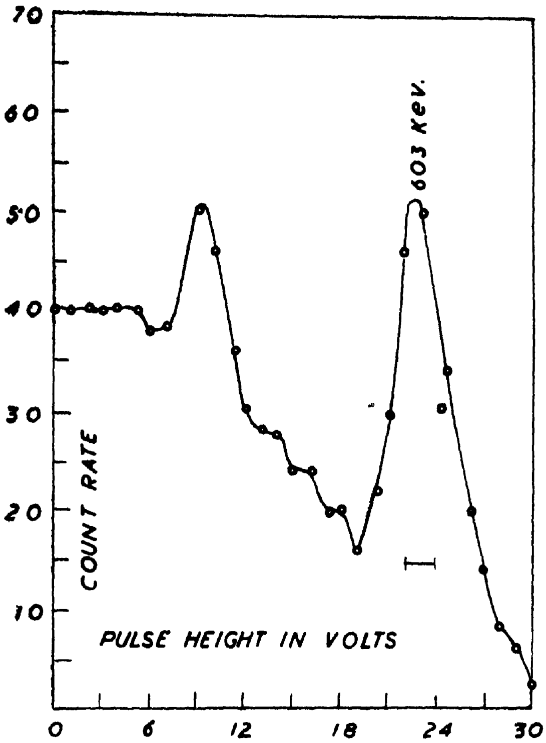

Fig. 6 Coincidence spectrum with 2085 KeV gamma component.

1963). Then the correction for finite angular resolution of the detectors is applied for the experimentally obtained correlation coefficients.

The angular correlation functions for the cascades that are studied in the present investigation are as follows :

$$W(\theta)2085-603 \text{ KeV} = 1 \;\; (0.042 \pm 0.006)P2 \cos\theta + (0.006 \pm 0.004)P4 \cos\theta$$

$$W(\theta)1710-603 \text{ KeV} = 1 - (0.0698 \pm 0.0072)P2 \cos\theta + (0.0082 \pm 0.0048)P4 \cos\theta$$

$$W(\theta)1362-603 \text{ KeV} = 1 + (0.288 \pm 0.0064)P2 \cos\theta - (0.695 + 0.0375)P4 \cos\theta$$

$$W(\theta)\ 989-723 \text{ KeV} = 1 + (0.207 \pm 0.006)P2 \cos\theta - (0.0015 \pm 0.0022)P4 \cos\theta$$

These values of correlation functions given are plotted against the angle subtended between the movable and the fixed detectors. The respective plots for all the functions are shown in Figs. 7 and 8.

DISCUSSION

The study of angular correlation of the cascades with energies 603–1710 KeV and 603–2085 KeV is under taken in order to assign the spins for the levels 603,2313 and 2688 KeV of Te^{124}. The correlation coefficients for 603–1710 KeV cascade are -0.06981 ± 0.0072 and $+0.0082 \pm 0.0048$. The probable spin sequences for this cascade are 4–2–0, 3–2–0, 2–2–0. The possibility of the spin value greater than 4 for the level 2313 KeV is excluded on the basis of the results obtained

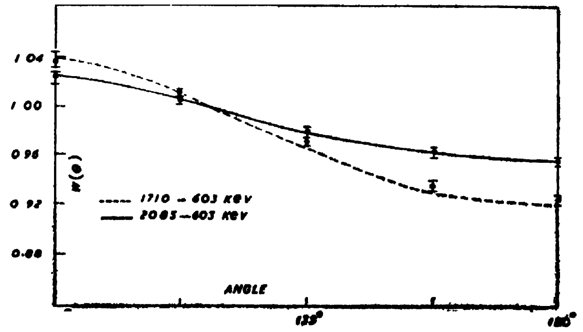

Fig. 7 Plots of $W(\theta)$ *vs* θ for the cascades 1085– 603 KeV & 1710– 603 KeV.

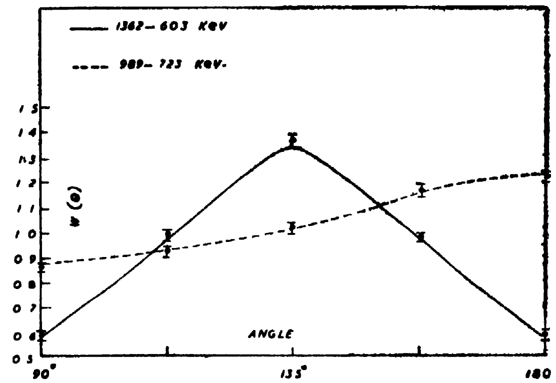

Fig. 8. Plots of $W(\theta)$ *vs* θ for the cascades 1362– 603 KeV & 989– 723 KeV.

from the conversion measurements (Hutchinson *et al.*, 1952). A comparison of theoretically computed coefficients A2 and A4 with experimentally obtained ones eliminates all spin combinations with the exception of 3(D) 2(Q)0. The small difference in the values of theoretical and experimental coefficients can be ascribed to the presence of 1% quadrupole admixture in the 1710 KeV transition. But this small amount of admixture can be neglected and 1710 KeV transition can be considered as pure dipole. From this data a spin of 3 units is assigned to the level at 2313 KeV.

The life time (Temmer *et al.*, 1956) of the 603 KeV level (1.3×10^{-11} sec) being small, the correlation coefficients obtained in the present exprimental analysis are not perturbed by external fields; with this consideration it can reasonably be concluded that the 603 KeV excited level has a spin of 2 units which agrees well with the conversion measurements of this level (Metzer, 1952 ; Schraff-Goldhaber *et al.*, 1955). The spin value and the sequence are consistent with the general characteristics of even-even nuclei in which the first excited states have a spin of 2 units and the transition from the first excited state to ground state is pure quadrupole transition.

The spin of the first excited state has further been confirmed by studying the cascade 2085-603 KeV. the same analysis is also used for the spin assignment of the 2688 KeV level. The correlation coefficients obtained can be best fitted into the spin sequence 3(D) 2(Q)0. Theoretical values with any other sequence are not concurrent with the experimentally obtained values. The little divergence in the value of the experimentally obtained coefficients with those computed from theory for 3(D) 2(Q)0 sequence may be attributed to the presence of a small amount of quadrupole admixture (less than 1%) in the 2085 KeV transition. The spin value has not been reported by the internal conversion measurements, this may be due to the small intensity of the 2085 KeV transition. The 2085 KeV-603 KeV cascade shows a correlation form similar to that of 1710-603 KeV cascade. The spin assignments and the small admixtures of quadrupole content in the 2085KeV transition are in agreement with the results of previous investigators (Lindquist *et al*, 1957 ; Weitkamp, 1963 ; Metzer, 1952).

In the present investigation the 1362-603 KeV cascade is studied for the spin assignment of the 1964 KeV level. The values of A2 and A4 obtained are consistent with the theoretically computed values of the sequence 3(DQ)2(Q)0. The slight divergence between the coefficients when analysed showed an admixture

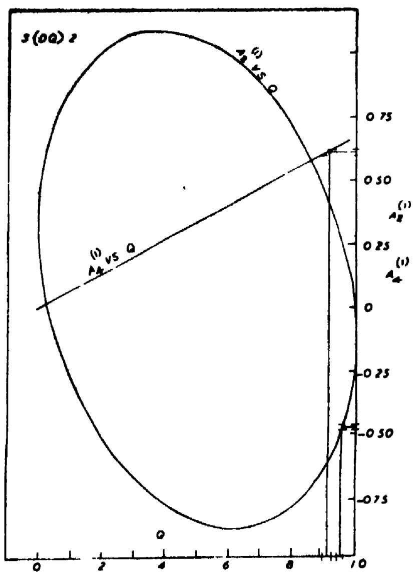

Fig. 9. Multipole admixture plot for the 1362 KeV transition.

of 5% dipole in the 1362 KeV transition which is shown in the Fig. 9. From this analysis a spin value of 3 units is assigned to the 1964 KeV level.

The study of the 989-723 KeV cascade yielded the values $+0.2075 \pm 0.0061$ and -0.0015 ± 0.0022 for the correlation coefficients A2 and A4 respectively. Taking into account the 4% dipole admixture in the 723 KeV transition from;the work of Glaubman *et al* (1964) and analysing for the admixture in the 989 KeV

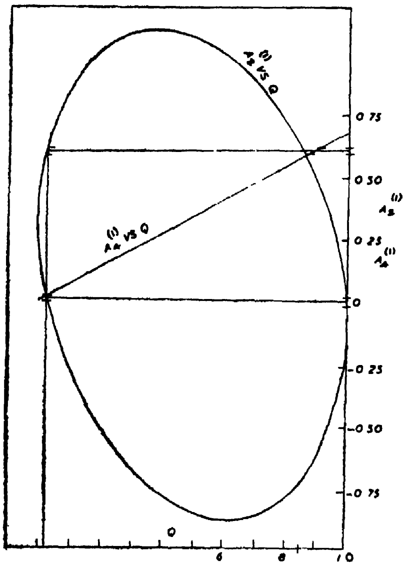

Fig. 10. Multiple admixture plot for the 989 KeV transition.

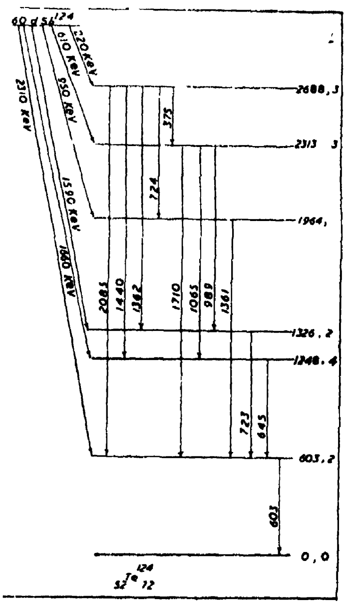

Fig. 11. Level scheme of Te^{124}.

transition it is found that this transition is a mixture of 98% dipole and 2% quadrupole, which is shown in Fig. 10. From this the multipole admixture of the 989 KeV transition is established and the spin of the 1964 KeV level has been fixed as 3 units.

From the coincidence curves it is inferred that the 603 KeV radiation is in coincidence with 723 KeV and 645 KeV radiations. But these cascades are highly interfering with one another. Hence a correlation study of the type employed in the present investigation is not suitable for a clear cut analysis, on the other hand only the method employed by Glaubman *et al* (1964) is suitable for such a complex analysis. Due to this difficulty the spin assignment of the 1248 KeV excited state is not extablished in the present work.

Employing the values of the energies of the excited levels and those of transitions along with their respective characteristics, a detailed level scheme of Te^{124} is drawn as shown in Fig. 11. The 0, (2), 4) spin assignment to the 0, 603, and 1348 KeV rotations as given by Bohr-Mottleson model. The ratio of the energy of the second exicited state to the first excited state is 2.06. which is in accordance with the theoretical predictions of Schraff-Goldhaber and Weneser (1955) for even-even nuclei in the slightly deformed region $44 \leqslant A \leqslant 154$.

REFERENCES

Cook, C. S. and Langer, L. M., 1948, *Phy. Rev.*, **73**, 1149.

Glaubman, M. J. and Oberholtzer, J. D., 1964 *Phy Rev.*, **135**, B1313.

Hales, E. B. and Jordon, E. B., 1943, *Phys. Rev.*, **64**, 202.

Hutchinson, D. R. and Wiedenbeck, M. L., 1952, *Phy. Rev.*, **88**, 699.

Journey, E. T. and Mitchell, A. C. G., 1948, *Phy. Rev.*, **73**, 1153.

Kern, B. D., Zaffarano, D. J. and Mitchell, A. C. G., 1948, *Phy. Rev.*, **73**, 1142.

Langer, L. M., Moffat, R A. and Price, H. C., 1950, *Phy. Rev.*, **79**, 808.

Lindqmst, T. and Marklund, I., 1957, *Nucl. Phy.*, **4**, 189.

Livingood J. J. and Seaborg, G. T., 1936, *Phys. Rev.*, **50**, 435.

Metzer, F. R., 1952, *Phy. Rev.*, **86**, 435., 1953, *Phy. Rev.*, **90**, 328.

Mitchell, A. C. G., Langer, L. M. and McDaniel, P. W., 1940, *Phys. Rev.*, **57**, 1107.

Mitter, L. C. and Curtiss, L. F., 1946, *Phys. Rev.*, **70**, 983.

Schraff-Goldhaber, G. and Wenesor, J., 1955, *Phys. Rev.*, **98**, 212.

Swami Jnanananda, 1947, *Phys. Rev.*, **72**, 1124.

Temmer, G. M. and Heydenberg, N. P., 1956, *Phy. Rev.*, **104**, 967.

Weitkamp, C., 1963, *Nucl. Phy.*, **43**, 57.

White, D. H., 1963, *Nucl. Inst.*, **21**, 209.