COINCIDENCE EXPERIMENTS ON 5.3y Co^{60}

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ABSTRACT. Coincidence experiments on 5.3y Co^{60} showed that a β-ray is followed by two γ-rays in the transition $Co^{60} \rightarrow Ni^{60}$. Absorption measurements with Cu foils indicated an average energy of the γ-rays to be 1.2 Mev. No angular asymmetry among the γ-rays was detected at different angles by $\gamma-\gamma$ coincidence.

INTRODUCTION

The β-ray spectrum and the end energy of 5.3 year Co^{60} were investigated in this laboratory by Das and Saha (1936). In continuation of that work, coincidence experiments were undertaken to arrive at a level scheme of the above nucleus. This nucleus has also been studied by Nelson, Pool and Kurbatov (1942) and Deutsch and Elliot (1942). Nelson *et al* found the end-energy of the β-ray spectrum to be $0.220 \pm .02$ Mev while Deutsch and Elliot found it to be $.300 \pm .006$ Mev. Das and Saha gave the end-energy as 0.23 Mev. According to the absorption measurements of Nelson *et al* each β-ray is followed by one γ-ray of energy $1.7 \pm .2$ Mev while according to Deutsch and Elliot each β-ray is followed by two successive γ-rays of energies $1.1 \pm .02$ Mev and $1.3 \pm .02$ Mev. The level schemes are given below.

$\beta-\gamma$ and $\gamma-\gamma$ coincidence experiments were undertaken in this laboratory to investigate this point further.

THEORY OF $\beta-\gamma$ AND $\gamma-\gamma$ COINCIDENCE EXPERIMENTS

The theory of $\beta-\gamma$ and $\gamma-\gamma$ coincidence experiments have been developed by Langer, Mitchell and McDaniel (1939). According to them, measurements of $\beta-\gamma$ coincidences per β-ray emitted and the $\gamma-\gamma$ coincidences per γ-ray emitted give the value of K, the average number of γ-rays per disintegration in the following way.

Let N be the number of disintegrations per sec. and K the average number of γ-rays per disintegration. Let N_β and N_γ be the rates of counting by two counters. Let S_β, S_γ be the overall efficiencies (including solid angle) for two kinds of particles. In addition let S_γ be essentially constant over the region of γ-ray energies investigated.

Therefore,

$$N_\beta = NS_\beta$$

$$N'_\gamma = NKS_\gamma$$

The number of $\beta-\gamma$ coincidences per sec. will be

$$N_{\beta\gamma} = NS_\beta KS_\gamma$$

The number of $\beta-\gamma$ coincidences per β-ray detected is

$$\frac{N_{\beta\gamma}}{N_\beta}=\frac{NS_\beta S_\gamma K}{NS_\beta}=S_\gamma K \qquad \ldots (1)$$

The number of $\gamma-\gamma$ coincidences per sec. is given by

$$N_{\gamma\gamma}=N\frac{K^2(K-1)S_\gamma.S_\gamma}{2}$$

therefore, the number of coincidences per recorded γ-ray is

$$\frac{N_{\gamma\gamma}}{N_\gamma}=\frac{NK^2(K-1)S_\gamma^2}{2}\Big/NKS_\gamma=\frac{K(K-1)}{2}S_\gamma \qquad \ldots (2)$$

From eqns. (1) and (2) the ratio R of the two sets becomes

$$R=\frac{N_{\beta\gamma}}{N_\beta}\Big/\frac{N_{\gamma\gamma}}{N_\gamma}=S_\gamma K.\frac{2}{K(K-1)S_\gamma}=\frac{2}{K-1} \qquad \ldots (3)$$

so that

$$K=1+\frac{2}{R}.$$

EXPERIMENT

The sample examined has been prepared by the Co^{59} (d, p) reaction. The source was in the form of cobalt chloride soln. and for this experiment is mounted on a rectangular thin aluminium foil by evaporation on it.

For γ-ray detection G. M. counters, with oxidised copper cathodes and central wires of 3 mm. diameter, were used. The counter assembly was enclosed in Pyrex glass. The counters were filled with argon and etheyl ether at a ratio of 10:3 at a total pressure of 5 cm.

For the β-counter, the central wire of tungsten of 3 m.m. diameter was suspended at one end on a thin glass fibre drawn out in the form of a diameter of circular section of this end and at the other it is silver-soldered to a thick tungsten wire sealed to the counter envelope. The end having the glass fibre was open and was sealed with a brass cap which carried a window 0.5 cm. × 0.5 cm. This window was covered with a thin film of Perspex (3 mgm/cm^2) so that β-particles could pass through it without being appreciably absorbed. All the sealings were made leak-tight with Apeizon sealing-wax. The counter was filled with a mixture of argon and alcohol in the ratio of 7:3 at a total pressure of 5 cm. It carried a side-tube with a stop-cock so that it could be refilled when necessary.

For coincidence experiments the source and the counters were mounted on stands which could be slided on a bench carrying a scale, so that the distances between them could be adjusted and measured quickly.

The arrangement of the detecting and recording circuits were as follows.

The quenching circuits used were the Neher-Pickering (1938) circuits the output pulses being taken from the cathode. The use of the quenching circuits improved the plateau of the counters remarkably, extending the plateau to more than 300 volts.

The coincidence circuit was a conventional three-fold one using sharp cut off pentodes, 6SJ7.

The scaling circuit used was a scale of eight Don Devault (1941) type of circuit with slight modifications. Tubes used were 76.*

The recorder was a Cenco impulse counter counting 3,000 regularly spared pulses per min. driven by the current through a 6V6 tube which is normally biased to cut off positive pulses from the scaling circuit trips it.

The high-voltage stabilizer used to supply the cathode voltage of the G. M. counters was a modification by Banerjee (1942) of the Neher-Pickering's circuit (*loc. cit*).

All the circuits excepting the high-voltage stabilizer were run from a common power pack.

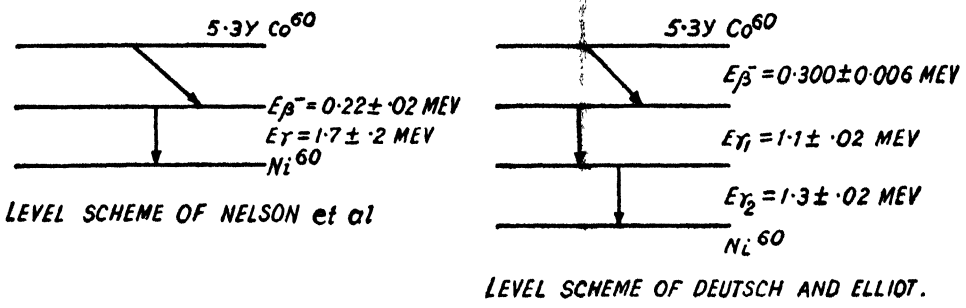

Fig. 1

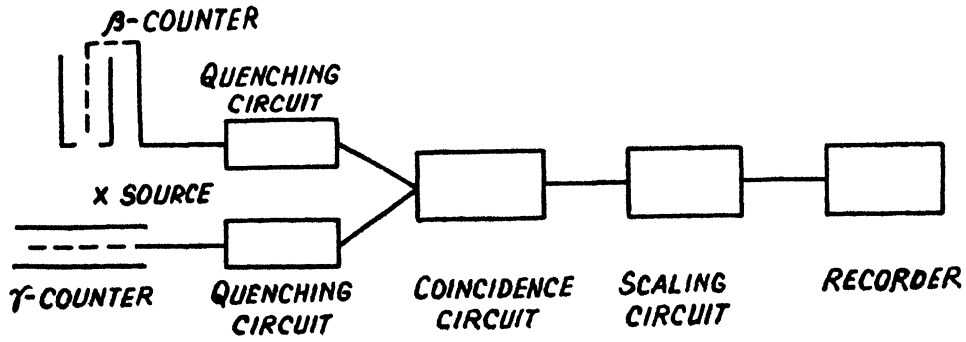

Fig. 2

For $\beta-\gamma$ coincidence the centre of the source, the centre of the window of the β-counter and the centre of the γ-counter were adjusted to lie in the same straight line. The β-counter and the γ-counter were placed symmetrically on both sides of the source, the dist. of the counters from the source being adjusted to give an optimum rate of counting.

For $\gamma-\gamma$ coincidence, the same arrangement was kept, only the β-counter was replaced by a γ-counter.

* The iron cored chokes used on the anodes of the 2nd valves of each stage being replaced by 25,000 Ω resistances.

TABLE I

Background counts of the β-counter in 5 min.	Counts recorded by β counter with source in 5 min	No of β count per min	Background counts of γ-counter in 5 min	Counts recorded by γ counter with source in 5 min	No of γ-counts per min	K
528.5	1078	109 9 ± 3 142	520	1451	186 2 ± 4.09	..
Background coincidence counts of β and γ counters in 15 min,	$\beta-\gamma$ coincidence counts with source in 10 min	True $\beta-\gamma$ coincidence counts per min.	Background coincidence counts of γ counters in 15 min,	Coincidence counts of γ counters with source in 20 min	True $\gamma-\gamma$ coincidence counts per min	1 844 ± 333
5	67	6 368 ± ,862	12	107	4 55 ± .702	.

The background counts were taken at the beginning and at the end of the experiment.

For measuring the single β-counts and the single γ-counts, the same arrangement was kept only the coincidence circuit was switched off for single counts. Readings were taken for 5 mins. time interval.

The results are given in Table I. The value of K as may be seen is $\sim$ 1 : 8. Thus it may be concluded that two γ-rays are emitted per disintegration which agrees with the level scheme given by Deutsch and Elliot. For γ-rays energy, the absorption measurement with copper foil indicated the average mass absorption coefficient as .0368 cm^{-1} gm^{-1} corresponding to an average energy of the two γ-rays to be 1.2 Mev which is fairly close to the values of Deutsch and Elliot. We have tried to find the angular asymmetry of these the two γ-rays by placing two γ-counters equidistant from the source and their axes making angles of 45, 90 and 180 degrees successively. But we could not detect anything more than their symmetrical distribution.

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