STUDIES WITH SCINTILLATION COINCIDENCE SPECTROMETER: Cs$^{134}$

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ABSTRACT

The set-up of 'Slow-Fast' coincidence scintillation spectrometer is described. Gamma-gamma coincidences in Cs$^{134}$ have been studied. The 604-kev. gamma transition is found to be in cascade with 460 ± 20, 555 ± 15, 794 ± 15 and 1349 ± 30 kev. gamma transitions. The 794-kev. gamma transition is found to be in cascade with 604 ± 10 and 555 ± 15 kev. gamma transitions. The results are consistent with the decay scheme of Cs$^{134}$ proposed by Forster et al.11

INTRODUCTION

COINCIDENCE studies with scintillation counters have been found to be a very useful method of determining the sequence of energy levels in a nucleus formed in a complex beta-decay of a radio-active nucleus. For this purpose a 'slow-fast' coincidence spectrometer as described below has been set up. This instrument was used to investigate the gamma transitions in Ba$^{134}$, resulting from the complex beta-decay of Cs$^{134}$. This isotope has been studied by several workers1–11 and in particular, the gamma-ray energies were determined from the photo-electron spectrum taken in the Siegbahn-S Mattis beta-ray spectrometer7 at this Institute. In the decay of Cs$^{134}$, eleven gamma transitions of the following energies were reported—467, 553, 571, 607, 794, 1027, 1164, 1368 and 1401 kev. Of these the two gamma-rays at 604 kev. and 794 kev. are the most intense ones. The aim of this work was to determine which of the other gamma transitions are in cascade with these two well-known gamma-rays in Ba$^{134}$.

In a previous report on beta-gamma and gamma-gamma coincidence study of this isotope, G. Bertollini et al.10, employed discriminators, one in each channel, for energy discrimination, the resolving time of the coincidence unit being 0.5 μ sec. In this work, gamma-gamma coincidences have been studied, employing a shorter resolving time, 1.5 × 10$^{-8}$ sec. of the coincidence unit and single channel pulse analysers, one in each channel, for energy selection. This helps in deciding more definitely the energies of gamma-rays that are in cascade and throws some light on the question
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of the sequence of levels in Ba\textsuperscript{134}. In particular, as a result of this investigation, it can be argued that the first excited state in Ba\textsuperscript{134} is 604 kev. rather than 794 kev.

**Experimental Arrangement**

The block diagram of the conventional ‘slow-fast’ coincidence scintillation spectrometer is shown in Fig. 1. For gamma-gamma coincidence measurements two NaI (TI) crystals each 1" in diameter and 1" thick, viewed by two EMI 6260 photomultipliers have been used. Both the crystals were shielded with \( \frac{1}{2} \)" thick lead collimators. They were kept 120° apart so that they do not see each other thus minimizing the false coincidences arising from scattering of gamma rays from one crystal to the other.

![Block Diagram of Slow-Fast Coincidence Scintillation Spectrometer](image)

Fig. 1. Block Diagram of Slow-Fast Coincidence Scintillation Spectrometer.

Pulses from the anode of the photomultiplier are limited to an amplitude of \( \frac{1}{4} \) volt by a limiter circuit. The limiter output pulses are carried to the fast coincidence unit by a coaxial cable RG8U which is terminated at both ends by its characteristic impedance to eliminate any reflections. These pulses are shaped at the input to the coincidence circuit by 400 cm. long RG8U coaxial cable shorted at the other end. The fast coincidence circuit is a bridge type circuit using crystal diodes. By inserting known delays in
either channel the prompt coincidence due to Co\textsuperscript{60} gammas were counted and from the curve thus obtained, the resolving time of the coincidence unit was determined to be $1.5 \times 10^{-8}$ sec.

![Gamma-ray Spectrum by a Scintillation Spectrometer](image)

Pulses from the third dynode, after amplification, are fed to a single channel analyser for energy selection. The fast coincidence output and those
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from the two single channel analysers are fed to a slow triple coincidence unit (resolving time 4 $\mu$s.) thus enabling coincidences between any two selected energies of gamma-rays to be counted. This indirect method of introducing energy selection to coincidence circuits is necessary, because the fast coincidence unit must be operated by the pulse derived from the first few photo-electrons produced in the photomultiplier, whereas the analyser is required to be triggered by a pulse proportional to the total number of photo-electrons released by the light scintillation from the phosphor. The analyser output pulse will therefore be considerably delayed with respect to the pulse operating the fast coincidence unit and, moreover, this delay will vary with pulse amplitude. The fast coincidence circuit therefore cannot follow the analyser. The chance coincidences are also counted simultaneously by feeding the same three pulses to another triple coincidence unit (resolving time 4 $\mu$s.) with one channel delayed by 10 $\mu$s.

![Graph](image-url)  

**Fig. 3.** Spectrum in Coincidence with 794 kev.
RESULTS

Gamma-ray spectra in coincidence with 604 kev., 794 kev. and 1349 kev. respectively were taken. A very strong source was used. The following results are obtained as shown in Figs. 3, 4 and 5:—

![Gamma-ray Spectrum Diagram]

Fig. 4. Spectrum in Coincidence with 604 kev.

1. One channel was fixed to allow full photo-peak of 794 kev. as shown in the inset of Fig. 3. Both crystals were shielded with lead and were kept 120° apart and were arranged to be 2° from the source. The gamma transitions in coincidence with the 794 kev. gamma-ray are found to be of energies 604 ± 10 and 555 ± 15 kev. There is also strong evidence for the existence of a gamma-ray of energy 460 ± 20 kev., which is not in coincidence with 794 kev. (Fig. 3).

2. One channel was fixed to allow a small fraction of the 604 kev. photo-peak as shown in the inset of Fig. 4. In this case the geometry was the same as above. The gamma-rays in coincidence with 604 kev. gamma-ray are found to be of energies 460 ± 20 kev., 555 ± 15 kev. and 794 ± 15 kev.

3. Finally, one channel was fixed to allow the full photo-peak of 1349 kev. gamma-ray. Since this is weak, the crystal corresponding to this
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**FIG. 5.** Spectrum in Coincidence with 1350 kev.

**FIG. 6.** Decay-Scheme of $^{134}$Cs Proposed by Forster and Wiggins.
channel was unshielded and kept at a distance of 1.5 cm. from the source. A lead plate, 1 cm. thick, was interposed between this crystal and the source in order to reduce the 604 kev. and 794 kev. radiations. The 1349 kev. gamma-ray is found to be in coincidence with 604 kev. gamma-ray but not with 794 kev. gamma-ray as seen from Fig. 5.

**DISCUSSION**

All the results obtained in this work, namely, the triple cascade 604 kev.–794 kev.–555 kev. and the double cascades 460 kev.–604 kev. and 1349 kev.–604 kev., are consistent with the decay-scheme of Cs$^{134}$ shown in Fig. 6 which is the decay-scheme proposed by Forster and Wiggins.$^{11}$

The main disagreement between the different decay-schemes proposed for Cs$^{134}$ seems to be about the energy of the first excited state in Ba$^{134}$. Since the weak gamma 1349 kev. (1369 kev. of Forster$^{11}$) is in cascade with the intense 604 kev. gamma-ray, 604 kev. as the energy of the first excited state seems to be more justified than 794 kev. If 794 kev. is assumed to be the energy of the first excited state, then the 1349 kev. gamma transition has to be to the ground state and the 604 kev. gamma-ray has to be emitted by the highest level 1972 kev. so as to be in cascade with the 1349 kev. transition. In that case, the 604 kev. gamma transition would be a weak one since the 1972 kev. level is formed by a rather weak beta-ray group (80 kev., 28%$^{11}$). In fact 604 kev. gamma-ray has been found to be the most intense one. Hence it is preferable to assume 604 kev. as the energy of the first excited state.

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**REFERENCES**

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