Search for anisotropy in the L x-gamma angular correlations following the decay of ^{207}Bi

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An investigation of the Ll x-γ angular correlations following the decay of ^{207}Bi is done by using a Si(Li) semiconductor counter as L x-ray detector. Coincidence measurements at five different angles were made between the 570-keV γ ray (gated in the movable counter) and the Ll x spectrum (displayed in a multichannel analyzer).

[RADIOACTIVITY ^{207}Bi, measured Ll X- $\gamma(\theta)$, deduced anisotropy. Si(Li) detector, 500 eV at 10 keV.]

In a recent paper Rupnik and Crasemann[1] reported an attempt of detecting anisotropy in the directional angular correlation between the Pb L x rays and the 570-keV γ rays emitted following second forbidden electron capture and internal conversion in ^{207}Bi decay (Fig. 1). The measured value for the A_{22} coefficient of the $Ll+L\alpha+L\beta$ x-γ directional angular correlation was $(1.3 \pm 1.3)\times 10^{-3}$, whereas the one derived from Dolginov's theory[1,2] is $A_{22}=-0.013$.

This difference was explained by the same authors[1] in the following way: There are many isotropic x rays which arise from transitions to the Pb L_3 subshell in coincidence with the 570-keV γ rays mainly due to the two following processes: (i) internal conversion in the K, L_1, and L_2 shells of the 1.06-MeV $M4$ γ rays (Fig. 1); (ii) capture from the K, L_1, and L_2 levels in the transition to the $\frac{5}{2}^-$ level. Consequently, of all L_3 vacancies arising in the decay, only $\simeq 1.1\%$ comes from L_3 internal conversion of the 1.06-MeV γ rays and only $\simeq 0.1\%$ originates from the second forbidden L_3 electron capture. Therefore, the anisotropy of L x rays following electron capture and internal conversion, and preceding emission of the 570-keV γ rays is expected to be strongly masked by the presence of the coincident isotropic x rays. In fact, the theoretically expected anisotropy taking into account all sources of L_3 vacancies could be as small as $A=-1.4\times 10^{-4}$ (Refs. 1, 3, and 4), which is consistent with the experimental value.

In their work Rupnik and Crasemann[1] suggested that asymmetry might be detectable if only the Ll x ray were considered in coincidence with the 570-keV γ transition. The Ll line, arising exclusively from $\frac{1}{2}$-$\frac{3}{2}$ transitions, is ~10 times more anisotropic than the $L\alpha$ group and ~7 times more anisotropic than the L_3 components of the $L\beta$ peak.

Following their suggestions we performed the present L_1 x-γ angular correlation measurement in the ^{207}Bi decay. In order to detect an anisotropy, we had to improve the experimental conditions with respect to those of the above mentioned work: stronger source and smaller resolving time.

EXPERIMENTAL PROCEDURE

The radioactive source consisted of 25 μCi ^{207}Bi in HNO_3 deposited on a Mylar backing of 900 $\mu g/cm^2$. The x-γ coincidence spectrometer used in the present experiment consisted of two movable 7.65-cm× 7.65-cm height NaI(Tl) counters for detecting γ rays, and a fixed 30-mm Si(Li) semiconductor counter for the detection of the x rays with a resolution of 500 eV at 10 keV. A typical coincidence spectrum is shown in Fig. 1. The resolving time 2τ of the spectrometer coincidence system was 40 ns.

The peak-to-spectrum method was employed. The L x spectrum in coincidence with the 570-keV γ transition was registered in a multichannel analyzer. The memory of the analyzer was subdivided into two sections in which the true-plus-chance and chance coincidences were stored simultaneously. A channel-by-channel subtraction gave the final true coincidence spectrum. The Compton contribution of γ lines of higher energy was determined by setting the gate above the 570-keV peak. Finally, coincidence background was considered.

Coincidence counting rates were determined for five different angles between the symmetry axes of the Si(Li) counter and of each of the NaI(Tl) detectors. A typical coincidence spectrum is shown in Fig. 1. As it can be seen the L_1 and $L\alpha$ lines are resolved. The coincidence data were handled in two different ways: (i) the counts under the Ll peak were considered; (ii) the counts under the $Ll+L\alpha+L\beta$ peaks were taken into account as

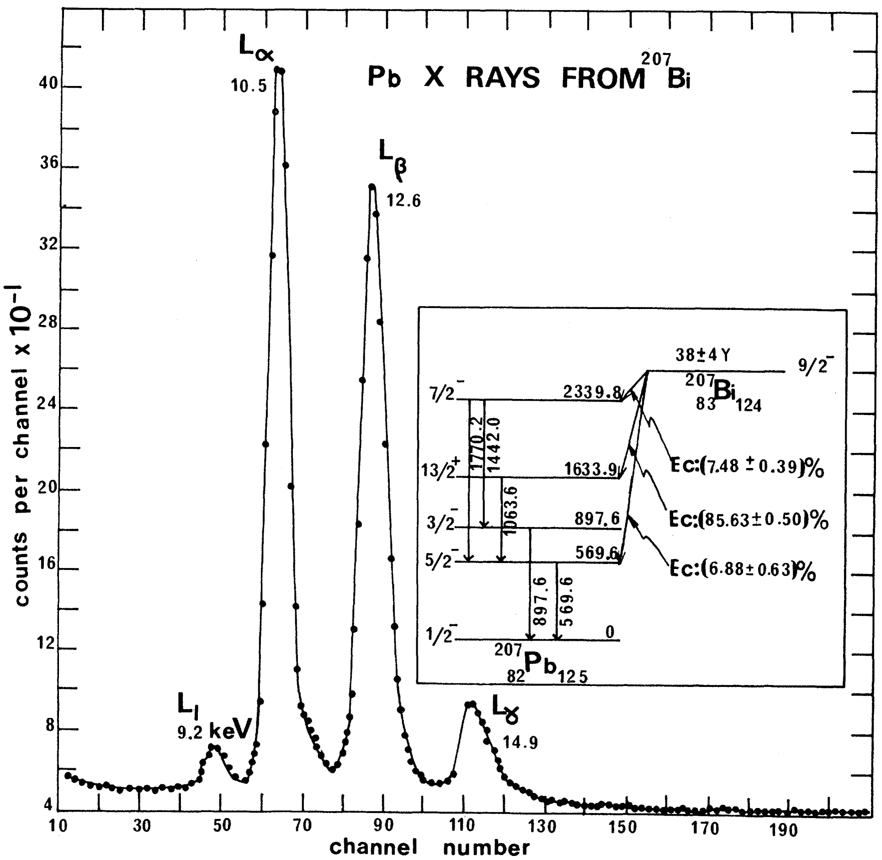

FIG. 1. Typcial lead L x-ray coincidence spectrum with the Si(Li) detector used in the present experiment. Inset: decay scheme corresponding to ^{207}Bi.

it was done in Rupnik's experiment.

For both cases the corrected coincidence counts were normalized and computer fitted to a directional correlation function of the form

$$W(\theta)=1+Q_{22}A_{22}P_2(\cos\theta)\ .$$

The Q_{22} coefficients are the finite-solid-angle correction factors. These were determined according to Krane[5] for the Si(Li) counter and to Yates[6] for the NaI(Tl) detectors.

The experimental results are shown in Table I. They are the weighted averages of the values obtained for the individual runs. The quoted errors are derived from the errors of the fit.

DISCUSSION

As it can be seen from the table we did not find anisotropy in the Ll x-570-keV-γ directional angular correlation even though we improved the experimental conditions, with respect to Rupnik's experiment: stronger source, smaller resolving time, two γ detectors acting simultaneously, and five independent angles of measurement. These improvements are reflected in the fact that the final error in the $Ll+L\alpha+L\beta$ x-570-keV-γ angular correlation is of the same order of magnitude as the one obtained by Rupnik and Crasemann,[1] although our error takes into account not only the statistical one but also the one of the fit.

The theoretical prediction for the Ll x-570-keV-γ ray angular correlation taking into account the primary and secondary L_3 vacancies is $A_{22}\simeq 10^{-3}$.

TABLE I. L x-γ angular correlation results.

L x peaks considered in coincidence with the 570-keV γ ray	A_{22}	Reference
$L_l+L_\alpha+L_\beta$	$(0.9\pm1.2)\times10^{-3}$	present
	$(1.3\pm1.3)\times10^{-3}$ [a]	1
L_l	$(-4\ \pm8)\ \times10^{-3}$	present

[a] This value was obtained with two independent angles of measurement.

Our experimental result, consistent with the predicted one, shows, after four months of measurement, that it is hopeless to try to detect anisotropy with this kind of experimental arrangement in which only L x-γ coincidences are measured. Such experiment would take at best more than two years and the interval of confidence of the error would be very small.

Considering that the ^{207}Bi is one of the best cases that can be found, due to the fact that it decays through a second forbidden nonunique branch to the first excited state of ^{207}Pb, one can arrive at the following conclusion. In order to detect anisotropy it is absolutely necessary to subtract the coincidences due to secondary L_3 vacancies. As most of them arise from primary K vacancies, one possibility is the simultaneous measurement of the L x-γ coincidences and the L x-Kx-γ triple coincidences. In this case, a 4π geometry would be required for the detection of the K x rays. Such an experiment could lead to an experimental confirmation of Dolginov's theory.

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