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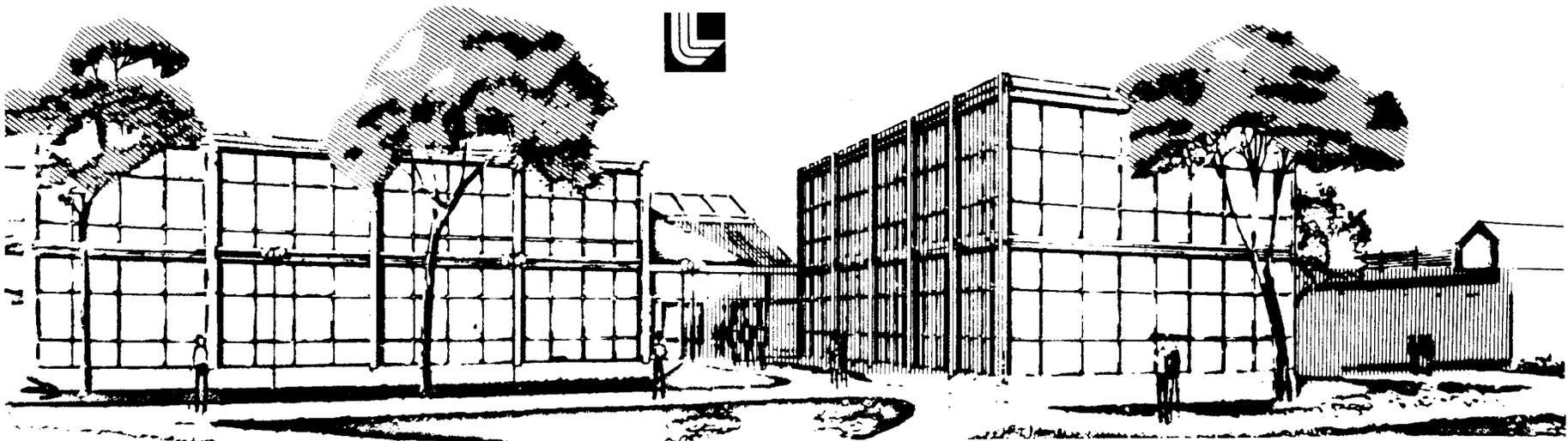
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RELATIVE HIGH-ENERGY GAMMA- AND X-RAY EMISSIONS
FOLLOWING DECAY OF ^{103}Pd

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FOLLOWING DECAY OF $^{103}\text{Pd}^*$

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ABSTRACT

The intensity ratio of the 357-keV gamma ray to the K x rays from ^{103}Pd decay has been measured to be 3.1×10^{-4} . This value gives an absolute intensity of 0.024% for the 357-keV gamma ray in ^{103}Pd decay.

The nuclide ^{103}Pd (half-life 17 days) decays by electron capture, emitting many 20- to 23-keV x rays. This nuclide has certain attractions as a simulator for ^{239}Pu (emits 13- to 20-keV x rays) in calibrating equipment for the assessment of plutonium in lungs, and for this purpose it has on several occasions been administered by inhalation to volunteers.⁽¹⁻³⁾ In such experiments the quantity of activity used must be known in absolute terms. In solutions of ^{103}Pd , this quantity can be measured by x-ray counting, but this entails either preparation of essentially weightless sources from a known fraction, or troublesome corrections for the effects of self-absorption. In such instances it may be simpler and better to measure the weak gamma-rays from ^{103}Pd (295 to 497 keV) with calibrated solid-state detectors, provided the intensities of these gamma rays are reliably known.

The most intense of these gamma rays is that at 357 keV and the various published estimates of its intensity⁽⁴⁻⁸⁾ are included in Table 1. Most of these studies determined gamma-ray intensity not absolutely, but by reference to x-ray emission; hence we have expressed the data in Table 1 as the ratio of gamma-ray intensity to x-ray intensity. The first two values reported, those of Rietjens *et al.*⁽⁴⁾ and of Saraf,⁽⁵⁾ were substantially in agreement, but a subsequent estimate by Avignon *et al.*⁽⁶⁾ was almost three times higher. However, the later results of Grunditz *et al.*,⁽⁷⁾ whose study was the first to employ solid-state detectors for measuring the gamma rays, appeared to confirm the earliest estimates.^(4,5)

In 1976, Macias *et al.*⁽⁸⁾ reported a value some three times lower than the three previous estimates that agreed. In each of our two laboratories, we have recently measured ^{103}Pd sources, and our values confirm those of Macias

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et al.⁽⁸⁾ Our sources were supplied by the Radiochemical Centre,* Amersham, Great Britain; the activity had been produced there by bombardment of rhodium by 15-MeV deuterons.

At Harwell a source of approximately 50 μ Ci was prepared by evaporation of a solution deposited on a thin paper filter. The x-ray emission from it was estimated by counting in the solid-angle defined by a 19-cm-diameter "phoswich" detector at a distance of 120 cm⁽⁹⁾; the detector's NaI(Tl) crystal, in which the x-ray interactions occurred, was covered by a 1-mm-thick beryllium window. The x-ray emission thus measured carried an estimated error of 5%, largely due to the difficulty of estimating the effective window diameter.

The 357-keV gamma-ray emission was measured with a 40-cm³ coaxial Ge(Li) detector at a distance of 13 cm. This detector was calibrated in two ways: The first calibration was by reference to the response to 356-keV radiation from a ¹³³Ba source. This ¹³³Ba source had been standardized by the Radiochemical Centre with an estimated accuracy of $\pm 1.6\%$; an intensity of 62.3% was assumed for this radiation.⁽¹⁰⁾ The second calibration employed a source of ¹⁵²Eu obtained from the Laboratoire de Metrologie des Rayonnements Ionisants, France. The spectrum of ¹⁵²Eu includes two gamma rays whose energies conveniently bracket the 357-keV radiation from ¹⁰³Pd; these appear at 344 and at 368 keV, and the gamma-ray emissions at these energies were quoted to us with uncertainties of ± 3 and $\pm 5\%$, respectively. The two methods of calibration agreed within 1%. The measurements at Harwell were repeated with a source made from a second solution of ¹⁰³Pd obtained two years later. The results for both sources are given in Table 1.

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U. S. Energy Research & Development Administration to the exclusion of others that may be suitable.

At Livermore, a source was prepared by flashing ¹⁰³PdCl₂ from a hot tungsten filament onto a thin (6.35- μ m), aluminized mylar film. This active layer was then covered with a second film of identical thickness. The x rays were measured both with a thin Ge(Li) diode and with an Si(Li) diode, and the x-ray emission rate was calculated by reference to curves relating efficiency with energy. The curves⁽¹¹⁾ had been derived from measurements of absolutely standardized sources of ²⁴¹Am, ¹³⁷Cs, and ⁵⁷Co. Similar ¹⁰³Pd sources produced and standardized by these methods have been examined by six other laboratories, and five of these agreed with Livermore's estimate of the x-ray output to within better than 5%. The gamma rays emitted from ¹⁰³Pd were measured with large-volume Ge(Li) spectrometers.⁽¹¹⁾

In Table 1, the ratios independently determined by our two laboratories are similar, and would agree even better if related to common standards of x-ray emission: an exchange of ¹⁰³Pd sources showed that the method employed at Harwell underestimated the x-ray output by 3% compared with Livermore's assessment. Together with the result of Macias et al.,⁽⁸⁾ our data imply an intensity of 0.024% at 357 keV, if we assume 80% intensity⁽⁸⁾ for the x-rays. Published intensities for ¹⁰³Pd gamma radiations at 295 and 497 keV vary as widely as the values in Table 1. For these emissions, our data again agree much better with those of Macias et al.,⁽⁸⁾ than with any of the others.

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TABLE 1. Intensity ratio: 357-keV gamma rays to K x rays (20 to 23 keV), both from ^{103}Pd .

Reference	Intensity ratio $\times 10^4$
Rietjens <u>et al.</u> ⁽⁴⁾	7.2 ± 0.8
Saraf ⁽⁵⁾	8.3 ± 1.3
Avignon <u>et al.</u> ⁽⁶⁾	21 ± 4
Grunditz <u>et al.</u> ⁽⁷⁾	8.5 ± 0.7
Macias <u>et al.</u> ⁽⁸⁾	2.99 ± 0.09
Present authors:	
Livermore	3.01 ± 0.05
Harwell	3.31 ± 0.22
	3.16 ± 0.25

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