Precision Energy Measurements of the Gamma Rays Following the Decay of Bi^{207}†

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The external conversion spectrum of the two intense gamma rays of Pb^{207} has been examined by means of a high resolution spectrometer. The 1.06-Mev gamma ray was found to consist of a single component of energy 1063.43±0.50 kev. The energy of the ground state transition was found to be 568.85±0.30 kev.

INTRODUCTION

THE usefulness of 8.0-yr Bi^{207} as an energy standard in beta- and gamma-ray spectroscopy has been pointed out by Alburger,[1] who made a precision measurement of the energy of electrons from the strongly-converted 1.06-Mev transition in Pb^{207}. However, Prescott[2] found an excess of coincidences between lead x-rays and the 1.06-Mev gamma ray, and accordingly suggested the existence of a closely spaced pair of nuclear levels giving rise to two gamma rays at very nearly 1.06 Mev. One of these was postulated to be a prompt transition, and the other the well-known 0.84-second isomeric decay. Very recently, Lazar and Klema[3] re-examined the gamma-ray spectrum with a scintillation-coincidence spectrometer and found no evidence for the existence of more than one transition at 1.06 Mev.

The work herein reported consisted of a search for a closely spaced pair of gamma rays near 1.06 Mev and precision measurements of the energies of both the 1.06- and the 0.57-Mev gamma rays.

EXPERIMENTAL METHOD AND RESULTS

The Bi^{207} was made in the University of Washington sixty-inch cyclotron by bombarding lead with 22-Mev deuterons for approximately 3000 microampere-hours. About 9 months after the bombardment was completed, the bismuth was separated from the lead following Alburger's[4] method. An external conversion source was prepared in the same manner as described by Keister, Lee, and Schmidt.[5] In order for the thorium radiator foil to subtend a maximum solid angle at the source material, a copper foil was placed between the source capsule and the radiator to absorb the K and L conversion electrons from the 1.06-Mev transition.

The photoelectric external conversion spectrum was measured in a uniform field solenoidal beta-ray spectrometer equipped with a ring focus.[6] Two runs were made: one with the spectrometer set at a nominal transmission of 4 percent utilizing a thorium foil radiator of 12.5 milligrams per cm² surface density, and a second with the spectrometer set at a nominal transmission of 2 percent utilizing a thorium foil radiator of 3.5 milligrams per cm² surface density. In each case, the radiators were of appropriate diameters (0.25 inch and 0.056 inch, respectively) to give optimum luminosity and momentum resolution. The inverse momentum resolution was approximately 1.5 percent and 0.4 percent full width at half-maximum for the two settings, respectively.

With the larger radiator and greater transmission, the peak counting rate of the K photoconversion line was 3 counts per second above background. The region from ~80 kev below to ~80 kev above the 1.06-Mev line was examined carefully. From this run we can state that no gamma ray exists in this region with an intensity greater than 10 percent of the 1.06 and differing by more than 10 kev in energy.

At the higher resolution setting with a 3.5 mg/cm² thorium radiator, the intensity of the 1.06-Mev K photoconversion line was only ~0.2 count/sec above a background of ~0.9 count/sec. These data are plotted in Fig. 1; the solid line is the transmission curve of the spectrometer as determined by the F line of thorium B. The results indicate that there is no other gamma ray differing in energy by more than

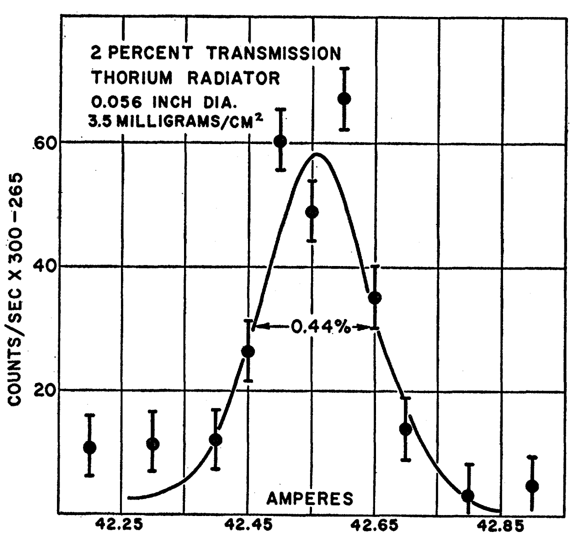

FIG. 1. K photoconversion line of the 1.06-Mev gamma ray at the higher resolution.

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[1] D. E. Alburger, Phys. Rev. **92**, 1257 (1953).
[2] J. R. Prescott, Proc. Phys. Soc. (London) **A67**, 540 (1954).
[3] N. H. Lazar and E. D. Klema, Phys. Rev. **98**, 710 (1955).
[4] D. E. Alburger and G. Friedlander, Phys. Rev. **81**, 523 (1951).
[5] Keister, Lee, and Schmidt, Phys. Rev. **97**, 451 (1955).
[6] F. H. Schmidt, Rev. Sci. Instr. **23**, 361 (1952).

5 kev and with an intensity greater than 50 percent of the 1.06-Mev line.

The F line of thorium B was used to recheck the earlier precision calibration[7] of the spectrometer. The instrument is known to be linear to a very high degree.[7]

At the higher resolution the K photoconversion line of the 0.57-Mev gamma ray was $\sim$0.6 count/sec above background. We conclude that two nearly equal energy gamma rays do not exist in the region of the 0.57-Mev gamma ray either.

Upon adding the 109.79-kev binding energy of thorium[8] to the measured energy of the K photoconversion electrons, we obtain 1063.43$\pm$0.50 kev and 568.85$\pm$0.30 kev, respectively, for the energies of the two gamma rays. The former is to be compared with the measurement of Alburger,[1] *viz.*, 1063.9$\pm$0.3 kev.

[7] D. I. Meyer and F. H. Schmidt, Phys. Rev. **94**, 927 (1954).
[8] Hill, Church, and Mihelich, Rev. Sci. Instr. **23**, 523 (1952).

Lazar and Klema[3] have shown that the 1.06−0.57 Mev cascade have relative gamma intensities of 0.77$\pm$0.06 and 1.00, respectively. Bi^{207} is thus particularly useful as a test source in gamma-ray coincidence spectroscopy. The 975.9-kev K conversion electrons[1] from the 1.06-Mev transition, together with the coincident 0.57 gamma ray, have proved to be of particular use in this laboratory for energy calibration of beta-gamma coincidence scintillation spectrometers.

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Electron Capture Decay of Am^{244} and the Spontaneous Fission Half-Life of Pu^{244}†

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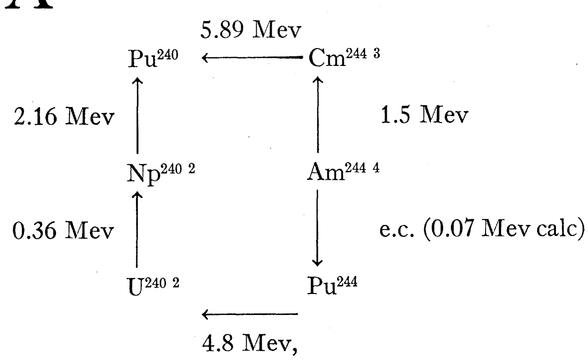
The branching ratio (electron captures/beta particles) of Am^{244} was determined as 0.039$\pm$0.003%. An enriched Pu^{244} sample was isolated from neutron irradiated Am^{243}, and the spontaneous fission half-life of Pu^{244} was found to be $(2.5\pm0.8)\times10^{10}$ years.

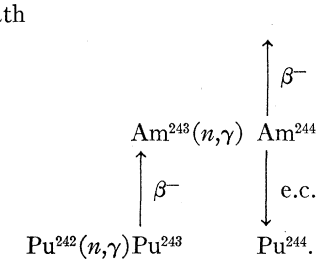
A CONSIDERATION of the closed energy cycle[1]



using available data and an estimated value of 4.8 Mev for the alpha disintegration energy of Pu^{244}, indicates that Am^{244} may be slightly unstable toward electron capture decay. The fact that Pu^{244} is apparently beta stable[1,5] suggests that Am^{244} is analogous to Am^{242} and is probably unstable toward electron capture decay. Evidence of electron capture decay for Am^{244} can be found in the Materials Testing Reactor (MTR) irradiations of plutonium. The Pu^{242} to Pu^{244} ratios in several MTR irradiations of plutonium (Table I) indicated that Pu^{244} was being produced more rapidly than would be predicted from the path

$$Pu^{242}(n,\gamma)Pu^{243}(n,\gamma)Pu^{244},$$

and that some Pu^{244} was probably being formed by the alternate path



† Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Studier, Fields, Sellers, Friedman, Stevens, Mech, Diamond, Sedlet, and Huizenga, Phys. Rev. **93**, 1433 (1954).
[2] Knight, Bunker, Warren, and Starner, Phys. Rev. **91**, 889 (1953).
[3] Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 611 (1953).
[4] Ghiorso, Thompson, Choppin, and Harvey, Phys. Rev. **94**, 1081 (1954).
[5] Inghram, Hess, Fried, and Pyle, private communication.