It is not hard to show (though we refrain from doing so here) that to this order of approximation the effect of the TM correction term in the denominator of Eq. (11) is actually canceled by some of the terms in the numerator which correspond to the principal multipole.

[1] N. Tralli and G. Goertzel, Phys. Rev. **83**, 399 (1951), henceforth referred to as TG.
[2] H. M. Taylor and N. F. Mott, Proc. Roy. Soc. (London) **A142**, 215 (1933), henceforth referred to as TM.
[3] Appendix B, Sec. 4, of TG.
[4] The superscript (1) indicates that in the matrix element a hankel function of the first kind replaces the bessel function. Similarly, we signal the presence of a hankel function of the second kind by a superscript (2).

Gamma-Ray Spectrum and Yield from Tritium Bombarded by Protons*

R. S. Rochlin
Cornell University, Ithaca, New York
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The energy spectrum and yield of the gamma-radiation[1–3] from the reaction $T^3(p,\gamma)He^4$ has been measured with a gamma-ray pair spectrometer previously described.[4,5] Tritium absorbed in a zirconium target[6,7] was bombarded by 0.96±0.06-Mev protons from the Cornell cyclotron. The proton energy was kept below 1.02 Mev so as to avoid a large neutron background from the $T^3(p,n)He^3$ reaction.[8] The zirconium used was 5.5 mg/cm² thick, and contained 0.47±0.05 atom of T^3 per atom of Zr throughout the bombardment. The gamma-rays were observed at an angle of 54.5 degrees to the proton beam in the laboratory system.

The energy region from 3 to 22 Mev was surveyed, using a 0.003-inch Pb radiator in the spectrometer. A single line was observed at an energy of 20.4±0.2 Mev. To obtain better resolution, additional data were taken around this line with a 0.002-inch Cu radiator. The data for both radiators are plotted in Fig. 1.

Correcting for the effective mean energy of the protons in the "thick" Zr target,[9] the doppler effect, and the recoil of the compound nucleus, we obtain a Q-value for this reaction of 19.7±0.3 Mev. By calculating the weighted mean Q-values from several independent cycles of more precise measurements on other nuclear reactions, Li *et al.*[10] have obtained 19.802±0.008 Mev for this Q-value.

The counting efficiency of the spectrometer decreases rapidly for lower gamma-ray energies for the following reasons: (a) the cross section for pair production in the radiator decreases; (b) each counting channel counts a smaller energy interval; (c) more electrons are lost through vertical multiple scattering in the radiator; (d) the resolution of the spectrometer decreases, due mainly to horizontal multiple scattering in the radiator. (The last reason is of importance only when considering the height of observed peaks, rather than the area under them.)

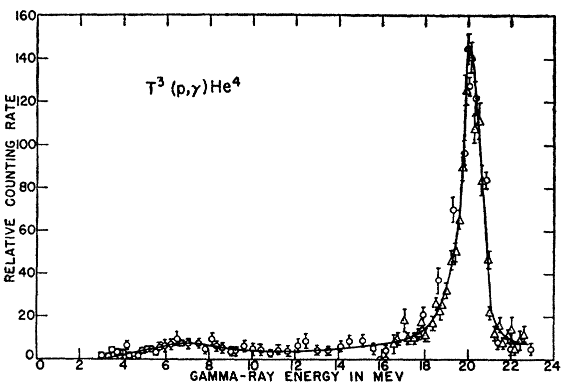

Fig. 1. Survey of the tritium gamma-ray spectrum. The circles represent data taken with a 0.003-in. Pb radiator and the triangles represent data taken with a 0.002-in. Cu radiator. Data for the two radiators are normalized to the same peak height. Standard deviations are indicated for each point.

Correcting[5] for these effects, it is estimated that any gamma-radiation from the tritium near 10 Mev and ¼ as intense as the 20.4-Mev line would have been observed if present. Near 6 Mev a line would have been observed if about 1.5 times as intense, and near 3 Mev only if roughly 40 times as intense.

The background at low energies shown in Fig. 1 is believed to come mainly from degraded radiation arising in the Pb collimator. The cosmic-ray shower background and accidental coincidences were found to be negligible.

The observed line width at half-maximum, which is about 5.4 percent in the case of the 0.002-inch Cu radiator, can be accounted for entirely by the resolution of the spectrometer. The resolution would not be significantly improved by the use of a thinner tritium target, since the target used caused a spread of only 1.1 percent of the total gamma-ray energy.

The yield from the $T^3(p,\gamma)He^4$ reaction was measured relative to the 17.6-Mev gamma-rays from the $Li^7(p,\gamma)Be^8$ reaction, using the pair spectrometer. The tritium-zirconium target was replaced by a thick lithium metal target. The proton energy and angle of observation were kept at the values given in the first paragraph. The proton beam was measured with a current integrator, and the two identical target holders were designed to eliminate error due to secondary electron emission. Correcting for the variation of spectrometer efficiency with energy, a (T+Zr)/Li yield ratio of 0.016±0.004 was found.

Argo *et al.*[1] made a similar yield comparison, except that they observed at 90 degrees and used a detector which counted the 14.8-Mev lithium line also. Adjusting[11,12] our value to their conditions would give a ratio of 0.012, while they[13] obtain 0.043. This discrepancy may be partly explained by a possible difference in the T^3/Zr atomic ratio in their target and ours.

From the lithium data of Fowler and Lauritsen,[11] the absolute yield of our tritium-zirconium target at 90 degrees was about 3×10^{-11} gamma-ray per steradian per proton. A $\sin^2\theta$ angular distribution[1] was assumed for the tritium gamma-rays.

In addition to its intrinsic interest for a study of the excited He^4 nucleus, the $T^3(p,\gamma)$ reaction should prove widely useful as a gamma-ray source. It provides the highest energy gamma-rays of any known nuclear reaction, is probably monoenergetic, and under suitable bombarding conditions can provide gamma-rays of an energy known to about 0.04 percent.

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Properties of the Isotope Pu^{243}

S. G. Thompson, K. Street, Jr., A. Ghiorso, and F. L. Reynolds*
Radiation Laboratory and Depatment of Chemistry, University of California, Berkeley, California
(Received July 30, 1951)

Investigation in this laboratory of the higher isotopes of plutonium produced by neutron irradiation has provided confirmation of the existence and properties of the new isotope Pu^{243}