Gamma Rays from 14-Mev Neutron Bombardment of C^{12}†

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The gamma rays emitted by C^{12} under 14-Mev neutron bombardment have been investigated with a three-crystal pair spectrometer. In the energy range 1.5−5.5 Mev, the observed pulse-height distribution is consistent with the assignment of a single-energy line at 4.4 Mev. The calculated value for the production cross section of 4.4-Mev gamma radiation is 245±35 millibarns.

THE production of gamma rays by materials under 14-Mev neutron bombardment has been studied by a number of investigators using either a single scintillator crystal[1] or coincidence counter measurements.[2] In experiments of this type, the background from extraneous gamma rays and from neutrons incident on the detector is of prime importance. The present measurement of gamma rays resulting from the interaction of 14-Mev neutrons with carbon was made with a three-crystal pair spectrometer[3] which, under certain operating conditions, allows discrimination against background not attainable by the single-crystal or coincidence-counter measurements.

The pulses from each of the three NaI(Tl) crystals, after amplification, pass through a differential pulse-height discriminator to a threefold coincidence circuit with 0.2-microsecond resolving time. Pulses from the center crystal are also observed on an 18-channel analyzer gated by the coincidence output. Initial tests of the spectrometer with uncollimated sources resulted in pulse-height distributions with a prohibitively large continuum of pulses on the low-energy side of the pair peak. An explanation of this continuum of pulses, substantiated by further tests, is that there is a significant number of coincidences due to the random coincidence of a pulse from one side crystal with a true double coincidence between the pulses from the other two crystals caused by a Compton event. This background was removed by (a) delaying the side crystal pulses with respect to the center crystal pulses to decrease the effective resolving time and (b) accepting from the side crystals only those pulses which lay within a narrow band of 0.42 to 0.60 Mev. Other observers[4] have also found that this general type of operation improves the resolution of the spectrometer.

Calibration of the spectrometer, both as to energy scale and number of counts in the pair peak per incident gamma on the center crystal, was accomplished by counting gamma rays from a Pu-Be source whose neutron source strength was measured. Assumption of a branching ratio of 0.60±0.06 for the $Be^9(\alpha,n)C^{12*}$ reaction[5] allowed calculation of its 4.4-Mev gamma-ray strength. The inset of Fig. 1 shows the pulse-height distribution obtained for this source. The area under the portion of the pulse-height distribution below the pair peak is about 25 percent of that under the pair peak, or an energy loss, due to radiative loss and electron escape in the center crystal of approximately 9 percent. Because of the experimental error, a small contribution to this region from a cascade 3.2-Mev line[6] would not be detected. The response of the spectrometer to neutrons was also measured, response

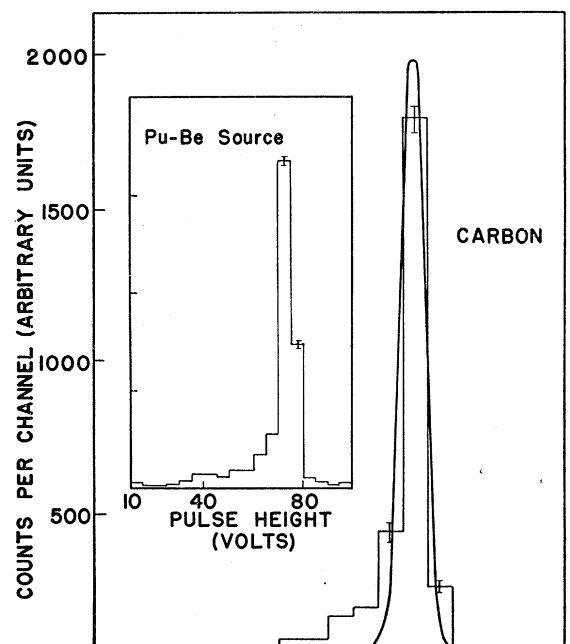

FIG. 1. Pulse-height distribution of gamma rays from carbon prior to adjustment for radiative loss and electron escape. Curve drawn shows the corrected pulse-height distribution. Inset: pulse-height distribution from Pu-Be source.

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being here defined as the number of coincidences in the pulse-height range corresponding to gamma-ray energies from 1.6 to 5.5 Mev in the center crystal per unit incident flux. Relative values for the response to 4.4-Mev gamma rays, to 14-Mev neutrons, and to 2.5-Mev neutrons were found to be 1.0, 0.08, and 0.008 respectively. From these measurements and available data on 14-Mev neutron elastic and inelastic scattering, it is estimated that the effect on the pulse-height distribution due to neutrons scattered by the sample into the detector is not more than a few percent for the geometries used.

A thick zirconium-tritium target bombarded by 130-kev deuterons from a Cockcroft-Walton accelerator provided the 14-Mev neutrons whose source strength was measured by a calibrated long counter. The long counter readings were corrected for the effect of neutron scattering by the graphite sample which was in the form of a ring and located so that the plane of the ring lay immediately behind the target. The spectrometer was placed 26 cm in front of the target, a tungsten bar providing shielding of the center crystal from the direct neutron beam.

Figure 1 shows the pulse-height distribution, scatterer in minus scatterer out, obtained for 14-Mev neutrons incident on carbon. The × points represent the net result after correction for radiative loss and electron escape obtained by normalization from the Pu-Be data, and the curve drawn shows the corrected pulse-height distribution. This distribution is consistent with the assignment of a single-energy line at 4.4 Mev in the 1.6–5.5 Mev region. The calculated value for the production of 4.4-Mev gamma rays from 14-Mev neutron bombardment of C^{12}, taking into account the attenuation of incident neutrons and resulting gamma rays in the scatterer, is 245 ± 35 millibarns.

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Coincidence Studies of the Disintegration of Pm^{151} and Nd^{147}†

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Chemically pure Nd_2O_3 was irradiated by slow neutrons on five successive occasions in the Brookhaven pile. The 27.5-hour Pm^{151} was found to emit gamma rays of energies 64, 100, 163, 177, 240, 275, 340, 440, 650, and 700 kev. The 11-day Nd^{147} was shown to emit quanta of energies 92, 165, 280, 320, 410, 440, 530, and 690 kev. The relative intensities of the various quantum radiations have been determined, and coincidence measurements have been performed to ascertain the various sequential relationships between pairs of gamma rays. Partial decay schemes for both radionuclides have been indicated.

INTRODUCTION

IT was originally reported by Law, Pool, Kurbatov, and Quill[1] that 2.3-hr, 47-hr, and 11-day activities can be produced when neodymium is irradiated by certain nuclear particles. The mass number of the 11-day activity has been shown to be 147.[2,3] The 2.3-hr activity has been identified as the neodymium parent of the 47-hr promethium,[2,4] the mass numbers being 149.[5] Beta-gamma coincidence studies, and absorption measurements were carried out by Mandeville *et al.*[6] to establish the principal features and general pattern of the decay schemes of the 11-day neodymium and the 50-hr[7] Pm^{149}. Kondaiah[8] has reported in the decay of the 11-day activity gamma rays of energies 520, 391, 309, and 91 kev and three beta-ray spectra having end points at 350, 470, and 780 kev. This author found no gamma rays to be emitted in the decay of the 50-hr Pm^{149}. Emmerich and Kurbatov[9] have investigated the disintegration of the 11-day activity and report gamma rays at 91.5, 320, and 534 kev and beta-ray energies of 380, 600, and 825 kev. More recently, Cork *et al.*[7] have reported for Nd^{147} gamma rays of energies 91.2, 120.5, 168.1, 197.1, 231.2, 259.8, 273.3, 300.8, 318.1, 398.4, 441.4, and 532.3 kev. These latter authors have also reported the presence of Pm^{151} ($T_{1/2}=27.5$ hr) in samples of irradiated Nd which had been enriched in Nd^{150}. This activity is apparently grown from the 12-minute Nd^{151}. Pm^{151} was reported[7] to emit gamma rays of energies 64.7, 65.8, 69.6, 100.0, 105.2, 116.2, 144.0, 163.1, 168.0, 177.1, 208.3, 231.9, 239.9, 275.2, 340.2, and 715 kev.

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