Emission of High-Energy Gamma Line from C^{12}†

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A gamma ray of energy 15.2 Mev has been observed with a 180° pair spectrometer in the bombardment of carbon by protons of energy 30–340 Mev. The line is also seen in deuteron bombardment of B^{11}, but not of B^{10}. These facts, along with energetics arguments and clear spectrometer separation from known lines in excited Be^8, strongly indicate an excited C^{12} origin for the line. It is tentatively proposed that the excited C^{12} level here involved is a $T=1$ state for which isotopic spin selection rules forbid a disintegration into three alpha particles.

IN connection with studies of proton bremsstrahlung, in which a 180° pair spectrometer is used to analyze the photon spectrum, a gamma line at 15.2±0.2 Mev has been observed which is believed to arise from the excited C^{12} nucleus. Such a line was suggested in Wilson's[1] experimental bremsstrahlung data on proton bombardment of carbon, but his methods did not permit resolution of the line.

Figure 1 shows this gamma emission revealed by the pair spectrometer as it appears superimposed upon the bremsstrahlung, viewed at 90° from the beam direction, in the bombardment of carbon by 340-Mev protons in the Berkeley cyclotron. The cyclotron target could be pushed in to a radius where the proton energy was 30 Mev; and at this energy the bremsstrahlung is negligible, leaving the line emission as shown in Fig. 2.

The breadth of the line as here shown is essentially entirely instrumental, and a more precise evaluation of its true energy awaits calculation of the instrumental line shape. Calibration of the spectrometer was accomplished by the floating-wire technique, and a calibration test of the spectrometer upon the 17.6-Mev gamma line from Be^{8*} indicates that the energy error is within the limits given above.

The assignment of the line to C^{12*} is based upon the following facts.

(A) It is present with a carbon target for proton energies ranging from 30 to 340 Mev, and is not observed in proton bombardment of Be, B, and O.

(B) It has been observed in deuteron bombardment of B^{11} in which deuterons of 18, 30, and 50 Mev were incident on a thick target. It is not observed in the deuteron bombardment of B^{10}. Recent work[2] at Indiana gives definite indication of high-energy (about 15-Mev) gamma emission from 11-Mev deuteron bombardment of a thick boron target (presumably natural boron which is 81 percent B^{11}).

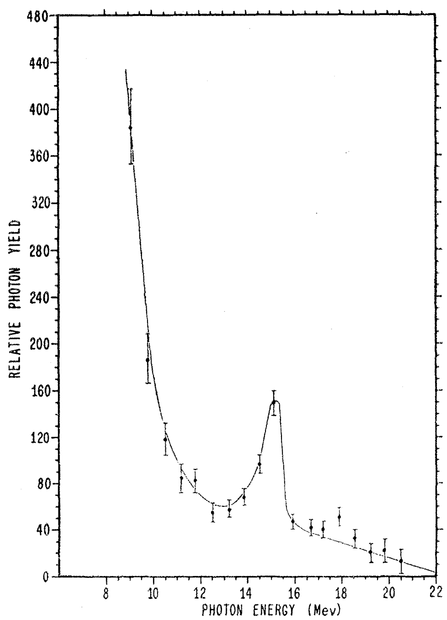

FIG. 1. Photon spectrum from 340-Mev proton bombardment of carbon.

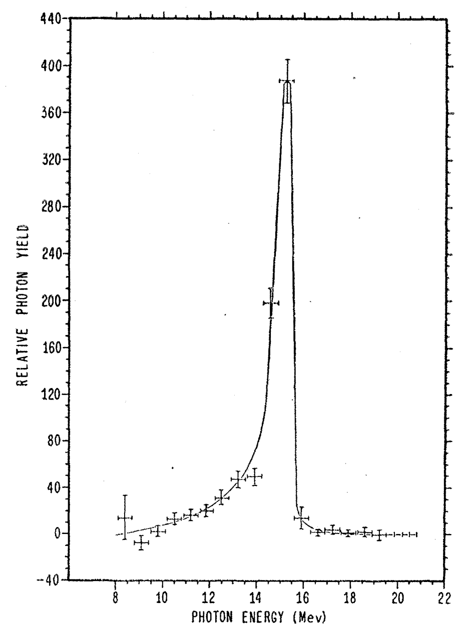

FIG. 2. Photon spectrum from 30-Mev proton bombardment of carbon.

† This work was done under the auspices of the U. S. Atomic Energy Commission.

[1] Richard Wilson, Phys. Rev. 85, 563 (1952).

[2] V. K. Rasmussen (private communication).

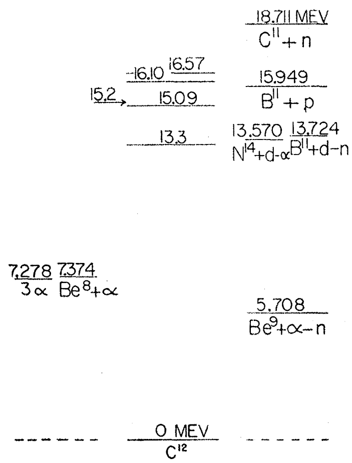

FIG. 3. Energy level diagram.

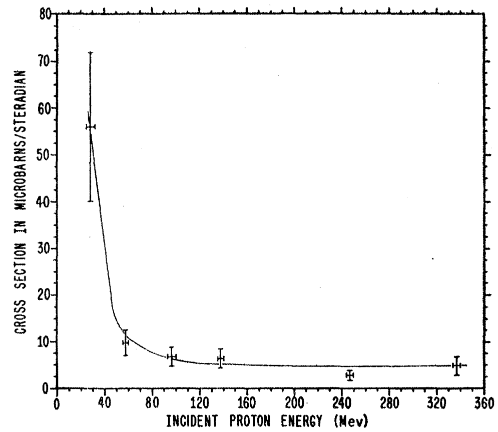

FIG. 4. Differential cross section for production of 15.2-Mev photons at 90° *vs* energy of protons incident upon carbon targets.

(C) A level below 15.95 Mev in C^{12} cannot decay by neutron or proton emission, as is made evident by Fig. 3. Consequently such a level must either disintegrate into three alpha particles or into Be^8 plus an alpha, or decay by gamma emission. If the gamma process is to predominate, a selection rule must operate which suppresses the alpha processes in the decay from this level.

Absolute values of the differential cross section for producing these gamma-ray photons into unit solid angle at 90° were roughly determined by a thermocouple monitoring of target temperature. This is related to beam energy loss in the target, and thus, at a known energy, to beam traversal of the target. The absolute efficiency of the spectrometer is calculated from established pair-production cross sections and geometry. In Fig. 4 is illustrated the dependence of the yield of the level in question upon energy of bombarding protons, with a carbon target.

It seems reasonable to propose tentatively[3] that the alpha disintegration may be considerably forbidden by isotopic spin considerations, which would be the case if this C^{12*} level were a $T=1$ state. This allows dipole gamma emission in the transition to the C^{12} ground state.[4] Upon this basis the B^{12}, C^{12*}, and N^{12} would form the isotopic triplet. The 15.09-Mev C^{12*} level listed by Ajzenberg and Lauritsen[5] may be the one here in question.

Attempts to produce this gamma emission by the alpha bombardment of Be^9, employing 170-Mev alphas upon a Be target of sufficient thickness to stop them, have not given a detectable yield. This apparent failure to produce the required state by $Be^9(\alpha,n)C^{12*}$ may be understood in terms of the $T=1$ proposal advanced above; since a process which amounts essentially to the coalescence of three alpha particles, with the release of the loosely bound neutron, could not develop a $T=1$ state.

Helpful discussions with Professor M. A. Ruderman are acknowledged.

[3] This suggestion has come to us by private communication from the group at the California Institute of Technology.

[4] L. Radicati, Phys. Rev. 87, 521 (1952).

[5] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. 24, 321 (1952).