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COMPARISON OF THE BETA SPECTRA OF B^{12} AND N^{12}[†]

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(Received August 3, 1961)

The observed near equality of the vector beta coupling constant given by the decay of O^{14} and the muon decay coupling constant led Feynman and Gell-Mann[1] to postulate the conservation of the vector part of the beta-decay current. Gell-Mann[2] pointed out that a consequence of this conserved vector current (CVC) theory is an additional coupling in the beta interaction analogous to the anomalous magnetic moment of the nucleon ("weak magnetism"). The interference between this term and the Gamow-Teller transition amplitude for a $1^+ \rightarrow 0^+$, $\Delta T = 1$ beta transition then results in a deviation from the allowed shape of the B^{12} and N^{12} spectra. The magnitude of the effect can be calculated[2,3] from the rate of the analogous $M1$ gamma transition in C^{12}. If $S(E)$ is the spectrum of each transition, divided by the corresponding allowed Fermi spectrum, then the CVC theory predicts

$$S(E, \mathrm{B}^{12})/S(E, \mathrm{N}^{12}) = \mathrm{const}[1 + (A + \delta A)E]f(E),$$

where the constant A arises from this interference term. The quantity $f(E)$ is the inner bremsstrahlung correction. The expected value for A is $(1.33 \pm 0.15)\,\%$ per Mev with an electromagnetic correction[4] δA of $(-0.25 \pm 0.15)\,\%$ per Mev. The uncertainty in A comes from the uncertainty in the C^{12} gamma-decay rate and the uncertainty in δA is an estimate of the error from using the shell model. Without the CVC theory hypothesis, A is estimated to be roughly 5 times smaller.[4,5]

The beta spectra of B^{12} ($E_{\mathrm{max}} = 13.369$ Mev) and N^{12} ($E_{\mathrm{max}} = 16.43$ Mev) were analyzed with the iron-free single-lens magnetic spectrometer described by Hornyak et al.[6] The baffle system was modified for the high electron energies involved. B^{12} (20.3 msec) was produced by bombarding targets of natural boron with 1.65-Mev deuterons, and N^{12} (12.5 msec) was produced by bombarding targets of enriched (96 %) B^{10} with 2.75-Mev He^3 ions. Both beams were pulsed at 60 cps at the ion source of the electrostatic accelerator. The targets consisted of approximately 0.3 mg/cm^2 of boron deposited by cracking diborane on foils of thickness 0.5 mg/cm^2 and 3 mg/cm^2 for B^{12} and N^{12}, respectively. The beta rays were detected in a 10-mm thick anthracene scintillator. This is sufficiently thin (approximately 2.3-Mev range for electrons) to give nearly identical pulse-height spectra for all energies in the range studied (5-13 Mev). The use of a thin scintillator allows amplifier gain and discriminator settings to be left constant, reduces background as a result of its small volume, and produces a negligible small pulse tail extending into the noise background.[7] The activity produced on the target was monitored by the reaction protons from B^{10}(d, p)B^{11} for B^{12} and B^{10}(He^3,p)C^{12} for N^{12}. A silicon p-n junction counter mounted in the spectrometer near the target served as a proton detector.

The spectra were sampled at 0.5-Mev intervals in the range 5 to 10.5 Mev for B^{12} and 5 to 13 Mev for N^{12}, the data being collected at alternating high- and low-energy points to minimize effects of target deterioration and instrumental drifts. The lower limit of 5 Mev was dictated by uncertainties in the branching ratios to excited states of C^{12}; the upper limit was maintained well below the spectrum end points to minimize uncertainties arising from calibration errors and background subtraction. The background was studied at energies above the end points of the beta spectra, at zero field, and by using target backings without the boron. The neutron background was separately investigated with a beryllium target. Typical background corrections at 8 Mev amounted to about 1.7 % for B^{12} and 4.2 % for N^{12}. A B^{12} spectrum taken with the relatively thicker backing used for the N^{12} showed no deviation from the other B^{12} spectra.

The observed spectra are corrected for branching[8,9] to the 4.4- and 7.6-Mev excited states of C^{12} and for inner bremsstrahlung.[4] The N^{12} branch to the 7.6-Mev state is assumed to be 3.5 %. The small inner bremsstrahlung correction has been applied entirely to $S(E, B^{12})$. The Fermi plots, not corrected for branching, are given in Fig. 1. The B^{12} and N^{12} matrix elements, normalized to 1.00 at 8 Mev, are displayed in Fig. 2. The B^{12} plot represents one typical run, and the N^{12} plot is the data of 8 runs. We find the B^{12} matrix element has an energy dependence of $(1.30 \pm 0.10)\%$ per Mev and the N^{12} energy dependence is $(0.17 \pm 0.20)\%$ per Mev giving $(1.13 \pm 0.25)\%$ per Mev for $A + \delta A$.

This result appears to be in agreement with the CVC-theory prediction of $(1.08 \pm 0.22)\%$ per Mev. An important uncertainty is the 7.6-Mev branching ratio in the N^{12} decay. If, for example, we have overestimated this branching ratio by 10%,

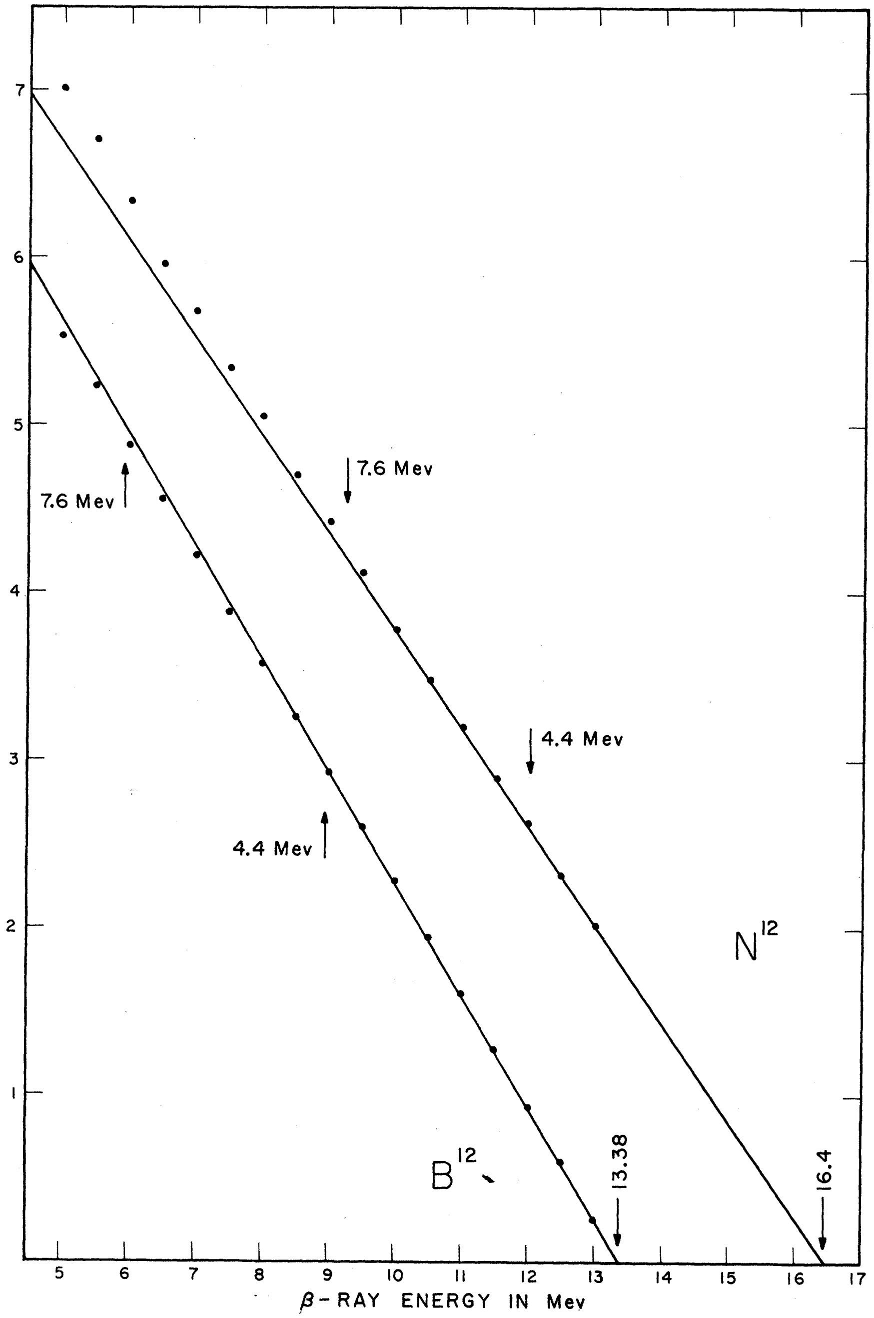

FIG. 1. Fermi plots for B^{12} and N^{12}. The observed end-point energies, indicated in the figure, are in agreement with the values from reaction data [F. Ajzenberg-Selove and T. Lauritsen, in Landolt-Börnstein Tables (to be published)] of 13.369 Mev for B^{12} and 16.43 for N^{12}. The curvature of the N^{12} plot due to branching can easily be seen. In the B^{12} plot this effect is overcompensated by the CVC shape factor. Branching end points are indicated by arrows.

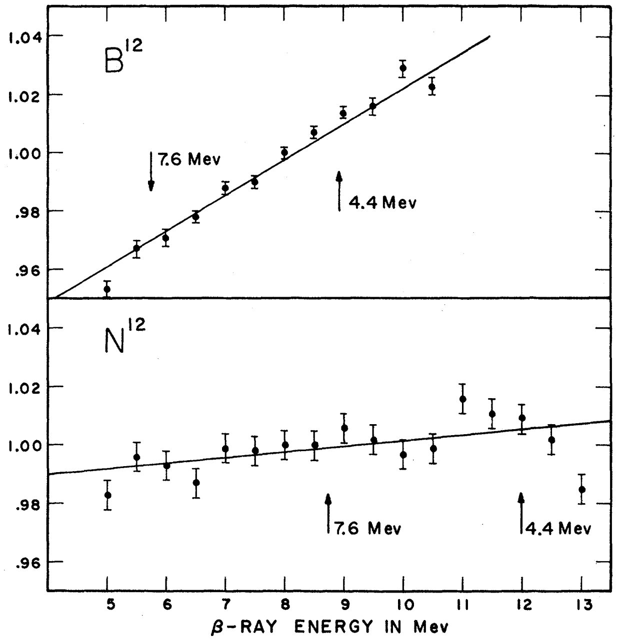

FIG. 2. Plots of the shape factors $S(E,B^{12})/f(E)$ and $S(E,N^{12})$ normalized to unity at 8 Mev. Statistical errors and least-squares fits are given. Branching end points are indicated by arrows. Slopes are 1.29 % per Mev for B^{12} and 0.17% per Mev for N^{12}.

our value for $A+\delta A$ should be increased by 0.12% per Mev. It is interesting that the relatively strong energy dependence of the B^{12} matrix element accounts for the failure of Hornyak *et al.*[10] to observe a B^{12} branch to the 4.4-Mev state of C^{12}, and in fact gives a Fermi plot that is slightly concave downwards.

Previously, Nordberg, Morinigo, and Barnes[11] compared the asymmetries of the beta-alpha angular correlation in the decays of Li^8 and B^8 and also found agreement with the CVC theory. A small discrepancy remains, however, between the muon lifetime and the Fermi coupling constant derived from the O^{14} decay.[12] Possibly this discrepancy is due to a charge dependence of the internucleon potential.[13]

The authors are indebted to Professor T. Lauritsen, Professor C. A. Barnes, Professor W. A. Fowler, Professor H. A. Weidenmüller, and Professor F. Boehm for valuable discussions. Two earlier experiments in this laboratory[14] by H. Hilton and V. Soergel, and H. Hilton and C. Van der Leun provided much of the groundwork which made the present experiment possible. One of us (Mayer-Kuckuk) was supported by Deutsches Bundesministerium für Atomkernenergie.

[†] Work supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

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