Letters to the Editor

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Observations Associated with the Reaction $B^{11}(p,d)$*

EMMETT L. HUDSPETH AND CHARLES P. SWANN
Bartol Research Foundation of The Franklin Institute, Swarthmore, Pennsylvania
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THE bombardment of boron with deuterons leads to the formation of a radioactive isotope which decays with the emission of beta-rays of maximum energy about 0.02 Mev[1] and with a half-life of 0.02 seconds.[2] The reaction involved has been ascribed to $B^{11}(d,p)$. We have recently made certain observations concerned with this reaction, and the results may be summarized as follows:

1. The yield of beta-rays has been obtained as a function of bombarding voltage in the interval from 250 to 1800 kilovolts. The beta-rays were detected by coincidence counters which recorded particles of energies above about 3 Mev. The yield was found to rise rapidly with bombarding voltage up to about 0.6 Mev, as previously observed;[1] beyond this region the rate of change of yield is much smaller, becoming nearly negligible at 1.6 to 1.8 Mev. No resonances of appreciable intensity were observed.

2. The shape of the excitation curve at the lowest bombarding voltages was carefully observed, and the best fit, assuming the Gamow penetration formula and various values of Q, was determined. Over a limited region, it was found that the experimental data corresponded most nearly to $Q=0.1$ Mev. The agreement between the observed and theoretical curve was not so satisfactory in the present case as it had been in the corresponding $Li^7(d,p)$ reaction for which Q was determined by the method just mentioned.[3] It seemed certain, however, that in the $B^{11}(d,p)$ case the value of Q is positive.

3. It appeared from the observations cited above that we might be able to observe the protons from the $B^{11}(d,p)$ reaction directly. We bombarded a thin aluminum foil onto which a thin film of boron had been evaporated. The scattered deuterons and products of transmutation were observed at 90° to the bombarding beam by putting photographic plates inside the vacuum system. With a bombarding voltage of 1.67 Mev, two groups of particles, with mean ranges of 14.3 and 18.9 microns, were observed; the first group corresponds to the scattered deuterons and the second is ascribed to the protons from the reaction. An aluminum foil with no coating was also bombarded, and only the group of scattered deuterons appeared on the plates. From these data, we find $Q=0.15$ Mev, in satisfactory agreement with our previous rough estimate. Using other mass values tabulated by Bethe,[4] we find that the mass of B^{12} is 12.01927, with a tentatively estimated error of 0.00004 mass units. This indicates a mass difference between B^{12} and C^{12} of 14.5 Mev; the end point of the beta-ray spectrum of B^{12} is about 12 Mev,[1,5] which indicates that C^{12} may be left in an excited state of about 2.5 Mev.[6]

4. A search has been made for beta-gamma-coincidences. The beta-rays were detected with two counters and the gamma-rays with a third counter; all three of the counters fed into a triple coincidence circuit. We have evidence for a beta-gamma-coincidence rate which would verify the above possibility, but work is continuing toward measuring the energy of the gamma-ray and in extending our other observations. Full details and curves will be published later.

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[1] D. S. Bayley and H. R. Crane, Phys. Rev. **52**, 604 (1937).
[2] R. A. Becker and E. R. Gaerttner, Phys. Rev. **56**, 854 (1939).
[3] L. H. Rumbaugh, R. B. Roberts, and L. R. Hafstad, Phys. Rev. **54**, 657 (1938). The Q-value for the lithium reaction has been more accurately determined by a recent observation of the protons by E. N. Strait, C. G. Stergiopoulos, and W. W. Buechner, Bull. Am. Phys. Soc. **23**, No. 4, 8 (1948).
[4] H. A. Bethe, *Elementary Nuclear Theory* (John Wiley and Sons, Inc., New York, 1947).
[5] F. L. Hereford, Phys. Rev. **74**, 574 (1948).
[6] This possibility has been pointed out previously by M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 327 (1937); see also H. A. Bethe, F. Hoyle, and R. Peierls, Nature **143**, 200 (1939).

On the Light and Heavy Mesons*

J. LEITE LOPES
Faculdade Nacional de Filosofia, University of Brazil, Rio de Janeiro, Brazil
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RECENT calculations by Tiomno and Wheeler show that one can get the right order of magnitude of lifetimes for β-decay of μ-mesons[1] and for the K capture of these mesons by nuclei,[2] if a Fermi coupling is assumed between μ-mesons and leptons[3] as between nucleons and μ-mesons. In these calculations μ-mesons are, of course, assumed to have spin $\hbar/2$. We wish to point out a reasonable interpretation of the so-determined nucleon-μ-meson coupling constant in terms of a nucleon-π-meson coupling assumed to be responsible for nuclear forces. A coupling between the two-meson fields is then required by the μ-decay of heavy mesons[4] and will be of the same nature as the nucleon-π-meson coupling. It has, as a consequence, an interaction between μ-mesons and nucleons analogous to the well-known potential energy of nucleons as deduced from the current meson field theory. We here assume that π-mesons have spin 0 and are described by a pseudoscalar field as suggested by the assumption that π-mesons are responsible for the nuclear forces. This interaction can give rise to the capture of negative μ-mesons by nuclei. The transition probability for the disintegration of a π-meson at rest

$$\pi\rightarrow\mu+\mu_0 \qquad (1)$$