shown in Fig. 1.

Baranger and Meshkov[4] have observed that a determination of the ratios of the stripping reduced widths of the levels of C^{13} can yield information concerning the ground state wave function of C^{14}. Accordingly, these reduced-width ratios have been calculated using those Butler curves yielding the best fits to the experimental

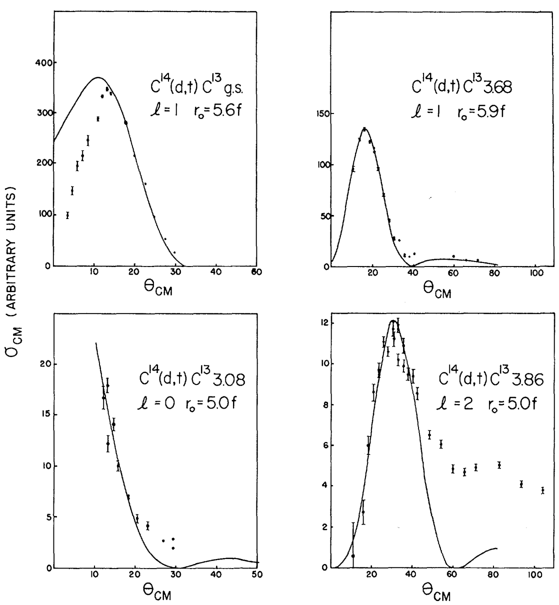

FIG. 1. Angular distributions of tritons from the low-lying states of C^{13}. The parameters r_0 and l are the standard parameters of the Butler theory.

data and are listed in Table I, along with the absolute cross sections for each of the levels observed. The absolute cross sections are calculated by comparison with the values given by McGruer et al.[5] for $C^{12}(d,p)C^{13}$, which are uncertain to ±50%. However, since all of the data were obtained using the same target, relative cross sections are less uncertain.

*Work done in the Sarah Mellon Scaife Radiation Laboratory and assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1]Douglas, Gasten, and Mukerji, Can. J. Phys. 34, 1097 (1956).

[2]F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. 27, 77 (1955).

[3]S. T. Butler and E. E. Salpeter, Phys. Rev. 88, 133 (1952).

[4]E. Baranger and S. Meshkov, following Letter [Phys. Rev. Lett. 1 30, (1958)].

[5]J. N. McGruer, E. K. Warburton and R. S. Bender, Phys. Rev. 100, 235 (1955).

CONFIGURATION MIXING IN THE C^{14} GROUND STATE *

Elizabeth Baranger and Sydney Meshkov
University of Pittsburgh,
Pittsburgh, Pennsylvania.
(Received June 2, 1958).

We wish to present an analysis of recent $C^{14}(d,t)C^{13}$ experiments[1] which indicates that there is considerable configuration mixing in the C^{14} ground state. With a rather arbitrary choice of the C^{14} and N^{14} ground state wave functions, there seems to be enough mixing to produce the required cancellation of the C^{14} to N^{14} beta-decay matrix element, without invoking any tensor force[2].

The levels of C^{13} with which we are concerned are the $\frac{1}{2}+$ level at 3.08 Mev and the $\frac{5}{2}+$ level at 3.86 Mev which belong to the $(1s)^4(1p)^8 2s$ and $(1s)^4(1p)^8 1d$ configurations respectively,[3] as well as the $\frac{1}{2}-$ ground state which arises from the $(1s)^4(1p)^9$ configuration. As shown in the preceding paper,[1] the $C^{14}(d,t)C^{13}$ angular distributions to the ground state, the 3.08-Mev level and the 3.86-Mev level can be fitted with ℓ_n equal to 1, 0, and 2 respectively. Inasmuch as the $C^{14}(d,t)C^{13}$ reaction proceeds via a pickup mechanism, the $0+C^{14}$ ground state must contain admixtures of $(1s)^4(1p)^8(2s)^2$ and $(1s)^4(1p)^8(1d)^2$ to the usual $(1s)^4(1p)^{10}$ configuration.

In order to make a numerical estimate of the amount of admixture, we make use of the experimentally determined reduced widths, θ^2. We take as the C^{14} wave function

$$\Psi(J=0,T=1)=\alpha\Psi_\alpha[(1s)^4(1p)^{10}]+\beta\Psi_\beta[(1s)^4(1p)^8(2s)^2]+\gamma\Psi_\gamma[(1s)^4(1p)^8(1d)^2]. \quad (1)$$

It can be shown that

$$\theta^2=\Omega^2\,\theta_{0,\ell}^2\,N_\Omega \quad (2)$$

where $\theta_{0,\ell}^2$ is the single-particle reduced width, a quantity dependent on the ℓ of the picked-up neutron; $\Omega=\alpha,\beta,$ or γ for the ground state, 3.08-, or 3.86-Mev levels respectively; N_Ω is a number dependent on the coupling modes and can be evaluated by the methods of Auerbach and French[4,5] and of Lane.[6]

The $C^{14}(d,t)C^{13}$ experiments give us the ratios

$$\frac{\theta_{\mathrm{gnd}}^2}{\theta_{3.08}^2} \cong 35 = \frac{\theta_{0,1}^2}{\theta_{0\,0}^2}\frac{\alpha^2}{\beta^2}\frac{N_\alpha}{N_\beta}, \qquad (3a)$$

$$\frac{\theta_{\mathrm{gnd}}^2}{\theta_{3.86}^2} \cong 5.4 = \frac{\theta_{0,1}^2}{\theta_{0,2}^2}\frac{\alpha^2}{\gamma^2}\frac{N_\alpha}{N_\gamma}, \qquad (3b)$$

from which we can obtain β^2/α^2 and γ^2/α^2.

We use values of $\theta_{0,\ell}^2$ obtained from analysis of various (d, p) and (p, d) experiments. The $\theta_{0,\ell}^2$ are not very well established experimentally, and introduce considerable uncertainty in our estimate of the amount of configuration mixing. The best known of these is $\theta_{0,1}^2$ which ranges from 0.045 to 0.060.[7] There are published values of $\theta_{0\,0}^2$ ranging from 0.17 to 0.32 and of $\theta_{0\,2}^2$ ranging from 0.06 to 0.14. We choose the values $\theta_{0,1}^2=0.055$, $\theta_{0,0}^2=0.32$ and $\theta_{0,2}^2=0.11$. The 0.32 and 0.11 values are based on Fairbairn's analysis[8] of the $O^{16}(d,p)O^{17}$ experiments of Burge et al.,[9] and are also the ones used by Halbert and French.[10] They also seem to be in reasonable agreement with unpublished calculations by E. Baranger for the $C^{12}(d,p)C^{13}$ reaction which give $\theta_{0,0}^2=0.28$ and $\theta_{0,2}^2=0.12$.

In addition to choosing $\theta_{0,\ell}^2$ we must also insert into (3) the values of N_α, N_β, and N_γ which depend explicitly on a pricise specification of the C^{13} and C^{14} wave functions. In order to arrive at a first estimate of the configuration mixing we arbitrarily make the following assumptions. We let the C^{12} ground state act as a core for the 2s and 1d particles in both C^{13} and C^{14}, inasmuch as the C^{12} core is a strongly bound system with weak coupling to outside particles.[11] This means that for C^{14} we should treat the $(1s)^4(1p)^8(2s)^2$ and $(1s)^4(1p)^8(1d)^2$ configurations as $(2s)^2$ and $(1d)^2$ with the coupling scheme that of intermediate coupling. For simplicity we treat these configurations in the LS limit, giving $N_\beta=2$ and $N_\gamma=1.2$.

For the $(1s)^4(1p)^{10}$ configuration we assume intermediate coupling with an $(a/K)=5$, where a is the p-shell spin-orbit parameter and K is the p-shell exchange integral. The calculations of Auerbach and French[5] then give $N_\alpha=1.8$.

Using our arbitrary choice of wave functions, $\theta_{0,\ell}^2$ and the experimental θ^2, we obtain

$$\beta^2/\alpha^2=0.0044;\ \delta^2/\alpha^2=0.14. \qquad (4)$$

It should be emphasized that these are very crude numbers which may vary by a factor of two with more careful experimental and theoretical work.

The C^{14} to N^{14} beta-decay matrix element [12] in our coupling scheme is

$$|\textstyle\int\vec{\sigma}|^2 = 6\,|a\alpha[C_3C_1+C_4C_2/\sqrt{3}]+b\beta+c\gamma|^2 \qquad (5)$$

where we have taken the wave function of the N^{14} ground state to be

$$\Psi(J=1,\ T=0)=a\Psi_a[(1s)^4(1p)^{10}]+b\Psi_b[(1s)^4(1p)^8(2s)^2] +c\Psi_c[(1s)^4(1p)^8(1d)^2]. \qquad (6).$$

We have taken

$$\Psi_\alpha=C_1\,{}^{31}S_0+C_2\,{}^{33}P_0 \qquad (7)$$

and

$$\Psi_a=C_3\,{}^{13}S_1+C_4\,{}^{11}P_1+C_5\,{}^{13}D_1\,. \qquad (8)$$

We have not included any contribution in (6) from the (2s,1d) configuration, in agreement with the findings of Standing,[13] who failed to observe any excitation of the $\frac{1}{2}+$ 2.37-Mev level in N^{13} from the reaction $N^{14}(p,d)N^{13}$. He puts an upper limit of 0.03 on the probability of admixture of the (2s, 1d) configuration in the N^{14} wave function. He also puts an upper limit of 0.01 on the ratio b^2/a^2. In view of the value $\beta^2/\alpha^2=0.0044$ obtained in (4), we neglect the term $b\beta$ in (5).

The work of Auerbach and French,[4] who use a Rosenfeld central force mixture together with a spin-orbit interaction and no tensor force, gives $C_1=0.73$, $C_2=0.69$, $C_3=0.19$, $C_4=0.27$, $C_5=-0.95$, for $(a/K)=5$.

Setting (5) equal to zero, and inserting the above values for the C's, we obtain

$$0 = |0.24a\alpha + c\gamma|. \qquad (9)$$

Inasmuch as there is no adequate experimental data on the ratio c^2/a^2, we arbitrarily assume $c=\gamma$ and $a=\alpha$ with signs such that cancellation is produced. It is hoped that information about c^2/a^2 will be forthcoming from $N^{14}(d,t)N^{13}$ experiments now underway at this laboratory.

The above assumptions yield $\gamma^2/\alpha^2=0.24$, a number which, considering the arbitrariness of our wave functions, the uncertainty in the values of $\theta_{0,\ell}^2$, and the error in the determination of the θ^2 ratios from the $C^{14}(d,t)C^{13}$ experiments, is in fair agreement with the value $\gamma^2/\alpha^2=0.14$ obtained from our analysis of the pickup experiments.

Our analysis clearly shows configuration mixing and suggests that this is the source of the vanishing of the C^{14} to N^{14} beta-decay matrix element. A cancellation produced in this way suggests that one can describe the properties of the mass 14 triad using only central and spin-orbit interactions, without invoking any tensor force.

*Work done in the Sarah Mellon Scaife Radiation Laboratory and assisted by the joint program of the Office of Naval Research and the U.S. Atomic Energy Commission.

[1] Moore, McGruer, and Hamburger, preceding Letter [Phys. Rev. Lett, 1, 29 (1958)].
[2] D. R. Inglis, Revs. Modern Phys. 25, 390 (1953).
[3] A. M. Lane, Proc. Phys. Soc. (London) A66, 977 (1953).
[4] T. Auerbach and J. B. French, Atomic Energy Commission Report NYO-3711, February 1, 1955 (unpublished).
[5] T. Auerbach and J. B. French, Phys. Rev. 98, 1276 (1955).
[6] A. M. Lane, Atomic Energy Research Establishment, Harwell Report T/R-1278 (unpublished)
[7] J. B. French (private communication).
[8] W.M. Fairbairn, Proc. Phys. Soc. (London) A67, 564 (1954).
[9] Burge, Burrows, Gibson, and Rotblat, Proc. Phys. Soc. (London) A210, 534 (1951).
[10] E. C. Halbert and J. B. French, Phys. Rev. 105, 1563 (1957).
[11] A.M. Lane, Proc. Phys. Soc. (London) A68, 197 (1955).
[12] Note the positive sign for the factor $1/\sqrt{3}$ in Eq. (5), a sign consistent with the phases of the fractional parentage coefficients of H. A. Jahn and H. Van Wieringen, Proc. Roy. Soc. (London) A209, 502 (1951).
[13] K. G. Standing, Phys. Rev. 101, 152 (1956).

NEUTRONS OF POSSIBLE THERMONUCLEAR ORIGIN*

W. C. Elmore,† E. M. Little, and W. E. Quinn
Los Alamos Scientific Laboratory,
Los Alamos, New Mexico
(Received May 12, 1958)

Published accounts of experiments designed to achieve plasma temperatures of thermonuclear interest have so far made use of the pinch effect. We have succeeded in producing neutrons from a deuterium plasma compressed by a rising axial magnetic field.

Our device, named Scylla, at present employs three single-turn coils having the configuration shown in Fig. 1. The coils, suitably insulated, surround a cylindrical ceramic tube

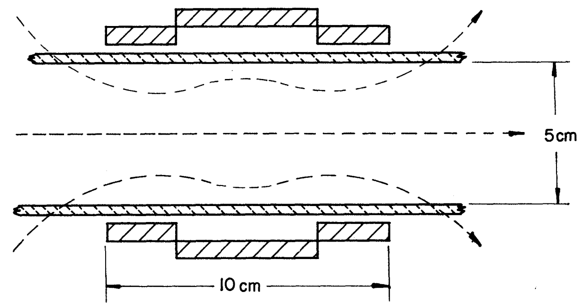

FIG. 1. Section through coils and ceramic tube, with typical magnetic field lines suggested by the broken lines. The set of coils in subsequent designs have been made from a single piece of brass with a common outer radius for the middle and end portions.

through which low-pressure deuterium gas slowly flows. The coils are connected in parallel to a short parallel-plate transmission line leading to an oil-immersed junction connecting with eighty 10-ft lengths of RG-14/U coaxial cable. These cables in groups of eight lead to ten four-element triggered spark gaps[1] each mounted on a low-inductance 0.88-μf capacitor of 100-kv rating.[2] The inductance of the coils is 0.034 μh and of the source 0.038 μh, so that 47% of the capacitor voltage appears initially across the coil terminals.

With the capacitors charged to 70 kv and with no gas present, a circumferential electric field of 1.6 kv/cm exists initially at the tube wall near each end coil. One quarter period (1.25 μsec) later this field has decreased to zero and the central axial magnetic field has risen to about 58 kilogauss.

With gas present, the initial electric field, aided by rf pre-excitation, promptly breaks down the gas and the resulting plasma current sheath is repelled by the current in the coils. The strong shock waves initiated by this mechanism[3] pass through the central region in about 0.1 μsec, ionizing the gas there, and heating the plasma. During the first compression cycle the gas is further heated by reversible adiabatic compression by the rising axial magnetic field and by irreversible joule heating. In Scylla the temperature reached at the first peak compression appears insufficient for the D-D reaction to occur.