also be applied to the results of Anderson, Knox, Quinton, and Bach. The broad energy distribution of heavy fragments may be due to the population of excited states in the residual nuclei. The lack of F, Ne, and heavier fragments follows from the de-excitation picture also. It would otherwise be quite puzzling why transfers from O^{16} to Al^{27} are so probable while transfers the other way are rarer by an order of magnitude, especially in view of the tightly bound structure of oxygen.

It is not the purpose of this paper to demonstrate that complex transfers such as ($p2n$) or ($2p3n$) do not occur, but rather that the existing data can be explained by simpler transfers and subsequent de-excitation of residual nuclei. In any event this mechanism should be considered in the interpretation of heavy-ion reactions.

The author is indebted to Dr. Knox, Dr. Quinton, Dr. Anderson, and Dr. Bach, who graciously allowed him the use of their data before publication, and to Dr. Halbert and Dr. Pinajian for instructive discussions.

---

[*] Operated for the U. S. Atomic Energy Commission by Union Carbide Corporation.

[1] Fisher, Zucker, and Gropp, Phys. Rev. 113, 542 (1959).

[2] Volkov, Pasiuk, and Fliorov, Zhur. Eksptl. i Teoret. Fiz. 33, 595 (1957) [translation: Soviet Phys. JETP 6, 459 (1958)].

[3] Karnaukhov, Ter-Akopian and Khalizov, Zhur. Eksptl. i Teoret. Fiz. 36, 748 (1959) [translation: Soviet Phys. JETP 9, 525 (1959)].

[4] Anderson, Knox, Quinton, and Bach (private communication).

[5] R. Kaufmann and R. Wolfgang, Phys. Rev. Letters 3, 232 (1959).

[6] J. J. Pinajian, Bull. Am. Phys. Soc. 4, 219 (1959).

[7] V. I. Goldansky, Nuclear Phys. 9, 551 (1958).

[8] M. L. Halbert and A. Zucker, Phys. Rev. 108, 336 (1957).

BETA-ALPHA ANGULAR CORRELATIONS IN B^8 AND Li^8[†]

M. E. Nordberg, B. Povh,[*] and C. A. Barnes
Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California

(Received December 10, 1959)

It has been suggested by Bernstein and Lewis[1] that a comparison of the β-α angular correlations in the isotopic spin triplet of mass 8 (Li^8, Be^8, B^8) might lead to a test of the conserved vector current theory of β decay.[2] These authors assumed $\Gamma(M1) = 0.15\ \Gamma_W$, where Γ_W is the Weisskopf unit, as a probable width for the $M1$ decay of the $J = 2^+$, $T = 1$ Be^8 state (analog state of the Li^8 ground state) to the $J = 2^+$, $T = 0$ state of Be^8. Taking the observed[3] near-isotropy of the β-α angular correlation in Li^8 as indicating the near cancellation of the various possible forbidden corrections to the predominantly allowed Li^8 β transition,[4] Bernstein and Lewis predicted a β-α angular correlation in B^8 as follows:

$$W(\theta) \approx 1 \pm 0.1 P_2(\cos\theta) \approx 1 \pm 0.15 \cos^2\theta.$$

We have measured the β-α angular correlations in Li^8 and in B^8 and have found that the difference in the angular correlations is probably not greater than 1/4 of the predicted difference.

In the present experiment Li^8 was produced by bombarding thin targets of natural lithium with 0.75-Mev deuterons, and B^8 was produced by bombarding thin targets of enriched Li^6 (99.7% Li^6) with He^3 ions of 3.15 Mev. The bombarding beams were allowed to strike the target for 0.4 second and then interrupted by a mechanical chopper. After a delay of 0.1 second the electronic circuits were switched on for 0.4 second. The cycle repeated after a further delay of 0.1 second.

The β rays were detected in a 3-in. deep plastic scintillator, which could be rotated around the target axis between 90° and 180° with respect to a fixed, silicon surface-barrier, α detector. A "slow-fast" coincidence system was used with a time resolution of 35 mμsec for the Li^8 experiment, and 80 mμsec for the B^8 measurements. The random to real coincidence ratios were, respectively, 0.06 and < 0.01 for the Li^8 and B^8 runs. Pulses from the α detector were displayed on a 100-channel analyzer, when a fast coincidence was recorded during the proper counting part of the cycle, and when the β-ray pulse lay between limits selected by a single-channel analyzer.

The coincident α spectrum was displayed in this way, in order to evaluate the energy loss of the α particles in escaping from the target. This information is necessary, since the α particles coincident with 180° β rays are shifted upwards in energy by recoil from the β rays and neutrinos, and this energy shift makes the laboratory solid angle of the α counter larger than the center-of-mass solid angle by an amount which depends on the β-ray energy, and original energy of the α particle in the center-of-mass system. For $E_\alpha \simeq 1.5$ Mev, and $E_\beta > 9.7$ Mev, this solid angle correction is $\simeq 10\%$. The ratio of solid angles is

$$\Omega_{\text{c.m.}}/\Omega_{\text{lab}} \simeq 1 - 2V_{\text{recoil}}/V_\alpha$$

$$\simeq 1 - (\bar{E}_\beta - \tfrac{1}{3}\bar{E}_\nu)/86.4(E_\alpha)^{1/2},$$

where we have assumed the axial-vector β interaction,[4] and the energies are in Mev. It should be noted that the solid angle corrections are similar in the Li^8 and B^8 runs, so inaccuracies in making these corrections tend to cancel in the ratio of the two angular correlations. The coincident α spectra are shown in Figs. 1 and 2. The singles (noncoincident) α-particle, and β-ray counts were recorded at the two angles of the β-ray counter and used to correct the ratio of coincident counts at 180° to the coincident counts at 90°. In the Li^8 runs the target surface was at 45° with respect to the incident beam as in Fig. 1. This meant that absorption in the 2-mil aluminum target backing was the same for both positions of the β counter. Under these conditions the corrections made to the coincidence ratio for inequalities in the singles rates were $< 1.5\%$.

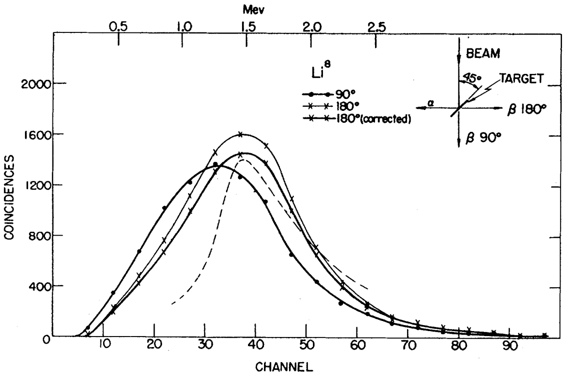

FIG. 1. α spectra in coincidence with β rays at 90° and 180° in the β decay of Li^8. The curve marked 180° (corrected) has been corrected for solid angle effects as discussed in the text. The dashed curve is the thin-target α spectrum obtained by R. T. Frost and S. S. Hanna, Phys. Rev. 99, 8 (1955), for comparison purposes.

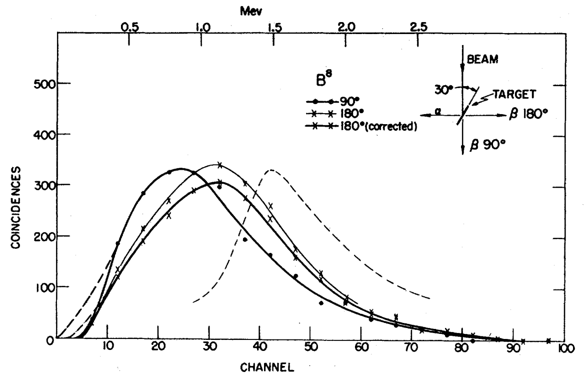

FIG. 2. α spectra in coincidence with β rays at 90° and 180° in the β decay of B^8. The dashed extrapolations to zero pulse size, represent a possible correction for coincidence inefficiency below channel 10, as described in the text.

The higher compound nucleus recoil velocity in the $Li^6(He^3,n)B^8$ reaction at 3.15 Mev caused the α particles to lose an excessive amount of energy in escaping from the target, when the target was placed at 45° to the beam direction. With the target plane at an angle of 20° to the beam, the singles rates gave a 6% correction to the coincidence rates, while a target angle of 30° to the beam gave a singles correction $< 3\%$. There is also a possibility that inefficiencies in the electronic circuits were causing a loss of α particles from the spectra below channel 10. This alters the 90° spectrum more than the 180° spectrum because of the energy shift of the 180° spectrum due to recoil from the β rays. The dashed extrapolations shown in Fig. 2 probably represent better estimates of the α spectra.

The results are summarized in Table I where the errors quoted are statistical only.

If the results of Hanna et al.[3] are corrected for solid angle on the basis of the axial vector interaction, rather than on the basis of the tensor interaction, then believed correct, they yield $W(\theta) \simeq 1 + 0.03(\pm 0.03)\cos^2\theta$ for Li^8 in close agreement with the present work.

The present results suggest that the ratio, $(I_{180°}/I_{90°})_{Li^8}/(I_{180°}/I_{90°})_{B^8}$, is 1.02 ± 0.04, where the error quoted is statistical only, to be compared with the predicted value, 1.15 or 0.85. The failure to observe the expected large asymmetry could be due either to the failure of the conserved vector current theory, or to an unusually small $M1$ matrix element. Experimental and theoretical attempts to estimate the $M1$ matrix element are in progress. If it is the case

Table I. Summary of measured asymmetries in the β-α angular correlations of Li^8 and B^8.

β decay and E_β	Target angle to beam	Corrected $I_{180°}/I_{90°}$
Li^8, $E_\beta > 9.7$ Mev	45°	1.03 ± 0.02
Li^8, 3.8 Mev $< E_\beta < 6.1$ Mev	45°	1.03 ± 0.02
Li^8, $1.5 < E_\beta < 3.8$ Mev	45°	1.05 ± 0.02
B^8, $E_\beta > 9.7$ Mev	30°	1.02 ± 0.03
B^8, $E_\beta > 9.7$ Mev	20°	1.00 ± 0.05
B^8, $E_\beta > 9.7$ Mev	30°	1.00 ± 0.03[a]

[a] Using the dashed extrapolations in Fig. 2.

that the $M1$ matrix element is anomalously small, then the present experiment would not be a suitable method for testing the conserved vector current hypothesis, since there are probably other corrections of the order of a few percent which could mask the expected anisotropy,[5] for example, a term proportional to the $E2$ matrix element.

The authors would like to acknowledge their indebtedness to Professor W. A. Fowler, Professor T. Lauritsen, and Dr. H. Weidenmuller for their advice and interest in this experiment.

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

[*] Present address: The Institute "J. Stefan," Ljubljana, Yugoslavia.

[1] J. Bernstein and R. R. Lewis, Phys. Rev. 112, 232 (1958).

[2] R. P. Feynman and M. Gell-Mann, Phys. Rev. 109, 193 (1958); M. Gell-Mann, Phys. Rev. 111, 362 (1958); E. C. G. Sudarshan and R. E. Marshak, Phys. Rev. 109, 1860 (1958); S. S. Gershtein and J. B. Zeldovich, Zhur. Eksptl. i Teoret. Fiz. 29, 698 (1955) [translation: Soviet Phys. JETP 2, 576 (1957)].

[3] Hanna, LaVier, and Class, Phys. Rev. 95, 110 (1954); D. StP. Bunbury, Phys. Rev. 90, 110 (1953).

[4] Lauritsen, Barnes, Fowler, and Lauritsen, Phys. Rev. Letters 1, 326 (1958); Barnes, Fowler, Greenstein, Lauritsen, and Nordberg, Phys. Rev. Letters 1, 328 (1958).

[5] M. Morita, Phys. Rev. 113, 1584 (1959).

DECAY OF OXYGEN 20†

Gertrude Scharff-Goldhaber
Brookhaven National Laboratory, Upton, New York

and

Albert Goodman and Myron G. Silbert
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

(Received December 2, 1959)

It is of considerable theoretical interest to discover the decay of the isotope O^{20} and its properties. Jarmie and Silbert,[1] by studying the energies of the protons produced in the reaction $O^{18}(t,p)O^{20}$, were able to deduce for the energy difference $Q(O^{20} \rightarrow F^{20}) = 3.75$ Mev. However, earlier attempts[2-4] to search for the decay of the isotope have been unsuccessful. Katcoff and Hudis[3] were able to exclude a half-life of $10 \text{ min} \leq \tau_{1/2}(O^{20}) \leq 150$ yr with reasonable certainty, and Amiel and Segel[4] showed that $\tau_{1/2} \leq 30$ to 50 sec.

We studied the decay of O^{20} produced by 2.66-Mev tritons from the 3-Mev Los Alamos Van de Graaff in an O^{18} (95% enriched) gas target. As detector for the γ rays we used a scintillation spectrometer. The front face of a 3 in. × 3 in. NaI(Tl) crystal was placed about 4 in. from the