counts and coincidence counts were recorded for 20-minute periods with alternating directions of the magnetic field in the analyzer. Averages were taken over runs of about 10 hours. The results of about 20 runs are statistically consistent. The relative difference in coincidence counting rates for opposite magnetic field directions is found to be $(0.73\pm0.09)\%$. The efficiency of our analyzer given in reference 1 has recently been checked over a wide energy region using bremsstrahlung of P^{32} electrons. If the polarization of these electrons is v/c, as indicated by other experiments,[6] the calculated efficiencies are correct within about 5%. The observed coincidence difference corresponds to a value of $+0.33\pm0.04$ for the asymmetry parameter A defined in reference 1.

The Sc^{46} decay scheme is accepted as being $4^{+}(\beta^{-})4^{+}(\gamma)2^{+}(\gamma)0^{+}$ on the basis of precise γ-γ[7] and β-γ[8] angular correlation measurements and ft values.[7,9] The parameter A can then only have values between 0 and 0.08, if there is no interference term as in the case of a pure V,T and a pure S,A interaction. This cannot be reconciled with our large experimental value. Specifically,[2] our experiment shows that

$$\left|\frac{\mathrm{Re}(C_SC_T'^*+C_S'C_T^*-C_VC_A'^*-C_V'C_A^*)}{|C_T|^2+|C_T'|^2+|C_A|^2+|C_A'|^2} + \frac{\alpha Z}{p}\,\frac{\mathrm{Im}(C_SC_A'^*+C_S'C_A^*-C_VC_T'^*-C_V'C_T^*)}{|C_T|^2+|C_T'|^2+|C_A|^2+|C_A'|^2}\right| > 0.5,$$

$$\alpha Z/p \simeq 0.14.$$

The present result therefore indicates that the β interaction contains at least a combination of S and T, or of V and A interactions.

The present experiment together with the longitudinal electron polarization measurement on this isotope by Frauenfelder *et al.*[10] can be explained by the two-component neutrino theory, assuming a mixture of T with comparable amounts of S and V interaction, or by assuming that in Fermi interactions $C'\approx 0$.[2]

We thank Professor R. Feynman and Professor M. Gell-Mann, and particularly Dr. K. Alder, Dr. B. Stech, and Dr. A. Winther for many illuminating discussions, and Professor J. W. M. DuMond for his interest in this work.

* Supported by the U. S. Atomic Energy Commission.
† On leave of absence from the Institute for Nuclear Research, Amsterdam, and the Technical University, Delft.

[1] F. Boehm and A. H. Wapstra, Phys. Rev. **106**, 1364 (1957).
[2] Alder, Stech, and Winther, Phys. Rev. **107**, 728 (1957) report, University of Illinois (unpublished).
[3] Ambler, Hayward, Hoppes, Hudson, and Wu, Phys. Rev. **106**, 1361 (1957).
[4] Postma, Huiskamp, Miedema, Steenland, Tolhoek, and Gorter, Physica **13**, 259 (1957).
[5] D. F. Griffing and J. C. Wheatly, Phys. Rev. **104**, 389 (1956).
[6] H. Frauenfelder *et al.* (private communication); H. de Waard *et al.* (private communication).
[7] Nuclear Level Schemes and Nuclear Data Cards, National Research Council, Washington, D. C.
[8] T. B. Novey (private communication).
[9] It may be added that a spin 5 for the Sc^{46} ground state would give a negative value of A,[2,10] as in the case of Co^{60}.[1]
[10] Frauenfelder, Bobone, von Goeler, Levine, Lewis, Peacock, Rossi, and DePasquali, Phys. Rev. **107**, 910 (1957).

Parity in Nuclear Reactions*

NEIL TANNER
Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California

(Received June 26, 1957)

THE failure of parity conservation recently observed in β decay has raised the question of how accurately parity is conserved in nuclear reactions. A quite sensitive test is to be found in certain (p,α) reactions which are rigorously forbidden by angular momentum and parity conservation. The particular case that has been studied is the 340-kev resonance of $F^{19}(p,\alpha)O^{16}$ which proceeds through a $J=1$, even parity state[1] of Ne^{20}. Normally the state decays by the α_1 group to the 6.14-Mev level of O^{16}, but a parity "impurity" in the wave functions of either the Ne^{20} excited state or O^{16} or He^4 ground states would allow a resonant α_0 group to the ground state of O^{16}. This group would appear in the cross-section curve as a resonance superimposed on the nonresonant yield[2,3] from broad states of Ne^{20}. In principle the resonant cross section can have a term proportional to the amplitude of the wave function impurity, due to interference between resonant and nonresonant processes. However, this term is zero if the spin of the proton or F^{19} nucleus is not aligned parallel to the proton momentum. The leading term is then proportional to the square of the impurity amplitude and can be written as $\sigma_{\alpha 0}=(\Gamma_{\alpha 0}/\Gamma_{\alpha 1})\sigma_{\alpha 1}$, where $\sigma_{\alpha 0}$ and $\sigma_{\alpha 1}$ are resonant cross sections for the (p,α_0) and (p,α_1) reactions, and $\Gamma_{\alpha 0}$ and $\Gamma_{\alpha 1}$ are the partial widths for α_0 and α_1 decay of the compound state of Ne^{20}. Both resonant reactions are isotropic as the state of Ne^{20} is formed by s-wave protons.

Measurements have been made of the yield of $F^{19}(p,\alpha_0)O^{16}$ in the region of the 340-kev resonance, using AlF_3 targets of thickness comparable with the resonance width of 3 kev. Counts were taken at both 0° and 90° with a CsI scintillation counter subtending a solid angle of 0.1 of a sphere. Scattered protons and short range α particles were excluded by absorbing foils.

Figure 1 shows a typical yield curve of $F^{19}(p,\alpha_0)O^{16}$, corrected for s-wave barrier penetrability, together with the yield of γ radiation from $F^{19}(p,\alpha_1\gamma)O^{16}$. This curve indicates an upper limit of 2% for a $F^{19}(p,\alpha_0)O^{16}$ resonance relative to the nonresonant yield. A slightly better limit was obtained by a series of counts at the $(p,\alpha_1\gamma)$ resonance energy and 6 kev above and below. The mean of the counts either side of the resonance agreed within the statistical error of 1% with the counts taken at the resonant energy. After correcting for target

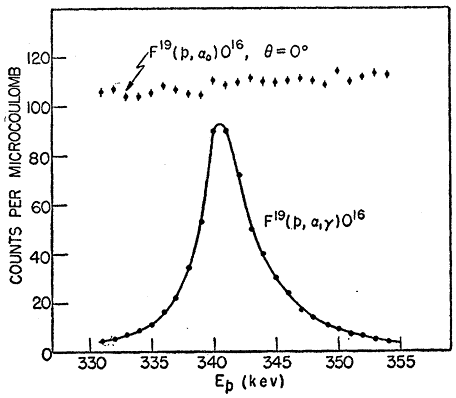

FIG. 1. Yield curve of $F^{19}(p,\alpha_0)O^{16}$, corrected for *s*-wave barrier penetrability, together with the yield of γ radiation from $F^{19}(p,\alpha_1\gamma)O^{16}$.

thickness and the angular distribution of the nonresonant yield,[3] a limit of 2% could be placed on the ratio of resonant to nonresonant cross sections. The latter was measured as 2 ± 1 μb at 340 kev, which appears to agree with the work of Streib, Fowler, and Lauritsen.[2] Thus the resonant (p,α_0) reaction has a cross section $\sigma_{\alpha0}\lesssim4\times10^{-2}$ μb. This is related to the $(p,\alpha_1\gamma)$ cross section by $\sigma_{\alpha0}/\sigma_{\alpha1}=\Gamma_{\alpha0}/\Gamma_{\alpha1}$, and putting $\sigma_{\alpha1}=10^5$ μb,[1] and $\Gamma_{\alpha1}=3$ kev[4] gives $\Gamma_{\alpha0}\lesssim1.2\times10^{-6}$ kev. Extracting an energy dependence of the form $2kR/(F^2+G^2)$, as used by Baranger,[5] gives a reduced width of $\lesssim1.5\times10^{-7}$ kev.

Reduced α-particle widths for nine nearby states of Ne^{20} have been tabulated by Baranger[5] and approximate values for other states can be obtained from the experimental widths given by Barnes[6] and others.[1,2,4] Several of the states, *viz.*, $F^{19}+p$ resonances at 669, 780, 840, and 1092 kev, have remarkably small reduced widths which suggest isotopic spin $T=1$.[6] Neglecting these supposed $T=1$ states, (the large α_1 width[5] of the 340-kev $F^{19}+p$ resonant state appears to label it as $T=0$), there remain forty values for reduced widths with a mean of about 40 kev and with a distribution such that about 80% of the reduced widths are greater than 4 kev. While there is no guarantee that the distribution is even approximately representative of the α-particle reduced widths of states of Ne^{20}, it is the only information available.

If a "probable" reduced α-particle width is taken as $\gtrsim4$ kev, then the parity selection rule inhibits the α_0 decay of the Ne^{20} state, corresponding to the 340-kev $F^{19}+p$ resonance, by a factor $\lesssim4\times10^{-8}$. This suggests that the wave functions of the Ne^{20} excited state and O^{16} and α-particle ground states have no odd-parity component greater than 2×10^{-4} of the even-parity component, and therefore that the nuclear interaction conserves parity at least to within 2 parts in 10^4.

I am indebted to R. E. Pixley for assistance with the experimental measurements.

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

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **27**, 77 (1955).
[2] Streib, Fowler, and Lauritsen, Phys. Rev. **59**, 253 (1941).
[3] McLean, Ellett, and Jacobs, Phys. Rev. **58**, 500 (1940); E. Gerjuoy, Phys. Rev. **58**, 503 (1940).
[4] Webb, Hagedorn, Fowler, and Lauritsen, Phys. Rev. **99**, 138 (1955).
[5] E. U. Baranger, Phys. Rev. **99**, 145 (1955).
[6] C. A. Barnes, Phys. Rev. **97**, 1226 (1955).