with the annihilation of B_1 and after the fermion has emitted B_2, the Fermi particles are annihilated with the emission of B_3. A second way in which this process can take place is obtained if the antifermion emits B_2. The triangles in the two cases differ only in the directions of the Feynman arrows.

The only difference in the matrix elements for the two transitions is that the first one contains the trace of the matrix

$$X=X_1(p_1-m)^{-1}X_2(p_2-m)^{-1}X_3(p_3-m)^{-1},$$

while the second contains the trace of the matrix

$$X'=X_1(-p_3-m)^{-1}X_3(-p_2-m)^{-1}X_2(-p_1-m)^{-1},$$

where p_i are appropriate functions of the energy-momentum four-vectors of bosons and Fermi particles combined with γ_μ according to Feynman. The minus signs of p_i in X' occur in the usual way when the behavior of fermions is contrasted with that of antifermions.

By Eq. (1)

$$X'^T=(-)^r CXC^{-1},$$

where r of the matrices X_i satisfy Eq. (1) with the minus sign. Taking the traces of the matrices makes it at once evident that the contributions of the two processes cancel each other if r is odd.

Other contributions to the total matrix element are obtained by permuting the processes involving B_i, which means orienting the triangle in different ways with respect to the time direction. These contributions can similarly be grouped into pairs.

For the sake of simplicity we have considered a triangular loop, but it is obvious that the above argument can be generalized for any closed loop. Hence, we have Furry's theorem for transitions between neutral bosons: processes associated with closed loops which can be traversed in opposite directions are forbidden if an odd number of odd Dirac matrices are associated with that closed loop.

Analogous selection rules can be formulated for the case where the bosons in Eq. (2) are neutral and charged mesons. In this case, to every way in which a transition can take place, there corresponds a second way which is obtained by replacing in the Feynman triangle, protons (neutrons) by antineutrons (antiprotons) or vice versa.

Let the contribution of the first process depend on the trace of

$$X=X_1\tau_i(p_1-m)^{-1}X_2\tau_j(p_2-m)^{-1}X_3\tau_k(p_3-m)^{-1},$$

where τ_i $(i=1, 2, 3)$ are the isotopic spin matrices. The contribution from the second process then contains

$$X'=X_1\tau_1\tau_i\tau_1(-p_3-m)^{-1}X_3\tau_1\tau_k\tau_1(-p_2-m)^{-1}\times X_2\tau_1\tau_j\tau_1(-p_1-m)^{-1},$$

where the introduction of τ_1 effects the above replacements. Since

$$\tau_1\tau_i{}^T=\tau_i\tau_1 \quad (i=1, 2),$$
$$\tau_1\tau_3{}^T=-\tau_3\tau_1,$$

it follows that

$$X'^T=(-)^{r+s}CXC^{-1},$$

where r denotes the number of odd matrices among X_i $(i=1, 2, 3)$, and s the number of neutral mesons.

This result can be generalized as follows for transitions between neutral and charged mesons via nucleons: Transitions between charged and neutral mesons associated with reversible closed nucleon loops are forbidden if the sum of the number of odd Dirac interaction matrices and the number of neutral mesons is odd.

The first theorem plays a fundamental role in a process like vacuum polarization. The second theorem will apply in cases where, for instance, a heavy charged meson decays into a lighter charged meson and a neutral one. Thus far no such decay process has been observed.

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[4] The γ-matrices are defined as in reference 1.

Disintegration of He³ by Fast Neutrons*

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THE large cross section found to exist for the $He^3(n,p)T$ reaction at thermal neutron energy[1-3] indicates that this reaction may be investigated with relative ease for fast neutrons. Such an investigation has been carried out using techniques similar to those previously described.[2]

A proportional counter having a known sensitive volume was filled with a 31.4-cc sample of pure He^3 to which was added Kr at suitable pressure. Nearly monenergetic neutrons were produced at various energies in the range from 0.4 to 3.0 Mev by use of the two reactions: $T(p,n)He^3$ and $D(d,n)He^3$. The number of disintegrations induced in the He^3 by these neutrons was measured with the counter and neutron source located in well-defined geometry.

The absolute number of neutrons entering the counter was determined by use of a "long counter,"[4] the sensitivity of which was calibrated against the half-gram Ra-Be source No. 44 whose neutron source strength has been measured by Walker.[5]

The disintegration pulses were sorted by a 10-channel pulse-height analyzer. For the determination of the total number of disintegrations the pulse-height distribution curves were extrapolated (using an estimation of "wall effect") to zero pulse height, and the area under the curve was obtained numerically. The area under the extrapolated portion ranged from 20 to 45 percent of the total. It is estimated that the uncertainty of the extrapolation may introduce errors of from 15 to 20 percent in the cross-section determinations.

Measured cross-section values are indicated by the circles plotted in Fig. 1. The estimated probable error, including a guess

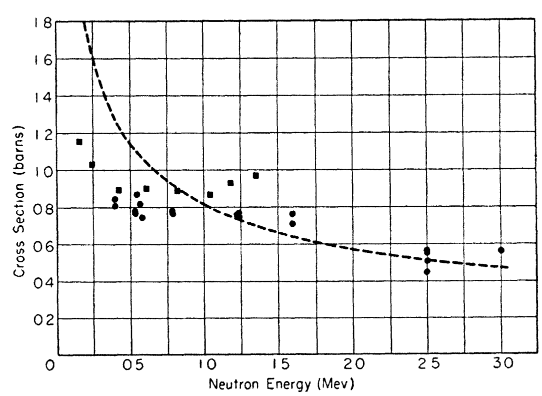

FIG. 1. Cross section for the reaction $He^3(n,p)T$ as a function of neutron energy. Directly measured values are indicated by circles. Values deduced by detailed balancing from measurements of the inverse reaction are indicated by squares. The solid curve is deduced by the $1/v$-law.

of systematic errors, is ±30 percent. For comparison, the $1/v$-law dependence is shown as a dashed curve, though it it not to be expected that the data follow such a dependence. The results of King and Goldstein[3] for neutron absorption in the thermal region were used to deduce the $1/v$-curve.

The data of Jarvis, *et al.*[6] for the cross section of the inverse reaction, *viz.* $T(p,n)He^3$, may be compared with the present measurements by the principle of detailed balancing. The squares in Fig. 1 indicate values deduced from their data. Within experimental errors the two sets of values agree.

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