of $\rho$ at 1 bev is equal to 9, no longer agreeing with the experiment.

We have carried out a calculation of $\rho$ on a statistical theory[4]. In the calculation we have included both the production of pions via the isobaric state and direct production. The relative importance of the two processes is determined only by statistical weights. It is assumed that at these energies in the reaction $Be^9 + p$, the incoming proton interacts with each of the nucleons of the nucleus as if it were free.

Let us examine first the situation when the energy of the incoming protons is equal to 1 bev. Then only the following processes are important: $NN$, $NN'$, $NN\pi$ ($N$ – nucleon, $N'$ – isobaric state). These correspond to elastic scattering, excitation of one isobar and direct production of one meson. These processes are easily calculated by the formulas given by Belinfante[4]. Simple calculations yield 5 for the value of $\rho$. At a proton energy of 2.3 bev, besides processes producing 1 or 2 mesons, 3 meson production has some importance. This corresponds to the processes $N'N'\pi$, $NN'\pi\pi$ and $NN\pi\pi\pi$. Evaluation indicates, however, that these reactions occur in only 4 to 5% of all collisions. The calculation of $\rho$ at 2.3 bev yields 1.8, agreeing exactly with the experimental result.

We have calculated, likewise, values of $\rho$ for intermediate energies. These are as follows:

| $E$ | $\rho$ |
|---|---|
| 1 | 5 |
| 1.46 | 2.7 |
| 1.75 | 2 |
| 2.3 | 1.8 |

Thus, both the value of $\rho$ and its dependence on energy agree with the calculation according to the statistical theory, in which is included both direct production of $\pi$ mesons and their creation via isobaric states. Inclusion in the statistical theory only of direct production of mesons given at 1 bev, $\rho = 3.5$ and at 2.3 bev, $\rho = 2.7$.

In conclusion, I am grateful to Professor C. E. Belen'kii for cricticism of this work and for valuable suggestions.

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180

## Numerical Values of the Constant of the Triplet Beta-Interaction

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THE ratio of the constants of the two elementary interactions leading to allowed beta-transitions can be estimated from experimental data[1,2] which have appeared in recent times. We shall employ nonrelativistic terminology and call these interactions singlet (Fermi selection rules) and triplet (Gamow-Teller rules).

In the general case of a mixed transition the $ft$ value found from experimental data is connected with the interaction constants by the equation

$$ft\left[\frac{M_0^2}{A_0}+\frac{M_1^2}{A_1}\right]=1, \qquad (1)$$

where $M_0$ and $M_1$ are the nuclear matrix elements for the singlet and triplet interactions; the universal times $A_0$ and $A_1$ are inversely proportional to the squares of the interaction constants $G$:

$$A=\frac{2\pi^3 \ln 2\, \hbar^7}{m_0^5 c^4 G^2}=\frac{1.2\cdot 10^{-94}}{G^2}. \qquad (2)$$

For a pure process $A = ftM^2$.

The nuclear matrix elements $M_0$ for the singlet interaction are found theoretically. For this, no other assumptions are required besides that of charge invariance. The latter is violated only at the expense of a distortion of the nucleon wave functions by the Coulomb field. For the triplet interaction the nuclear matrix elements $M_1$ can be found theoretically only for pure states.

Because of the indicated reasons only the singlet constant can be found directly from the $ft$ value for a pure process. For the singlet interaction it was found directly from the decay of $O^{14}$ that $A_0 = ftM_0^2 = 6550 \pm 150$ sec.

For processes going by a pure triplet interaction the matrix elements are unknown. Therefore, one has to turn to mixed transitions for an estimate of the triplet constant. An exact value of the matrix element $M_1$ is known only for the free neutron, whose lifetime has been measured with very low accuracy. But we can give an accurate upper limit of the quantity $A_1$ in those transitions for which an upper limit of $M_1^2$ is known. The beta decay of triton yields the extreme of such estimates. On the basis of detailed calculations[3] one can assume that here $M_1$ cannot be greater than three. The value $ft = 1014 \pm 20$ sec has been obtained from very precise measurements[2].

From this we obtain that $A_1 \leq 3600$ sec. This upper limit practically coincides with the very lower limit which can be derived from the lifetime of the free neutron measured by Robson[4] with a quoted error of ±18%. Evidently, the errors of measurement specified by Robson[4] are to be regarded as probable errors in the statistical sense, but not as outer limits of the error of measurement. Apparently, the actual error of these measurments[4] is larger, inasmuch as $M_1^2$ for triton must be less than three.

Thus, it turns out that the lifetime of the free neutron, at the precision with which it is known at present, yields practically nothing for the determination of the constant of beta-decay.

A lower limit for $A_1$ can at present be obtained only from astrophysical data. Among all the possible models of the sun, the pure hydrogen-helium model gives the lowest rate of heat production. In addition to this, the total heat production is provided by the hydrogen cycle, whose rate is determined by the triplet beta-process $H^1+H^2=H^2+e^2+\nu$.

This is the only beta-transition for which the matrix element can be calculated accurately from theory, which has been done by Frieman and Motz[5] and also by Salpeter[6]. The observed energy production of the sun is provided by the hydrogen cycle alone with $A_1 = 2060$ sec, which can be regarded as a lower limit of the quantity $A_1$.

Thus, the value of $A_1$ must lie inside the limits

$$3600 \geq A_1 \geq 2060 \text{ sec},$$

and the ratio of the constants $R = G_1^2/G_0^2 = A_0/A_1$ is between the limits $3.18 \geq R \geq 1.82$.

All theories that require equality of the constants[7,8] are thus completely eliminated.

It should be emphasized that the present discussion is not about statistical errors but about upper and lower limits. Hence, the half-life of the free neutron must lie within the limits $600 \geq t \geq 370$ sec.

We can likewise estimate limits within which the values of $M_1^2$ for the simplest beta-transitions must lie. By substituting the experimental $ft$ values, the known values of $M_0^2$ and $A_0$, and the limiting values of $A_1$ into (1), we obtain

| | $ft$ | $M_0^2$ | | |
|---|---|---|---|---|
| $He^6 - Li^6$ | 815 | 0 | $4.4 \geqslant M_1^2 \geqslant 2.5$ | (6) |
| $H^3 - He^3$ | 1014 | 1 | $3.0 \geqslant M_1^2 \geqslant 1.7$ | (3) |
| $N^{13} - C^{13}$ | 4700 | 1 | $0.22 \geqslant M_1^2 \geqslant 0.12$ | (1/3) |
| $O^{15} - N^{15}$ | 3750 | 1 | $0.41 \geqslant M_1^2 \geqslant 0.25$ | (1/3) |
| $F^{17} - O^{17}$ | 2420 | 1 | $1.0 \geqslant M_1^2 \geqslant 0.52$ | (7/5) |
| $Be^7 - Li^7$ | 2547 | 1 | $0.87 \geqslant M_1^2 \geqslant 0.49$ | (5/3) |
| $Be^7 - Li^{7*}$ | 3590 | 0 | $1.00 \geqslant M_1^2 \geqslant 0.56$ | (4/3) |

For comparison, the reduced values of $M_1^2$ for the nearest pure states are given in parentheses.

The cited limits do not include the experimental error, which, however, is small for these transitions: in all cases the error in $ft$ does not exceed 3%.

For $N^{13}$ and $F^{17}$ our estimates of $M_1^2$ differ markedly from the estimates cited in the literature[9,10], which were derived from magnetic moments.

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164

## Consideration of the Nuclear Quadrupole Moment in Electron Scattering

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AT the present time many experiments have been carried out on the elastic scattering of electrons by nuclei. In this connection, it is of interest to estimate the influence on this effect of the nuclear