alpha particles[7,8] may be possible.

I am indebted to Dr. M. H. Macfarlane, Dr. B. J. Raz, and Dr. B. Zeidman for discussions and suggestions in connection with this work, to W. J. O'Neill for technical assistance, and to W. Ramler and the cyclotron group for their cooperation.

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†Work performed under the auspices of the U. S. Atomic Energy Commission.

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POSSIBILITY OF A TEST OF THE CONSERVED VECTOR CURRENT THEORY IN THE $A=8$ POLYAD*

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(Received February 23, 1960)

The measurement of the β-α angular correlation function in the beta decay of Li^8 and B^8 has been proposed[1] as a test of the conserved vector current theory (C.V.C.T.) of beta decay.[2] In order to interpret recent experimental information,[3] a knowledge of the unknown $M1$ and $E2$ transition probabilities for the transition from the first $J=2$, $T=1$ state in Be^8 to the first excited state ($J=2$, $T=0$) is necessary.[4] It is especially interesting to know how much of the $M1$ transition probability in question is due to the spin part of the magnetic moment operator since only that part gives an enhancement of the corresponding second forbidden matrix element in beta decay, compared to the prediction of the Fermi theory (F.T.).

This Letter reports on an attempt to determine the quantities of interest by an intermediate-coupling calculation.[5] The over-all agreement of Kurath's[6] results with the experimental level scheme in the $A=8$ polyad, his calculation of the $M1$ widths of the 17.6-Mev state[7] in Be^8, and especially the close agreement of his calculation[8] of the magnetic moment of Li^8 with observation seem to encourage such an attempt.

Using the standard notation as defined in reference 6, we carried through the calculation for force mixtures of the Serber, Kurath, and Rosenfeld types, for values of L/K between 5.3 and 8.3 and of a/K between 0 and 5. We calculated the energy spectrum for $J=2$ states, the magnetic moment of Li^8, the $\log ft$ of the beta decay, the $M1$ and the $E2$ transition amplitudes, and corrections to the magnetic moment and the $M1$ amplitude. These corrections are due to the presence of spin-orbit and exchange forces and have to be introduced in order that the Hamiltonian be gauge-invariant.[9,10] It is hoped that the calculation of these corrections provides an order of magnitude estimate of unknown terms in the magnetic moment operator, such as exchange moments, etc.

The relative position of the low-lying $J=2$ states obtained with the three different types of forces and different values of L/K differ very little from each other over the whole range of a/K if one adopts the scale parameter K properly. The attempt to fit simultaneously the magnetic moment and $\log ft$ fails the Serber forces. This is due to the fact that these forces produce a very strong admixture of $[31]D$ states to the $J=2$, $T=1$ state (which in L-S coupling is $[31]^3P$). These states contribute considerably to the magnetic moment and very little to the beta transition. This result is in agreement with the observation that one cannot reproduce the level scheme of Li^6 using Serber forces. We will therefore not consider Serber forces in the following.

The spread of the other curves obtained for μ, logft, and the $M1$ amplitude when plotted versus a/K is surprisingly small and confirms the reliability of the estimate. Since the operator for the beta decay seems to be much better known than the magnetic moment operator, we tried to fit[11] log$ft = 5.7$ by choosing a/K properly.[12] In this way one obtains for each set of parameters a prediction of the magnetic moment. The deviations of these numbers from the observed value exceed in no case 20%. The range of values of a/K for such a fit is 1.25, ... 2.50, in agreement with Kurath's calculations. From these values of a/K and the calculated curves for $\Lambda(M1)$, the transition strength in the definition of Lane[12] as shown in Fig. 1, one obtains $0.40 \leq \Lambda(M1) \leq 0.50$, or for the $M1$ width 3 ev $\leq \Gamma(M1) \leq$ 4 ev.

Figure 2 shows the composition of the $M1$ matrix element for a typical case, $L/K = 6.8$ and Kurath force mixture. In this case, the a/K value which fits logft is 2.00. The matrix element is defined so that $\Lambda(M1) = \frac{3}{5}\langle \| M1 \| \rangle^2 = 0.5$ in this case. Only the isovector part of the magnetic moment operator,

$$\vec{\mu}_v(i) = (e\hbar/2Mc)[-\tfrac{1}{2}\tau_z^{(i)}\vec{l}(i) + \tfrac{1}{2}\tau_z^{(i)}(\mu_n - \mu_p)\vec{\sigma}(i)],$$

contributes to the transition, and one sees that orbital and spin part give contributions with the same sign and similar in magnitude. This statement holds approximately for all cases calculated. The dashed line indicates the value one obtains for the $M1$ matrix element if one neglects the anomalous moments, i.e., replaces $\vec{\mu}_v$ by $(e\hbar/2Mc)[-\frac{1}{2}\tau_z^{(i)}\vec{l}(i) - \frac{1}{2}\tau_z^{(i)}\vec{\sigma}(i)]$.

The smallness of the spin-contribution can be easily understood by the observation that the final state is in pure L-S coupling a $[4]^1D$ state. For $a/K = 2.5$ the admixtures of other states are very small (largest admixture 15% in amplitude). Since the $J = 2$, $T = 1$ states do not contain the symmetry class [4], the operator $(\sigma\tau)$ has vanishing matrix elements between any of the $T = 1$ states and the $[4]^1D$ state. This statement does not hold, however, for the orbital part of the operator. For later use we note that

$$3.2 \leq \langle \| l \| \rangle / \langle \| \sigma \| \rangle \leq 4.13,$$

and also that Λ varies practically as the square of a/K and is therefore extremely sensitive to this choice. If one chooses slightly higher values for a/K, one obtains bigger Λ's and a larger predicted asymmetry in the β-α angular correlation. At the same time, however, one would predict a larger Gamow-Teller matrix element than observed.

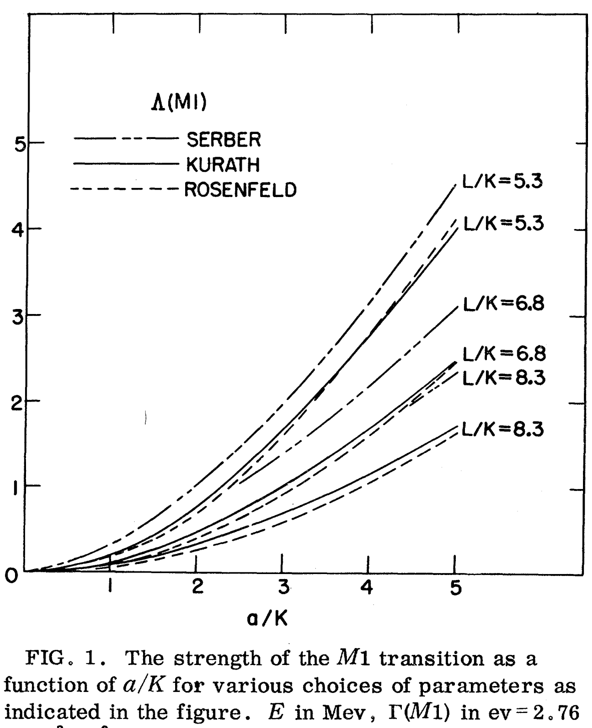

FIG. 1. The strength of the $M1$ transition as a function of a/K for various choices of parameters as indicated in the figure. E in Mev, $\Gamma(M1)$ in ev $= 2.76 \times 10^{-3} \times E^3 \times \Lambda(M1)$.

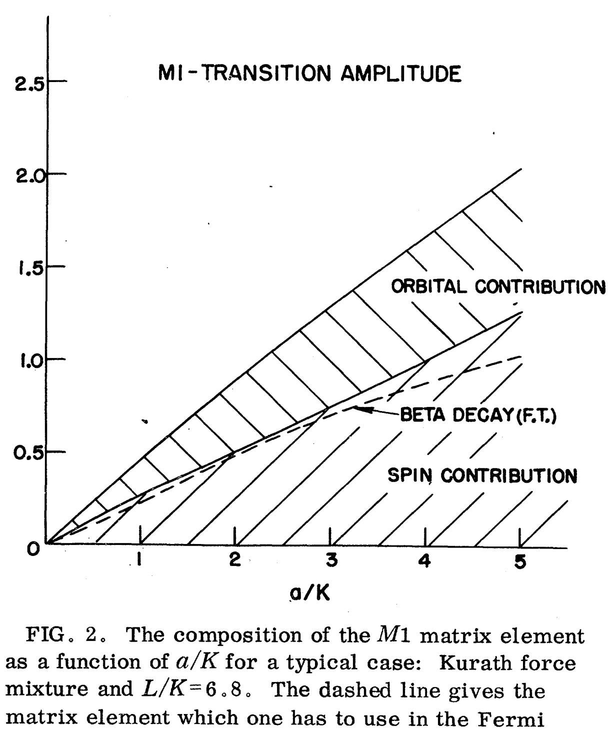

FIG. 2. The composition of the $M1$ matrix element as a function of a/K for a typical case: Kurath force mixture and $L/K = 6.8$. The dashed line gives the matrix element which one has to use in the Fermi theory of beta decay; the uppermost line (the total $M1$ amplitude) gives the matrix element in the conserved vector current theory.

As an order of magnitude estimate of additional contributions to the $M1$ transition amplitude and the magnetic moment of Li^8, the contributions due to the presence of a spin-orbit-coupling term in the Hamiltonian were calculated. The magnetic dipole operator corresponding to this term is given in reference 9:

$$\vec{\mu}_{\rm add}(i)=\frac{e\hbar\gamma}{2Mc}\,\tfrac{1}{2}(1-\tau_z^{(i)})\left\{\left(\vec{\sigma}_i\cdot\frac{\vec{r}_i}{r_i}\right)\frac{\vec{r}_i}{r_i}-\vec{\sigma}_i\right\}.$$

Here, $\gamma=aM\langle r^2\rangle/\hbar^2\approx-\frac{1}{2}$ for $a=-2.5$ Mev. This gives a correction of +10% at $a=-2.5$ Mev, +25% at $a=-5$ Mev to the magnetic moment and of -15% at $a=-2.5$ Mev, -25% at $a=-5$ Mev to the $M1$ amplitude. This is within the uncertainty of our fit. It changes, however, the above statement to $1.6\leq\langle\|l\|\rangle/\langle\|\sigma\|\rangle\leq 5.0$. No attempt was made to estimate the contribution due to exchange forces[10] since there are radial integrals involved on which the expression seems to depend sensitively and about which no information is available.

For the parameters of interest, calculation of the ratio of the transition strengths for the $E2$ and $M1$ transitions gave values smaller than 6×10^{-4}. Here, as in the preceding estimate of γ, we assumed $\langle r^2\rangle=\frac{1}{2}\times10^{-25}$ cm^2. The actual value of the ratio of the reduced matrix elements depends, however, very sensitively on the parameters used; in particular, it can be positive or negative.

With this information we are now in a position to discuss the prediction of the β-α angular correlation functions in B^8 for F.T. and C.V.C.T., assuming zero anisotropy in the Li^8 correlation function. One obtains the following results.

(a) Fermi theory:

$$W(\theta,\text{F.T.})=1-0.008\frac{\langle\|l+\sigma\|\rangle}{\langle\|\sigma\|\rangle}P_2(\cos\theta)\frac{P^2}{WW_0}\left\{1+2\frac{\langle\|E2\|\rangle}{\langle\|l+\sigma\|\rangle(\frac{3}{5})^{1/2}}-1.44\frac{\langle\|i\rho_1[3\sigma_ix_k+3x_i\sigma_k-2(\vec{\sigma}\cdot\vec{r})\delta_{ik}]\|\rangle}{(\frac{3}{5})^{1/2}\langle\|l+\sigma\|\rangle}\right\},$$

where the reduced matrix elements $\langle\|O\|\rangle$ are dimensionless quantities.

(b) Conserved vector current theory:

$$W(\theta,\text{C.V.C.T.})=1-0.008\frac{\langle\|l+4.7\sigma\|\rangle}{\langle\|\sigma\|\rangle}P_2(\cos\theta)\frac{P^2}{WW_0}\left\{1+0.56\frac{\langle\|E2\|\rangle}{(\frac{3}{5})^{1/2}\langle\|l+4.7\sigma\|\rangle}\right\}.$$

Here, W_0 is the maximum, W the actual energy of the electrons in units $\hbar=c=m=1$, P their momentum. In both cases the quantities in brackets have a small energy dependence, which for practical purposes, however, can be neglected.

We know from our calculation that $\langle\|l+\sigma\|\rangle/\langle\|\sigma\|\rangle\approx1.6,\ldots5$; $\langle\|l+6.7\sigma\|\rangle/\langle\|\sigma\|\rangle\approx6,\ldots9.5$; and $\langle\|E2\|\rangle/|\langle\|l+\sigma\|\rangle(\frac{3}{5})^{1/2}|\lesssim 0.03$.

If we neglect the $E2$ terms in both expressions for the moment, we obtain

$$W(\theta,\text{F.T.})=1+\alpha P_2(\cos\theta),$$

where $-0.04\leq\alpha\leq-0.01$,

$$W(\theta,\text{C.V.C.T.})=1+\alpha P_2(\cos\theta),$$

where $-0.08\leq\alpha\leq-0.05$.

This is to be compared with an experimental finding of $\alpha\approx(-1.5\pm3)\%$, where the quoted error is purely statistical, and includes no estimates of possible systematic errors.[3] This result favors the F. T. over the C.V.C.T., though not strongly.

In conclusion it must be stressed, however, that the $A=8$ polyad does not seem well suited for a critical test of the C.V.C.T. because of the large contribution of the orbital angular momentum operator to the $M1$ transition amplitude, and because of the well-known fact that our estimate of the $E2$ amplitude may be too small by a factor of three or even ten.

The author would like to thank Mr. E. Nordberg and Mr. F. Morinigo for their help in the numerical calculation. He is greatly indebted to Professor C. A. Barnes, Professor F. Boehm, and Professor R. F. Christy for discussions and to Professor B. Stech of Heidelberg University for communications. The assistance and interest of Barbara Zimmermann in preparing the program for diagonalizing the matrices is gratefully acknowledged. It is a pleasure to thank the Kellogg Radiation Laboratory for its hospitality.

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

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R PARAMETER IN p-p SCATTERING AT 142 MEV

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(Received February 23, 1960)

As part of the Harwell program on nucleon-nucleon scattering a measurement has been made of the Wolfenstein R parameter in proton-proton triple scattering at 142 Mev.

The proton beam whose direction of polarization was vertical, and for which $P_1 = 0.46 \pm 0.01$, was passed along the axis of a solenoid of such integrated field strength that the proton spins were rotated into the horizontal plane. The direction of horizontal polarization could be reversed by reversing the direction of the magnetic field in the solenoid. The beam was then focussed by a quadrupole pair on to a 6-inch long liquid hydrogen target.

The horizontal transverse polarization of protons scattered at angle θ in the horizontal plane (i.e., in the plane containing the direction of polarization and the incident vector) was then measured by scattering in the up-down plane from targets of beryllium of analyzing power P_3. Protons scattered up and down were detected in two two-counter telescopes placed in coincidence with a counter immediately in front of the beryllium analyzer. Altogether ten counter telescopes were used, which allowed measurements to be made at five different scattering angles θ simultaneously, in a self-monitoring system. The asymmetry RP_1P_3 in the scattering from the beryllium analyzers was determined by comparison of the counting rates in a given counter telescope for the two directions of solenoid field (or proton spin).

The over-all analyzing power P_1P_3 was determined by moving each telescope to $\theta = 0$ and reducing the energy of the beam with an absorber so that it corresponded to the energy of protons scattered from the hydrogen target at the appropriate angle θ.

The R experiment, particularly when it is self monitoring and performed with a solenoid, is very little subject to systematic errors. There is, however, one serious possibility for error which arises from the focussing properties of the solenoid for protons. It is necessary to position the solenoid extremely carefully so that the mean position of the beam at the hydrogen target does not move appreciably when the solenoid current is reversed. In the present experiment, the movement was not more than 0.2 mm, which called for corrections much less than the final standard errors on all the measurements.

As a final check on the systematic errors in the measurements, the experiment was repeated with an unpolarized incident beam, and the asymmetries were found to be consistent with zero in this case.