symmetric form, leaving unaltered the interaction between two symmetrically coupled particles, this will affect only negligibly the binding energies of the highly symmetric H^3 and He^4 nuclei,[3,6] but it produces a large change (arising of course exclusively from the antisymmetrically coupled pairs of particles) in the energy matrix of Be^9. The simple $(1s)^4(2p)^5$ term mentioned does not describe a bound state of Be^9 at all with the symmetric form of (1), and while this lends weight to the view[7] that the purely charge-symmetric interaction is not an admissible one either, it is not conclusive. To investigate more closely the binding predicted by this interaction for light nuclei, more states, mixed configurations, and wave functions made more flexible by the introduction of different oscillator-parameters into the different single-particle states must be considered. To this end formulas generalizing integrals of Elliott[5] and Talmi[8] have been developed.

In calculations with many-parameter oscillator wave functions, for central, tensor, or spin-orbit terms, the radial integrals are always of the form

$$\int_0^\infty \int_0^\infty r_1^{L_1} r_2^{L_2} \exp(-\nu_1 r_1^2 - \nu_2 r_2^2) f_k(r_1, r_2) r_1^2 dr_1 r_2^2 dr_2; \qquad (2)$$

where L_1, L_2, k are integers of the same parity (L_1, L_2 both $\geqq k$), the ν's arise as sums of the oscillator parameters, and the f_k's are defined by

$$\sum_{k=0}^{\infty} f_k(r_1, r_2) P_k(\cos\omega) = V(r), \quad [r^2 = r_{12}^2 = r_1^2 + r_2^2 - 2r_1 r_2 \cos\omega], \quad (3)$$

with $V(r)$ the distance-dependence of the interaction (divided by r^2, for tensor force terms[5]).

Then, on putting $\nu_1 = \sigma^{-2}$, $\nu_2 = \tau^{-2}$, $L_1 + L_2 = 2L$, Eq. (2) can be written

$$\sigma^{L_1+3} \tau^{L_2+3} \sum_{l=0}^{L} \varphi_l\{L_1, L_2, k; \tau/\sigma\} I_l(1/[\sigma^2+\tau^2]),$$

where

$$I_l(\tfrac{1}{2}\nu) = N_l^2(\tfrac{1}{2}\nu) \int^\infty r^{2l+2} \exp(-\tfrac{1}{2}\nu r^2) V(r) dr, \qquad (4)$$

$$N_l^2(\tfrac{1}{2}\nu) = 1 \Big/ \int_0^\infty r^{2l+2} \exp(-\tfrac{1}{2}\nu r^2) dr,$$

and

$$\begin{aligned} &\varphi_l\{L_1, L_2, k; \tau/\sigma\} \\ &= \pi(2k+1) \frac{(\frac{1}{2}[\sigma^2+\tau^2])^{L+2}}{(2\sigma)^{L_1+2}(2\tau)^{L_2+2}} \sum_{g=0}^{[k;l]} (-1)^g \frac{(2l+1)!!}{(2l-2g+1)!!} \\ &\quad \times \sum_{p=g}^{k} \binom{k+p}{k} \binom{k}{p} \binom{p}{g} \sum_{n=2p-2g}^{2L-2g+2} C_{L_1+1-p,\, L_2+1-p}(2g-2p+n) \\ &\quad \times \sum_{s=0}^{[\frac{1}{2}n;\, L-l]} (2l+1-2g-2s)!!(2s-1)!! \\ &\qquad \binom{n}{2s} \left(\frac{\sigma^2-\tau^2}{\sigma^2+\tau^2}\right)^{n-2s} \left(\frac{2\sigma\tau}{\sigma^2+\tau^2}\right)^{2s}. \end{aligned} \qquad (5)$$

Here $P!! = P(P-2)(P-4)\cdots 5\cdot 3\cdot 1$; $(-1)!! = 1$; and

$$\binom{Q}{R} = Q!/(Q-R)!R!;$$

$C_{A,B}(N)$ = coefficient of t^N in the expansion of $(1+t)^A(1-t)^B$; and $[a; b]$ denotes (the integral part of) the lesser of a and b. ($\frac{1}{2}n$ is the only possibly nonintegral term.)

An important special case of Eq. (5) is

$$\begin{aligned} \varphi_l\{L_1, L_2, k; 1\} &= \pi(2k+1) 2^{-2L-4} \sum_{g=0}^{[k;l]} (-1)^g \frac{(2l+1)!!}{(2l-2g+1)!!} \\ &\quad \times \sum_{p=g}^{[k;\, L-l+g]} \binom{k+p}{k} \binom{k}{p} \binom{p}{g} \sum_{m=p-g}^{L-l} C_{L_1+1-p,\, L_2+1-p} \\ &\quad \times (2g-2p+2m)(2L+1-2g-2m)!!(2m-1)!!. \end{aligned}$$

(This expression subsumes the results of Elliott and Talmi.)

The functions I_l of (4) have been evaluated explicitly for several types of distance-dependence by Talmi.[8] For a Yukawa-type distance-dependence, the $V(r)$ in (3) is of the form $\exp(-r/r_c)/(r/r_c)$ for the central force and of the form $\exp(-r/r_t)/(r/r_t)^3$ for the tensor force. The I_l's can be most conveniently expressed in this case by single Hh functions,[9] which were used by Elliott, who also pointed out that the coefficient of the divergent tensor force term [i.e., (4) when $l=0$] always vanishes in the complete matrix.[5] (This result is independent of the distance-dependence used.) For an interaction which is constant when $0 \leqq r \leqq r_0$, say, and of Yukawa type when $r > r_0$, (4) can be expressed as a sum of Hh functions, and such an expression has been used in preliminary calculations with an interaction possessing a finite hard core.

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Formation and Decay of Mo^{93m} †

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THE even-odd nuclide Mo^{93m} was produced by the (p,n) reaction on Nb^{93} in irradiations with the Princeton University cyclotron.[1] Our excitation function shown in Fig. 1 differs

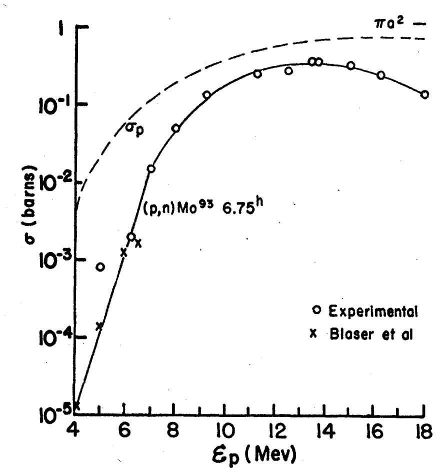

FIG. 1. Excitation function of $Nb^{93}(p,n)Mo^{93m}$ reaction. The σ_p-curve is theoretical.

slightly from that of Boyd and Charpie[2] but is in agreement with the curve obtained by James.[3] A search was made for the long-lived ground state of Mo^{93}, but only a lower limit to the half-life of several years could be assigned.

Additional evidence for the decay of Mo^{93m} by isomeric transition was obtained by studying the associated x-rays. These K x-rays were established as originating from Mo by critical absorption measurements, by a difference of 17.2 kev in K and L conversion electrons from the 262-kev gamma-ray, and by measurements on a bent-crystal x-ray spectrometer at the University of California Radiation Laboratory.

The internal conversion electrons were examined on the precision 180° beta-ray spectrometer of Dr. E. P. Tomlinson at

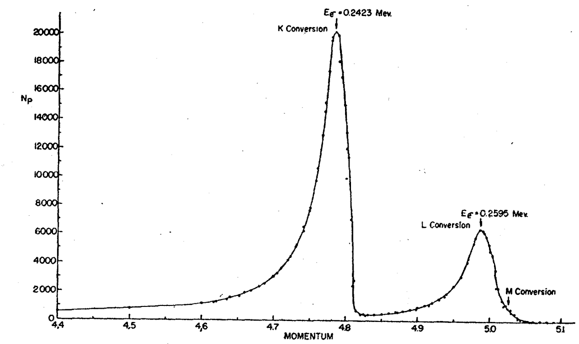

FIG. 2. K, L, M conversion of 0.2622-Mev gamma-ray of Mo^{93m}.

Princeton University. The spectrum obtained is shown in Figs. 2, 3, and 4 and agrees substantially with other results.[1,4] Our measured K/L ratio of 3.09 ± 0.06 for the 262-kev gamma-ray may be compared with values of 2.9 ± 0.2,[4] 2.8 ± 0.3,[5] and 2.79 ± 0.15.[1] Alburger has reported the total conversion coefficient of the 262-kev gamma-ray as $N_{e^-}/N_\gamma=0.7$.[5] Using our measured K/L ratio and the ratio of the numbers of K electrons in the three conversion lines, K conversion coefficients may be calculated for the three gamma-rays in cascade. Using these calculated K electron conversion coefficients and the new K/L ratio for the 684-kev gamma-ray, an attempt was made to assign the multipole order and type of transitions involved. Goldhaber's classification of K/L ratios[6] and the theoretical conversion coefficients of Rose *et al.*,[7] were used. We assign an $M1$ type transition to the 684-kev gamma-ray and $E2$ or $M1$ type to the 1479-kev gamma-ray. The results are summarized in Table I.

TABLE I. Gamma-ray transitions of Mo^{93m}.

E_{e^-} (Mev)	$E\gamma$ (Mev)	Ratio of K electrons	$\alpha_K=N_{e^-K}/N\gamma$	K/L	Type of transition
0.2423 } 0.2595 }	0.2622	1	0.53	3.09 ± 0.06	$E4$[a]
0.6640	0.6842	$(4.8\pm1)\times10^{-3}$	$(1.5\pm0.3)\times10^{-3}$	$8.0\ \pm1.$	$M1$
1.459	1.479	$(7.8\pm1.6)\times10^{-4}$	$(2.4\pm0.5)\times10^{-4}$	—	$E2$ or $M1$

[a] See reference 6.

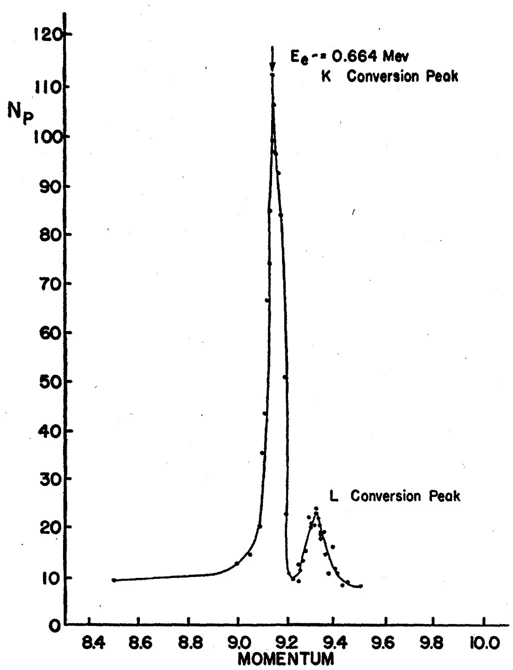

FIG. 3. K, L conversion of 0.6842-Mev gamma-ray of Mo^{93m}.

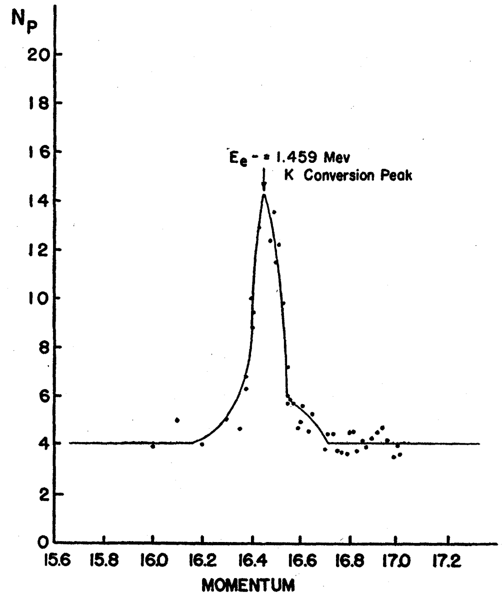

FIG. 4. K conversion of 1.479-Mev gamma-ray of Mo^{93m}.

Goldhaber has suggested that Mo^{93m} is an example of "core isomerism" with the three-step isomeric transition going $8+\rightarrow 4+\rightarrow 2+\rightarrow 0+$.[8] This leads to assignments of $E4$ to the 262-kev transition and $E2$ to the 684-kev and 1479-kev transitions.[9] The α_K value only for the 1479-kev transition cannot distinguish between $E2$ and $M1$ for this transition but is closer to the expected $E2$ value.

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9 The calculated values of α_K and K/L for the 684-kev transition are 1.7×10^{-3} and 8, respectively, if the transition is $M1$ as assigned here, or 2.1×10^{-3} and 12, if it is $E2$.

Interference Terms of the Electron-Neutrino Angular Correlation

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WE have deduced the electron-neutrino angular correlation functions $\mathfrak{W}$ in the allowed and first forbidden transition of beta-decay for the Fermi theory. The interaction Hamiltonian is assumed to be a linear combination of five relativistic invariants

$$H_\beta=\lambda_S S+\lambda_V V+\lambda_T T+\lambda_A A+\lambda_P P.$$

Although there exist several arguments bearing on the determination of the interaction types,[1] we shall take only the well-known Fierz conditions which exlude mixtures of S and V or T and A.