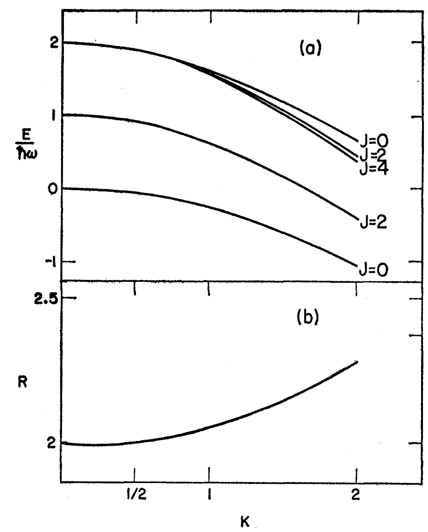

FIG. 3. (a) The energy levels as a function of the coupling strength K. $K=0.67[(\hbar^2/2B)/\hbar\omega]^{\frac{1}{2}}k$, where B denotes the mass parameter and k the coupling parameter. (b) $R=E_2/E_1$, where E_1, E_2 denote the energy above the ground state of the first and second 2+ state respectively. The anharmonic terms are not included.

and simplicity, the outer nucleons are taken as $(f_{7/2})^4$, and $E(J=2, s=2)=3\hbar\omega$, $E(J, s=4)\sim 6\hbar\omega$.[12] The choice of other, perhaps more realistic conditions, does not appear to change the qualitative conclusions. In addition, it is necessary to increase the mass parameter B by a factor 5 to fit the experimental data.[13] The results of the calculations of the energy levels are shown in Fig. 3. For the range of coupling strength shown, the intensity rules are found to be essentially the same as in the zero-coupling case, with the exception that a weak $M1$ component is introduced. The $E2$ transition probability between the first 2+ state and the ground state also remains nearly the same; for zero coupling the ratio of the transition probability to that given by the simple shell model is:

$$\mathfrak{M}(\text{coll})/\mathfrak{M}(\text{shell})=\left[\frac{9}{16\pi^2}Z^2\left(\frac{\hbar^2/2B}{\hbar\omega}\right)R^4\right]\bigg/\left(\frac{1}{25}R^4\right)\sim 25,$$

where $\hbar^2/2B=0.008$ Mev, $\hbar\omega=0.75$ Mev, $Z=40$.

The addition of possible anharmonic terms affects the position of the energy levels. Reasonable assumptions result in effects opposite to that of the coupling between the core and the particles and of similar magnitude. Hence, superposition of anharmonic terms and coupling does not affect the general agreement with the empirical results, although it may change the sequence of the triplet levels.

These ideas are proving valuable for the interpretation and construction of decay schemes. However, the existence of the triplet of levels together with the natural extension of the intensity rules for all these levels need further examination.

Although it seems difficult to explain the great uniformity of the pattern without a collective model approach, it would be interesting to study the alternative interpretation in terms of a shell model. The electromagnetic intensity rules I and II would follow directly from seniority considerations.[9] It is conceivable that the simple behavior of E_2/E_1 could be obtained, and moderate speed-up factors of the $E2$ transition probability are possible for suitable mixing.

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First-Forbidden Nonunique Beta Spectra in Re^{186}†

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THE anomaly of the isotropic β-γ angular correlation[1] and the apparent[2] alpha shape of the first inner beta group in Re^{186} led us to an examination of the beta spectrum in coincidence with the 137-kev gamma. Six-mm-diameter samples of Re^{186} (10 $\mu g/cm^2$) volatilized onto 100-$\mu g/cm^2$ aluminum backing, containing <0.1 percent Re^{188}, were measured in the double-lens spectrometer at a transmission of 6 percent with a resolution of 6 percent. Gammas were counted at 3 percent geometry in NaI(Tl) crystal 1 in. behind the sample, and betas with a 1-mm-thick×11-mm-diameter anthracene disk, using 24-in. Lucite light guides and DuMont 6292 photomultipliers. Amplified shaped pulses were counted in fast ($2\tau_F=0.12$ μsec) coincidence and then in slow coincidence ($2\tau_F=2.6$ μsec) with the output of single-channel gamma and beta pulse analyzers set to accept only the 137-kev gamma photopeak (and higher energy gammas) and to reject beta noise. The beta photomultiplier was cooled to $-80°C$.

Considerable effort was devoted to ascertaining the efficiency for measuring coincidences. A long low tail on the beta pulse amplitude distribution (due to backscattering from anthracene) extended into the noise region, leading to a small (1.4 percent) loss in coincidence efficiency at the lowest energy observed, 148 kev. Real/chance >10 for all points below 760 kev. The

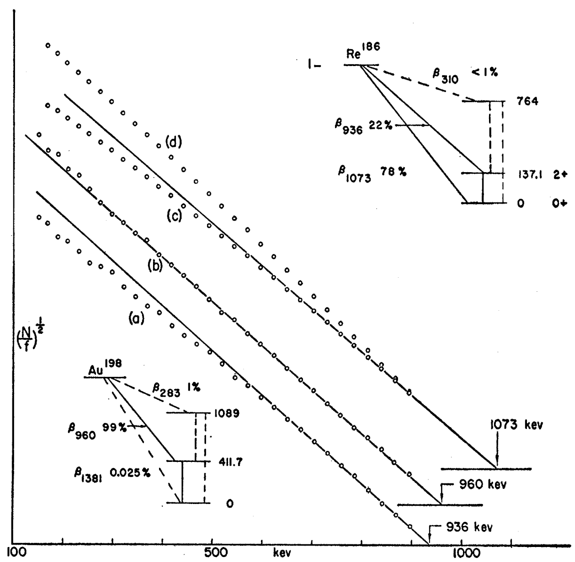

FIG. 1. Kurie plots of: (a) Re^{186} coincidence spectrum; (b) Au^{198} coincidence spectrum; (c) Re^{186} ground-state transition by subtraction; (d) Re^{186} total singles spectrum.

resolving time and its small dependence on beta energy were determined with independent Re^{186} sources to ± 5 percent and monitored during the 70-hr experiments at frequent intervals. Six to eight complete spectra constituted each experiment, accumulating *ca* 4000 coincidences at each point. Corrections were made for finite resolving times of the analyzers and slow coincidence circuits and for other small (0.1 percent) effects. The magnetic spectrometer resolution correction was made by using constants derived from the profile of the 137-kev K line.[3] Figure 1(a) exhibits the Kurie plot calculated with shielding-corrected Fermi function.

To illustrate the performance of the coincidence spectrometer, Fig. 1(b) shows the Kurie plot of Au^{198} taken in coincidence with the 411-kev gamma, under conditions identical in all respects save that the gamma pulse amplitude was lowered slightly below that of the Re^{186} 137-kev gamma by reducing the light collection efficiency. The volatilized sample (70 $\mu g/cm^2$) contained <0.5 percent Au^{199}. The 300-kev component in Au^{198} accounts for the magnitude of the upturn below 300 kev.

Comparison of the Re^{186} results with the allowed experimental (coincidence and singles) shape for Au^{198} shows a downward deviation below 500-kev amounting to 13 ± 2 percent reduction in the momentum spectrum at 300 kev and clearly not of the alpha type. A slight upturn below 300 kev may be due to the weak 300-kev group.[4] $E_0=936$ kev, in excellent agreement with the ground state E_0 of 1074 kev[2] and the gamma energy[5] of 137.1 ± 0.2 kev.

We have also observed (not illustrated) the same downward deviation in Re^{186} using a low-pressure proportional-counter beta detector, which produces smaller pulses with increasing beta energy, opposite to the behavior of the scintillation detector.

We have observed an angular anisotropy of the 137-kev gamma with 500-kev betas $[W(180°)-W(90°)/W(90°)=+0.08\pm0.02]$, and are now determining its energy dependence which is needed to obtain the true "isotropic" shape from the observed coincidence beta spectrum, owing to the restricted range of beta and gamma detection angles employed. Thus we present no values for "shape" factors as yet.

Ignoring this small correction (<2 percent), we subtract the observed coincidence spectrum from the singles spectrum [Fig. 1(d)], normalizing so as to secure $E_0=1073$ kev $(936+137)$, and the resultant ground-state curve [Fig. 1(c)] shows a shape similar to the inner group and a relative abundance of 78 ± 2 percent.[6]

The only spin assignment for Re^{186} consistent with the similar ft values and shapes for the two prominent beta branches and with the small but definite beta-gamma angular anisotropy as $1-$, in agreement with the conclusions of Koerts,[4] who found, however, an allowed shape for the inner group in coincidence.

Together with the cases of RaE,[7] whose curvature is in the opposite direction, and Sb^{124},[8] observable only from 2.32 to 1.60 Mev, these confirm the existence of first-forbidden nonunique spectral shapes. In agreement with theoretical predictions a beta-gamma angular anisotropy is associated with an energy-dependent shape factor, contrary to two cases, Rb^{86} and Tm^{170},[9,10] in which even larger correlations are found with allowed shapes.

† Based on work performed under the auspices of the U. S. Atomic Energy Commission.

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