variations. The apparatus did not permit either counter to be moved azimuthally about the beam axis and it has been arbitrarily assumed that such a correlation is azimuthally isotropic. An experiment to check this point will be undertaken. The ratio of 3.95-Mev cross-over transitions to 1.64-Mev transitions, corrected as described, was 4.3±0.8%.

Since both transitions can be $M1$, the 3.95-Mev transition would be 14 times as intense as that for the 1.64 Mev if the energy-cubed law alone governed. Recently Elliott[2] has proposed an explanation for the long beta lifetime of C^{14} which requires that the branching ratio of the 3.95-Mev level in N^{14} be $\sim 1\%$ by cross-over transitions which he finds would be predominantly $E2$. He remarks that any collective motion, which he did not consider, would enhance the $E2$ transition and so increase the branching ratio. The problem of C^{14} and N^{14} has also been considered by Visscher and Ferrell,[3] who predict a branching ratio of 3.9% without any requirement of collective motion.

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Regularities in the Level Schemes of Heavy Even-Even Nuclei

G. Scharff-Goldhaber
Brookhaven National Laboratory, Upton, New York*

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It has been pointed out recently[1] that at $A\sim 150$ an abrupt transition takes place in the nature of the level schemes of even-even nuclei and that this transition is solely governed by the number of neutrons in the nucleus. For $N\leq 88$ we find that the energy of the first excited state $E_1>300$ kev and that $E_2/E_1\sim 2.2$, where E_2 is the energy of the second excited state with even spin and parity. From the study of decay schemes one finds that this state has in most cases the character 2+, somewhat less frequently 4+, and rarely 0+. This type of level scheme and the observed transition probabilities and multipole mixtures have been interpreted in terms of the Bohr-Mottelson model in the region of weak to moderate coupling[1] and also in terms of a Bohr-Mottelson strong coupling model with "γ-unstable potential."[2] We shall call here this pattern the "near-harmonic pattern," in contrast to the well-known rotational pattern, which occurs for $N\geq 90$ and is characterized by the spin sequence 0+, 2+, 4+, $\cdots$, $E_1<125$ kev, and E_2/E_1 approaching 3.33 with increasing neutron number. An explanation for the dramatic increase in nuclear deformation between $N=88$ and $N=90$ has been suggested by Mottelson and Nilsson.[3]

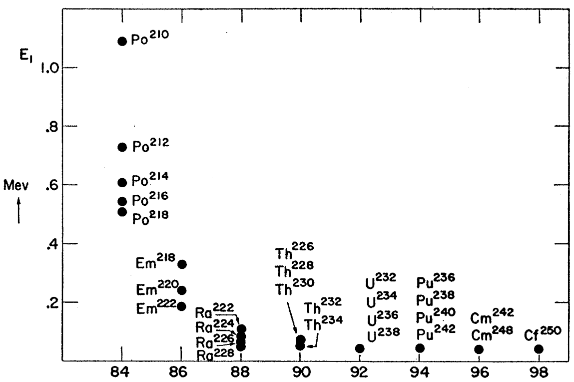

FIG. 1. Energy E_1 of first excited states of nuclei with $Z>82$ and $N\geqslant 126$, plotted against Z. For $Z\leqslant 88$, the addition of 2 protons produces a greater change in E_1 than the addition of 2 neutrons (except when the neutron number is magic).

Since it is known that another rotational region exists among the heavy nuclei,[4] it seemed interesting to find out whether it, too, is preceded by a near-harmonic region. In Fig. 1 the energies of the first excited states of even-even nuclei with $Z>82$ and $N\geq 126$ are plotted against the number of protons in the nucleus, showing a rapid decrease with increasing Z. It is seen that in this region E_1 depends more strongly on the *proton* number than on the neutron number, as indicated by the isobar pairs $Po^{218}-Em^{218}$ and $Em^{222}-Ra^{222}$. The question arises whether, if a near-harmonic region exists here, the transition to the rotational region is also governed by the number of protons, and if so, which are the critical proton numbers. It is known that several of the Ra isotopes possess a fairly well-developed rotational pattern.[4] Ra^{222}, the radium isotope which has the smallest number of neutrons and which is furthest removed from the pure rotational nuclei, has a second excited even spin state of character 4+, and an energy ratio $E_2/E_1=2.75$.[5] This ratio falls considerably above the range of E_2/E_1 ratios observed for the near-harmonic pattern; hence we conclude that the rotational pattern starts at $Z\leq 88$. Since no higher excited state had been established beyond the first 2+ state for any of the Em isotopes,[6] it seemed desirable to find at least one second excited state.

Harbottle, McKeown, and Scharff-Goldhaber[7] have now studied the γ rays following the α emission from Ra^{226} and have established that besides the well-known 2+ state at 188 kev there exists in Em^{222} a second excited state at 448 kev. They confirmed the existence of a weak γ transition of 260 kev previously observed by Stephens[8] in coincidence with Ra^{226} α rays and found that it coincided with the 188-kev γ transition. No 448-kev γ rays were observed, the upper limit being $\sim 1/20$ of the intensity of the 260-kev transition. The character of the 448-kev state was not directly determined but there is good reason to believe that it is 2+ or 4+, or possibly 0+. The ratio $E_2/E_1=2.38$, which is fairly close to the average 2.2 for the near-harmonic pattern. This result proves that the transition is indeed mainly governed by the proton number, since ${}_{86}\mathrm{Em}^{222}$ with its near-harmonic pattern contains more neutrons than ${}_{88}\mathrm{Ra}^{222}$ with its almost rotational pattern.

Figure 2 presents in graphical form the conclusion which may be drawn from the knowledge of the level scheme of Em^{222}. The left-hand side of the figure shows the ratio E_2/E_1 as a function of the number of protons, and the right-hand side shows this ratio as a function of the energy of the first 2+ state, E_1. For comparison, the values for the corresponding transition in the rare earth region are given. Here E_2/E_1 is plotted as function of the neutron number N at the left. We see that while in this region the transition takes place between the *neutron* numbers 88 and 90, it occurs for the heavy elements between the *proton* numbers 86 and 88. The closeness of these pairs of numbers seem significant. However, while the proton number seems to be irrelevant in the lower A region, in the heavy element transition region an increase in the number of neutrons produces a slight increase in nuclear deformation which makes the transition less abrupt.

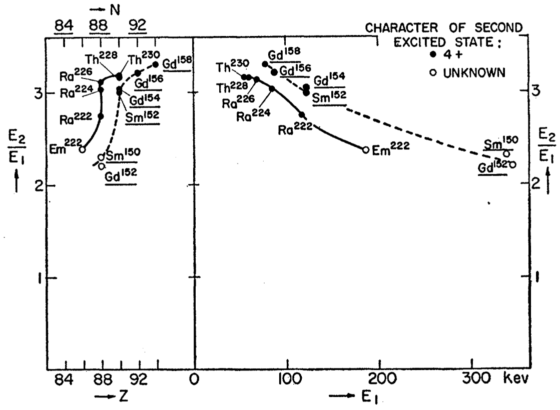

FIG. 2. Left side: the curve at the left, representing the ratio E_2/E_1 plotted against Z (scale at bottom), shows an abrupt rise between $Z=86$ and $Z=88$, while the curve at the right, showing the same ratio plotted against N (rare earth region, scale on top) rises steeply between $N=88$ and $N=90$. Right side: E_2/E_1 plotted against E_1. Solid curve: heavy elements; Dashed curve: rare earth region.

A thorough study of the level schemes of the Em isotopes, in particular a definite assignment of the character of the second excited state and, where this is found to be 2+, of the degree of $M1$ admixture in the $2+\rightarrow 2+$ transition, as well as of the ratio

$$(2+\rightarrow 0+)/(2+\rightarrow 2+)$$

of the reduced $E2$ transition probabilities from the second excited state, seems desirable. It will also be interesting to see whether other properties depending on the degree of nuclear distortion, e.g., quadrupole moments, isotope shifts, and $E2$ transition probabilities, parallel the findings derived from the level schemes of the heavy even-even nuclei.

We wish to thank Dr. J. Weneser for valuable discussions.

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