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Nuclear Physics **30** (1962) 328—331; © *North-Holland Publishing Co., Amsterdam*

THE LOWEST $T = 0$ STATES IN THE ODD $N = Z$ NUCLEI WITH $A > 40$

J JÄNECKE

H. M. Randall Laboratory of Physics, University of Michigan, Ann Arbor, Michigan †

Received 8 September 1961

Abstract: There is indication that the lowest $T = 0$ and $T = 1$ states are inverted not only in Cl^{34} but also in Sc^{42}, V^{46}, Mn^{50} and Co^{54}. Isomerism in all these nuclei is likely.

The β-decays of the odd self conjugate nuclei in the $f_{\frac{7}{2}}$-shell, namely Sc^{42}, V^{46}, Mn^{50} and Co^{54} have superallowed character with ft-values [1, 2]) close to the ft-value of the O^{14}-decay. Consequently the transitions are $0^+ \rightarrow 0^+$ transitions between states of isobaric spin $T = 1$. There is only little information about the lowest $T = 0$ states in these nuclei.

Fig. 1 shows a plot [3, 4]) of the known energy differences [5]) Δ_{10} between the lowest $T = 1$ and $T = 0$ states for the odd and even selfconjugate nuclei as a function of A. Some values have been calculated [5]). The lowest $T = 0$ states in the nuclei with $A < 40$ are the ground states except in Cl^{34}. From an extrapolation of the set of values for the odd nuclei and a comparison with the set of values for the even nuclei one would expect the heavy odd nuclei ($A > 40$) to have energies Δ_{10} up to about ± 0.5 MeV. Thus the lowest $T=0$ states in Sc^{42}, V^{46}, Mn^{50} and Co^{54} should be up to about 0.5 MeV above or below the known states with 0^+, $T = 1$.

This also has another consequence. Assuming the $T = 0$ states to be lower, these states have to undergo β-decay (allowed or forbidden, but not superallowed). The known $T = 1$ states are thus isomeric states like Al^{26m} or K^{38m}. Spin and parity of 1^+ for a $T = 0$ ground state is excluded from the existence of the superallowed decay. Assuming the lowest $T = 0$ states are higher, you have inversion of the $T = 0$ and $T = 1$ states. This condition was known up to now only in Cl^{34}. Also in this case isomerism is likely if spin and parity of the $T = 0$ states is not 1^+, but 3^+, 5^+ or 7^+.

To get information about the lowest $T = 0$ state in Sc^{42} a search was undertaken for a long-lived activity with emphasis for a 14 d half-life. Walke [6]) in 1940 bombarded KCl with α-particles and found such an activity which he

† Most of this work was carried out while on leave of absence from the Max-Planck-Institut fur Kernphysik, Heidelberg.

assigned to Sc^{42}. In our experiment no long-lived Sc^{42} activity could be found †. Instead a weak 14 d activity was found but assigned to P^{32} which was produced from the bombardment of KCl with 43 MeV α-particles †† according to the reaction Cl^{35} (α, α 2p n)P^{32}. This is the same reaction [7]) which produces Na^{24} from Al^{27} with relatively high cross section.

Recent measurements [8]) at another laboratory show the existence of an excited isomeric state in Sc^{42} which undergoes an allowed β^+-decay with a half-life of 62 ± 4 sec. The spin of Sc^{42m} is probably 7^+. Also in Co^{54} an excited

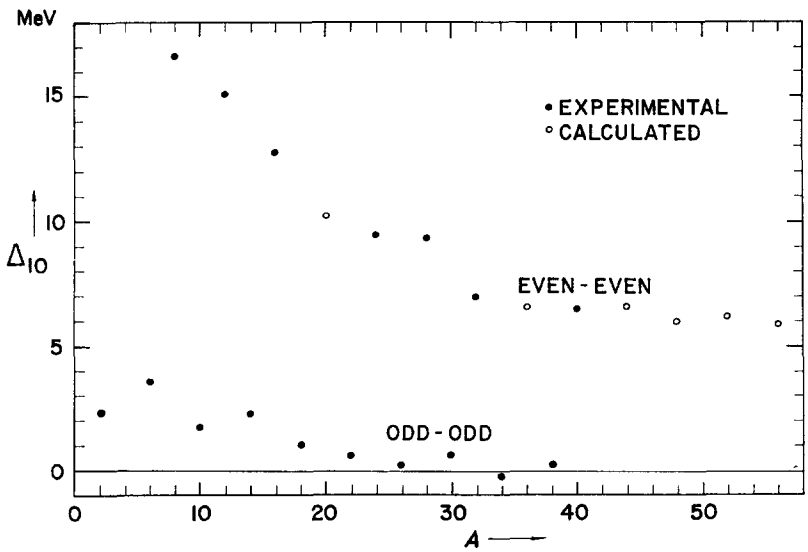

Fig. 1. Energy differences Δ_{10} between the lowest $T = 1$ and $T = 0$ states in the odd and even $N = Z$ nuclei as a function of A. Data taken from ref [5]) The estimated error for the calculated energies is ±200 keV. The experimental errors are ±100 keV for the even nuclei from $A = 24$ on, less for the other nuclei

long-lived isomeric state was found [9]) with spin 7^+. These results indicate that it is likely that also in V^{46} and Mn^{50} the lowest $T = 0$ and $T = 1$ states are inverted and that long-lived isomeric states exist. Spins of 3^+ or 5^+ should result in allowed β-transitions with half-lives of the order of 1 min †††. Measurements are in progress.

† Re-examination of a decay curve of the activities obtained from the bombardment of KF with 20 MeV α-particles showed an activity with a half-life of 63.3 ± 1.7 sec It follows from later experiments (see next paragraph) that this activity has to be interpreted as that of Sc^{42m}.

†† These targets were activated at the Institut fur Strahlen- und Kernphysik der Universitat Bonn

††† *Note added in proof:* The author's attention has been called to the fact that a Mn^{50} activity with a half-life of 2 min has already been observed [15])

The selfconjugate odd nuclei belong to those nuclei which follow the revised [10]) Nordheim rule R 2. This rule states that the spin of the ground state should be $J = |J_1 \pm J_2|$. The rule seems to be violated in Cu^{58}, the first odd selfconjugate nucleus in the 2 $p_{\frac{3}{2}}$-shell. Rule R2 favours spins of 0 or 3. From the allowed β-decay [11]) with 3.3 sec half-life it follows that the ground state spin for Cu^{58} is 0^+ or 1^+. A spin of 0^+ however is very likely to imply $T = 1$ and consequently a superallowed β-decay which is in disagreement with the experimental evidence [11]). This implication is strictly true only for jj-coupling and with the proton and neutron in equivalent orbits [4]). The state with 0^+, $T = 1$ is expected at an excitation [5]) of 110 ± 150 keV, assuming a discontinuity of 150 keV for the Coulomb energy difference at $A = 54$. If the 0^+, $T = 1$ state is an excited state, M1 γ-radiation suppresses the superallowed β-transition, which is actually not observed as in P^{30}.

A violation of rule R 2 can be shown from theoretical calculations [12]) with jj-coupling and extreme δ-function interaction. These calculations show that for the ground states of selfconjugate nuclei spins of 0, 1 and $2J_1$ are possible rather than only 0 and $2J_1$.

In addition these calculations predict for Sc^{42} with a groundstate of 0^+ a spin sequence of 0^+, 1^+, 7^+. Other shell model calculations [13]) favour the 7^+ state as the lowest odd spin $T = 0$ state. Calculations in terms of the collective model [14]) are not quite conclusive and give negative as well as positive deformation at the beginning of the $f_{\frac{7}{2}}$-shell, i.e., 7^+ or 1^+ for the level of interest.

The above considerations show that the inversion of the lowest $T = 0$ and $T = 1$ states seems to be restricted to Cl^{34} and the four odd selfconjugate nuclei in the $f_{\frac{7}{2}}$-shell namely Sc^{42}, V^{46}, Mn^{50} and Co^{54}, and that isomerism in all these nuclei is likely.

I appreciate very much the stimulating discussions with Professor K. T. Hecht. I also appreciate the help and assistance of Professor W. Riezler and Dr. H. Brückmann, Universität Bonn, and Professor W. W. Meinke and Dr. J. R. DeVoe, Chemistry Department, University of Michigan. A Fulbright Travel Grant was gratefully accepted.

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