The similarity of the low-lying level structures of Cu^{59} and Cu^{61} as illustrated in Fig. 18 is rather striking. It is not clear why this similarity exists, because one might expect a closer low-lying level spacing in Cu^{61} than in Cu^{59} as is observed in the resonance density. The level structures of these two copper isotopes will be compared with the nickel isotopes of the same mass numbers in a forthcoming publication.[33]

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Decay of Ca^{38}†

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The decay of a new isotope, Ca^{38}, produced by the reaction $Ca^{40}(\gamma,2n)$, has been observed via branching of the beta decay to a 3.5-Mev excited state of K^{38}. The observed half-life of (0.66 ± 0.05) second is consistent with a log (ft) value of 3.5 for the ground-state transition. The tentative assignment for the K^{38} excited state is $J=1^+$, $T=0$ although $J=0^+$, $T=1$ is also possible. A search for branching in the decay of S^{30} is also discussed.

INTRODUCTION

INTEREST in the odd-odd, self-conjugate $(N=Z)$ nuclei has led to a search for their parent $(N=Z-2)$ isobars and the modes of decay of the latter. Moszkowski and Peaslee[1] have pointed out that several of these $N=Z-2$ isobars may be produced by photonuclear reactions on stable targets, and have suggested that branching of their beta decays should usually occur. The $N=Z-2$ ground state $(0^+, T=1)$ in general decays by superallowed positron emission to the corresponding isobaric-triplet level of the self-conjugate nucleus; if a $(1^+, T=0)$ excited level of the latter lies energetically below the ground state of the $N=Z-2$ nucleus, then branching should take place by allowed positron decay to this state, with subsequent $M1$ gamma-ray emission.

Kofoed-Hansen[2] has pointed out that for the superallowed transitions, the $\log(ft)$ value should be 3.5 in all cases. The disintegration energy may be calculated from nuclear-mass systematics, and from this and the ft-value, the half-life may be predicted. In particular, for the ground-state decay of Ca^{38}, Kofoed-Hansen predicts a positron end-point energy of 5.21 Mev and a half-life of 0.7 sec. The observed lifetime would, of course, be somewhat shorter if branching occurs.

EXPERIMENTAL CONSIDERATIONS

Thick targets (≈ 10 g/cm^2) of Ca and CaH_2 have been exposed to the 85-Mev bremsstrahlung beam of the Michigan electron synchrotron. The targets were viewed by a NaI(Tl) scintillation spectrometer and single-channel pulse-height analyzer, signals from which were then analyzed in time with a 20-channel time-delay analyzer. An electronic timing circuit, synchronized to the accelerator cycle, was used to operate alternately the accelerator and the analyzing equipment. Thus annihilation radiation from the positron decays, or nuclear gamma rays, could be selected by the single-channel analyzer and their decays analyzed with the 20-channel delay analyzer. In most cases the decays were followed for several half-lives; the half-lives quoted are taken from least-squares fits to these data.

When Ca^{40} is irradiated with high-energy x-rays, the predominant reactions, in order of intensity, are $Ca^{40}(\gamma,n)Ca^{39}$ and $Ca^{40}(\gamma,np$ or $d)K^{38}$. Ca^{39}, K^{38}, and K^{38m} are all positron emitters; both Ca^{39} and K^{38m} have lifetimes of the order of 0.9 sec and both have end points of the order of 5 Mev. Hence it would be exceedingly difficult to identify the ground-state transition from Ca^{38}, produced by the weaker reaction

Table I. Delayed gamma radiation observed after irradiation of potassium and calcium targets. The term mc^2 indicates two-quantum annihilation radiation.

Target	Gamma-ray energy	Observed half-life	Assignment
K^{39}	mc^2	7.67 ± 0.03 min	$K^{38}(\beta^+)A^{38*}$
K^{39}	2.18 Mev	7.67 min	$A^{38*}(\gamma)A^{38}$ after $K^{38}(\beta^+)A^{38*}$
K^{39}	mc^2	0.951 ± 0.007 sec	$K^{38m}(\beta^+)A^{38}$
Ca^{40}	mc^2	0.89 sec	$Ca^{39}(\beta^+)K^{39}$ *and* $K^{38m}(\beta^+)A^{38}$
Ca^{40}	mc^2	7.67 min	$K^{38}(\beta^+)A^{38*}$
Ca^{40}	2.18 Mev	7.67 min	$A^{38*}(\gamma)A^{38}$ after $K^{38}(\beta^+)A^{38*}$
Ca^{40}	3.5 ± 0.1 Mev	0.66 ± 0.05 sec	$K^{38*}(\gamma)K^{38}$ after $Ca^{38}(\beta^+)K^{38*}$

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[1] S. A. Moszkowski and D. C. Peaslee, Phys. Rev. **93**, 455 (1954).

[2] O. Kofoed-Hansen, Phys. Rev. **92**, 1075 (1953).

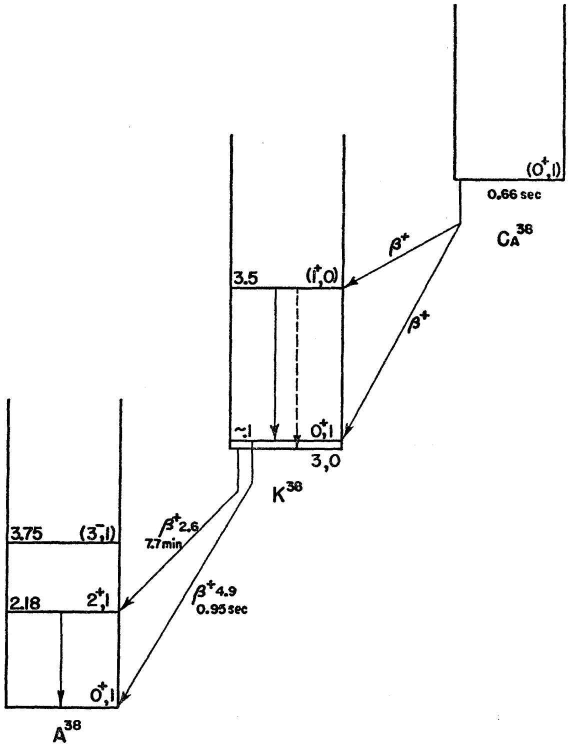

FIG. 1. Tentative energy-level diagram for the mass-38 isobaric triplet. Higher known levels of A^{38} are not shown. The excitation energies are in Mev; spin, parity, and isotopic spin are indicated thus: J^{Π},T. Uncertain values are in parentheses.

$Ca^{40}(\gamma,2n)Ca^{38}$, among the competing processes. In this experiment, therefore, a search was made for nuclear gamma radiation accompanying branching of the beta decay.

RESULTS

The radiations which were identified and whose lifetimes were measured are listed in Table I, together with results from a potassium target for comparison. The 2.18-Mev gamma ray observed in both cases is ascribed to an $E2$ transition in A^{38} following the long-lived decay of K^{38}. The 3.5-Mev gamma ray is observed only with calcium targets; its lifetime is significantly shorter than those of Ca^{39}, K^{38}, and K^{38m}, and hence it is interpreted as a transition in K^{38} following a branching of the Ca^{38} decay. Its intensity (estimated within a factor of two) is consistent with (a) the measured ratio of $(\gamma,2n)$ to $(\gamma,np$ or $d)$ yields from other targets and (b) the branching ratio computed by Moszkowski and Peaslee[1] for allowed branching to a $(1^+, T=0)$ state. If the 3.5-Mev gamma ray were to be interpreted as isomeric, at least an $E5$ or $M5$ transition would have to be invoked to account for the observed lifetime. In the present experiment, beam intensity considerations do not permit the use of coincidence techniques to verify the identification further.

A proposed decay scheme is presented in Fig. 1. The 3.5-Mev state of K^{38} is tentatively assigned $J=1^+$, $T=0$ since even a first-forbidden transition would be too weak, in competition with the superallowed ground-state transition, to be observed. It has been pointed out[3] that the branching could also be superallowed, in which case the 3.5-Mev state would have $J=0^+$, $T=1$. Either of these (J,T) combinations could be formed by $(s_{\frac{1}{2}})^{-2}$ configurations.

The 3.5-Mev gamma ray is shown leading to the 0^+ state, i.e., K^{38m}, which would be predominantly an $M1$ transition; however it may also lead to the 3^+ state, being in that case predominantly $E2$ radiation. The excitation energy of K^{38m} is not accurately known, but is of the order of 0.1 Mev.[4] The 3.5-Mev gamma ray may actually be a doublet.

NOTE ON S^{30}

With a S^{32} target, a search has been made, by the same technique, for a similar branching of the S^{30} decay, specifically to the 690-kev level of P^{30}. This level has been identified in two separate experiments[5,6] as $J=0$ (implying $T=1$) and $T=0$ (implying $J=1$). In the present experiment, no branching is found occurring to this level, although a gamma ray of five times less than the calculated intensity would have been detected. Hence one is led to believe that the 690-kev level has both $J=0$ and $T=0$, in agreement with the direct results of both of the experiments mentioned above. Such a (J,T) assignment could result from a mixed configuration for this level.

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