Search for Double Beta Decay in Ca^{48} and Zr^{96}*

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A new search for double beta decay in Ca^{48} and Zr^{96}, using two scintillation detectors in a 4π solid angle geometry, was performed far underground, in order to reduce the background counting rates to small values in the spectral regions of interest. The results of this experiment showed no evidence for double beta decay in either Ca^{48} or Zr^{96}. Lower limits for the half-lives of these isotopes were estimated as follows: Ca^{48}, $T_{\frac{1}{2}}>2\times10^{18}$ yr; Zr^{96}, $T_{\frac{1}{2}}>0.5\times10^{18}$ yr.

AN experiment to check McCarthy's seemingly positive evidence for the existence of double beta decay in Ca^{48} and Zr^{96} [1,2] has been made.

A 4π solid angle scintillation spectrometer generally similar to the one employed by McCarthy[1] was used.

The experiment was performed in a salt mine, at a depth of 1070 ft (900 m.w.e.). Thus, the part of the background due to cosmic rays was very small, and the main source of background counts was low-energy gamma rays, with counting rates and pulse heights consistent with those expected from the decay of K^{40} in the natural potassium existing in the mine. The detectors were shielded locally by 1 in. of iron.

The samples used were supplied by the Isotope Division of the Oak Ridge National Laboratories. The calcium sample was enriched to 84.28% in Ca^{48}. It was in the form of $CaCO_3$, and the amount of Ca^{48} was 182 mg. The Zr of the Zr^{96} sample was enriched to 85.25% in Zr^{96}, it was in the form of ZrO_2, and the amount of Zr^{96} was 200 mg. The natural calcium sample was in the form of chemically pure $CaCO_3$ from the Merck Chemical Company.

Because of the uncertainty in the mass determinations for Ca^{48}, Ti^{48},[3] Zr^{96}, and Mo^{96},[4] because of the finite energy resolution of the spectrometer, and because of the thickness of the sources, events due to the double beta decay of Ca^{48} were looked for in the 3.0- to 4.75-Mev region of the observed spectrum. In the case of Zr^{96}, the corresponding region was 2.5 to 4.5 Mev.

Sometimes a record was made of all pulses, and at other times only those pulses were recorded which involved a coincidence of counts between the two detectors.

A résumé of the important data and results is given in Table I.

Since there was no activity which could be specifically assigned to either Ca^{48} or Zr^{96}, lower limits for the half-lives of these isotopes for double beta decay were estimated from the value of the background counting rates and the detection efficiency of the spectrometer. The criterion used for the detectability of any activity was that the net excess activity due to the active sample over the inactive one be twice the standard deviation corresponding to the total number of counts.

TABLE I. Summary of the main data and results of the search for double beta decay in Ca^{48} and Zr^{96}.

Sample	Running time (hours)	Detection efficiency (%)	Counting rates in region 2.5–4.5 Mev (events/100 hr)	Counting rates in region 3.0–4.75 Mev (events/100 hr)	Half-life (yr)
Total activity measurements					
Ca^{48}	303.97	81	24.0	12.8	$>1.1\times10^{18}$
nat-Ca	207.27	...	26.5	14.2	...
Zr^{96}	319.24	60	25.5	13.4	$>0.36\times10^{18}$
Coincidence activity measurements					
Ca^{48}	640.49	35	7.4	4.4	$>2\times10^{18}$
nat-Ca	252.13	...	4.8	4.4	...
Zr^{96}	503.52	25	5.5	4.9	$>0.5\times10^{18}$

These lower limits for the half-lives are probably too high to be explained by using Majorana neutrinos[5]; however, they are not inconsistent with the half-lives predicted by using Dirac neutrinos.

These half-lives are also in disagreement with those found by McCarthy in his experiments, particularly in the case of Ca^{48} where his results seem better statistically than in the case of Zr^{96}. Although no explanation is offered for this discrepancy, it may be pointed out that the present experiment was carried out under more favorable circumstances than McCarthy's.

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