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#### SEARCH FOR RARE NATURAL DECAY MODES FROM $^{228}\text{Th}$

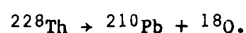
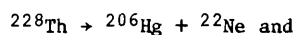
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In a recent letter Rose and Jones<sup>1</sup> reported the discovery of a new kind of natural radioactivity observed in the decay,  $^{223}\text{Ra} \rightarrow ^{209}\text{Pb} + ^{14}\text{C}$ . They identified the  $^{14}\text{C}$  particles using a solid state counter telescope whose  $\Delta E$ ,  $E$  signals uniquely define both the charge and total energy. The observed energy sum of  $\sim 30$  MeV was in good agreement with the calculated  $Q$ -value of 31.8 MeV after taking into account the recoil energy of  $^{209}\text{Pb}$ . The branching ratio for the emission of  $^{14}\text{C}$  relative to  $\alpha$ -decay from  $^{223}\text{Ra}$  was measured to be  $8.5 \pm 2.5 \times 10^{-10}$  which corresponds to a partial half-life of 36.8 My. Due to the small branching ratio, counting intervals of about one half-year were required to accumulate statistics of 8-12 events. The possibility of such strange and rare decay modes were calculated by Rose and Jones<sup>1</sup> by comparing the ratios of the Gamow factors of the exotic emissions to that of  $\alpha$ -decay. A comparison of the preformation probabilities of  $^{223}\text{Ra}$  decaying by carbon emission indicated that  $^{14}\text{C}$  was preferentially favored

by several orders of magnitude over other carbon nuclei resulting in a very selective decay.

This new type of decay was first predicted in 1980 by Sandulescu, Poenaru and Greiner.<sup>2</sup> The new decay, intermediate between  $\alpha$ -decay and fission, was treated as fission with maximal asymmetry of the fragment masses or as emission of a heavy cluster. This exotic decay could therefore be viewed as the spontaneous emission of an intermediate mass fragment (IMF) similar in many ways to spontaneous fission into two roughly equal heavy fragments. Predictions of the relative penetrabilities for a number of these strongly mass-asymmetric two-body fragmentation decay modes were made. Two important factors were noted by these authors which can account for the selectivity observed in the  $^{14}\text{C}$  decay. These are: a) the existence of two minima in the potential energy surface, a deep asymmetric minimum and a shallower more nearly symmetric minimum, and b) shell effects which play an important role in the descent from the saddle point to

the scission point. These two factors combine to limit decay into a few selective mass-asymmetric channels leading to final state nuclei near  $N=126$  closed shell. In the present study we have searched for rare decays of the type



The  $^{228}\text{Th}$  source used in this study had a nominal specific activity of  $1 \mu\text{Ci}$ . The thorium oxide was electrodeposited and diffusion bonded on platinum foil with a  $100\text{--}200 \mu\text{g}/\text{cm}^2$  Au layer. The detectors consisted of a gas ionization chamber (GIC) with a  $100 \mu\text{Si}$  detector mounted inside. With a typical operating pressure of 30 torr of isobutane. The total energy loss measured for the 5.48 MeV  $\alpha$ -particles was  $\sim 0.9$  MeV whereas for 50 MeV  $^{22}\text{Ne}$  the total energy loss was calculated using range energy tables<sup>3</sup> to be  $10.56 \pm 0.16$  MeV. The energy calibration was performed using both  $^{228}\text{Th}$  and  $^{241}\text{Am}$   $\alpha$ -particles and a precision pulser. The uncertainty in the energy calibration at 50 MeV was estimated to be approximately  $\pm 1.5$  MeV. Using standard nuclear electronic techniques the GIC ( $\Delta E$ ) was used to gate the coincident Si( $E-\Delta E$ ) events. Lower level discriminators were set on both the  $\Delta E (>1 \text{ MeV})$  and  $E (>7 \text{ MeV})$  counters in order to bias out single  $\alpha$ -events and minimize dead time problems. Pile-up rejection gates were used on  $\Delta E$  and  $E$  counters. The detected  $\alpha$ -particle rate was  $\sim 200 \text{ s}^{-1}$  with a total of  $\sim 170$  million events deposited during the 10d counting

interval. A ten day background run under identical conditions using a  $1 \mu\text{Ci } ^{241}\text{Am}$  source did not produce any detectable amount of background in the energy regions of interest. Data were stored in a Canberra 8180 MCA as coincident ( $E-\Delta E$ ) events with the gated  $\Delta E$  signal used as the coincidence start for the ( $E-\Delta E$ ) signal. The  $E$  spectrum was calibrated to look for events up to about 98 MeV.

In two runs of  $9 \times 10^5 \text{ sec}$  several high energy events (30-50 MeV) were observed but no  $\Delta E$  signals of the proper energy were recorded. We can understand this result as due to multiple pile-up which is uniquely associated with the  $^{228}\text{Th}$  decay chain. Specifically, 300 ns  $^{212}\text{Po}$  ( $E_\alpha=8.785 \text{ MeV}$ ) is so short lived that it allows multiple pile up within the  $1 \mu\text{s}$  resolving time of the slow coincident gate. Further checks with an  $^{241}\text{Am}$  and  $^{226}\text{Ra}$  sources indicated that this was the case since double and triple  $\alpha$  pile up events dominated the 10-20 MeV region but no events were observed at the higher energies.

The results of this study can be compared with those of Rose and Jones<sup>1</sup> and with the predications of Saudulescu, Poenaru and Greiner.<sup>2</sup> The branching ratio for the emission of  $^{18}\text{O}$  or  $^{22}\text{Ne}$  from  $^{228}\text{Th}$  was set at a limit of  $> 3 \times 10^{-9}$  which corresponds to partial half-lives  $> 600 \text{ myr}$ .

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