Comment on "Exotic Nuclear Decay of ^{223}Ra by Emission of ^{14}C Nuclei"

In their recent Letter confirming the ^{14}C radioactivity of ^{223}Ra,[1] Gales *et al.*[2] state, "Nearly a century after Becquerel, Rose and Jones (RJ) from the University of Oxford have recently reported a novel mode of radioactive decay[1] which was completely unexpected." They noted that because this "was a surprising discovery," it was "highly desirable to confirm this first result" which they did.[2]

The purpose of this Comment is to point out that the ^{14}C decay is but one example of a broader range of heavy nuclear decays and should not have been *unexpected* as seen from an earlier paper[3] (unknown in Refs. 1 and 2), which predicted, in the region of heavy nuclei with $Z \geqslant 88$, "a new type of decay which can be interpreted as highly *mass-asymmetric fission* or as *emission of a heavy cluster.*" The usual argument against heavy-cluster emission is the fact that the Coulomb barrier increases strongly with increasing charge of the emitted particle and, therefore, the barrier penetrability is very low. However, it was noted that the influence of shell effects for some particular two-body fragmentations give rise to a barrier penetrability comparable with the penetrability in α decay.[3]

The penetrabilities for various heavy cluster emissions with $Z = 4$ to 30 were calculated for several Ra, Th, Pu, U, Cf, Cm, No, and Fm nuclei and found to be comparable to those of α decay.[3] These calculations did not take into account the probability of formation of such clusters. Noting that heavy-cluster emission had not been observed, the authors concluded that the probability of formation of heavy clusters is many orders of magnitude smaller than the probability of α-particle formation. While they estimated that the emission of Si in the region of ^{238}U was the most probable emission to be observed, their Fig. 7 shows a very large penetrability for carbon emission by several Ra isotopes.

That work was continued and extended in two ways. A new semiempirical formula was obtained for the alpha-decay half-life[4] and an analytical expression for the lifetime was obtained.[5] These were then used to make a systematic study of various cluster emissions from the ground states or low excited states populated by beta decay of a precursor (β-delayed heavy-cluster radioactivity). The $^{3-10}$He clusters were studied first and ^{5}He radioactivity and β-delayed-^{5}He radioactivity were predicted.[5,6] There, it was stressed[5,6] that the maximum probability of a heavy-cluster emission occurs for processes which lead to a doubly magic daughter. While their more extensive calculations of higher Z clusters were being completed,[7] Rose and Jones[1] reported the ^{14}C radioactivity of ^{223}Ra to give the first evidence for the earlier predicted[3] new type of decay mode.

In a subsequent first report of the more extensive calculations, Poenaru *et al.*[7] found that while Rose and Jones[1] indeed had found the best ^{14}C emitter relative to α decay in ^{223}Ra there are a number of other cases deserving of attention based on their calculated half-lives compared to those for α decay, for example, ^{14}C radioactivity of ^{226}Ra, the ^{26}Ne radioactivity of ^{232}Th, ^{24,25}Ne radioactivity of ^{233}U, and ^{30}Mg emission by ^{237}Np. The ^{14}C radioactivity of ^{223}Ra was also confirmed by Ogloblin *et al.*[8] Thus the new radioactivity decay mode predicted by Sandulescu, Poenaru, and Greiner[3] is well established. It will be interesting to confirm the other predicted modes. These modes offer new ways to probe nuclear clustering and shell effects in nuclei.

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