

Heavy Particle Radioactivities

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Heavy Ion Radioactivities were predicted [1] in 1980, four years before the first experimental [2] evidence (see the multi-authored book [3] and the references therein). Recently performed measurements of cluster decay modes, showing a good agreement with calculated half-lives within analytical superasymmetric fission model, are included in a comprehensive half-life systematics [4] from which other possible candidates for future experiments may be obtained. The experimental data on half-lives and branching ratios relative to α -decay of ^{14}C , $^{18,20}\text{O}$, ^{23}F , $^{22,24-26}\text{Ne}$, $^{28,30}\text{Mg}$ and $^{32,34}\text{Si}$ radioactivities are in good agreement with predicted values within the analytical superasymmetric fission (ASAF) model (see the examples given in Fig. 1).

A strong shell effect can be seen in Fig. 1 and Fig. 2:

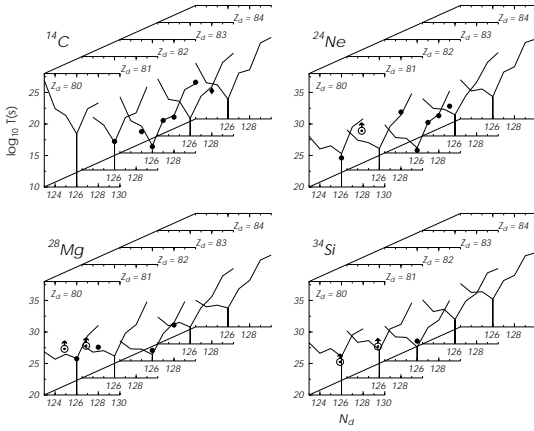


Figure 1: Predicted half-lives within ASAF model (lines) and measurements (points) for four kinds of cluster decay modes versus neutron number of the daughter nucleus.

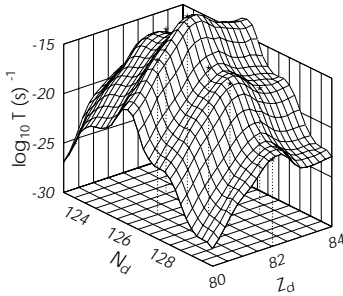


Figure 2: The surface of calculated half-lives (within ASAF model) of heavy nuclei against ^{14}C radioactivity and the measured points.

as a rule the shortest value of the half-life (maximum of $1/T$) is obtained when the daughter nucleus has a magic number of neutrons ($N_d = 126$) and/or protons ($Z_d = 82$). The cluster emitters ^{221}Fr , $^{221-224,226}\text{Ra}$, ^{225}Ac , $^{228,230}\text{Th}$, ^{231}Pa , $^{230,232-236}\text{U}$, $^{236,238}\text{Pu}$, and ^{242}Cm are either β -stable or not far from stability nuclei. By comparing the

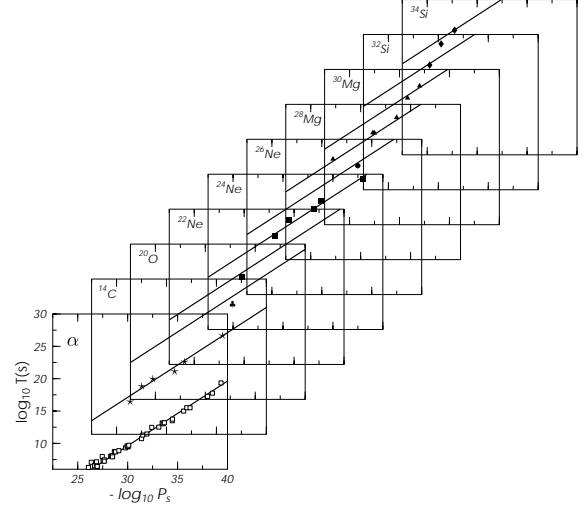


Figure 3: Universale curves and experimental points for heavy ion radioactivities and α -decay.

systematics of calculated value and of experimental data one can list [4] other possible candidates for future experiments: $^{220,222,223}\text{Fr}$, $^{223,224}\text{Ac}$, and ^{225}Th as ^{14}C emitters; ^{229}Th for ^{20}O radioactivity; ^{229}Pa for ^{22}Ne decay mode; $^{230,232}\text{Pa}$, ^{231}U , and ^{233}Np for ^{24}Ne radioactivity; ^{234}Pu for ^{26}Mg decay mode; $^{234,235}\text{Np}$ and $^{235,237}\text{Pu}$ as ^{28}Mg emitters, as well as $^{238,239}\text{Am}$ and $^{239-241}\text{Cm}$ for ^{32}Si radioactivity. Also ^{33}Si decay of ^{241}Cm could be observed.

The preformation probability can be calculated within a fission model as a penetrability of the internal part of the barrier, which corresponds to still overlapping fragments. With good approximation one can obtain the universal curve displayed in Fig. 3 for any kind of cluster decay mode, including α decay:

$$\log T = -\log P_s - 22.169 + 0.598(A_e - 1) \quad (1)$$

where

$$-\log P_s = 0.22873(\mu_A Z_d Z_e R_b)^{1/2} \left[\arccos \sqrt{r} - \sqrt{r(1-r)} \right] \quad (2)$$

with $r = R_t/R_b$, $R_t = 1.2249(A_d^{1/3} + A_e^{1/3})$, $R_b = 1.43998Z_d Z_e/Q$, and $\mu_A = A_d A_e/A$.

References

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