

β -delayed particle emission from very neutron-rich light nuclei

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Abstract : The probability of β -delayed emission of n, 2n, α and t from neutron-excess light nuclei is discussed, Na isotopes being taken as examples.

The combination of high-energy fragmentation and mass spectroscopy has recently made possible the study of the β decay of neutron-rich Na isotopes up to ^{32}Na . Both γ activities and delayed neutron emission have been observed and measured. From these results and the current mass predictions², several features of the process of β -delayed particle emission are anticipated, which are largely independent of the used mass formula.

1) delayed neutron emission : In ref.1, the P_n probability for ^{32}Na is measured as $20 \pm 8 \%$ which is very similar to the P_n values for ^{30}Na or ^{31}Na . The variation of P_n with A should reflect the width of the $Q_{\beta} - B_n$ energy window of β branches to n-unstable levels as compared to Q_{β} (Fig.1). In fig.2, the variation of $B_n(\text{Mg})$ with $Q_{\beta}(\text{Na} \rightarrow \text{Mg})$ is represented. Clearly P_n should tend to 100 % for odd-A Na isotopes from ^{33}Na up. But, for even-A isotopes, the neutron binding energy of the Mg daughter remains higher than 3 MeV up to ^{40}Na . Hence, the value of P_n should vary between 20 % or so and 100 %, depending on the possibility of the Gamow-Teller β transitions to the first (mainly 0^+ and 2^+) states of the even Mg. For even-Z parent nuclei, the above conclusions should be inverted, P_n reaching 100 % for even-A and remaining around a few tens of % for odd-A isotopes, when A increases.

2) delayed two-neutron emission : For very neutron-rich Na nuclei, the daughter Mg nuclei are barely more bound for two- than for one-neutron emission. Hence β -delayed two-neutron emission should be observed as a new mode of β decay. Goldanskii³ already discussed delayed 2p-emission but found that it became energetically possible only for proton-unbound nuclei, hence did not exist. For neutron-rich nuclei it becomes possible for Na nuclei as soon as ^{30}Na with an energy window (table 1) broad enough to insure a sizable probability for that process. In the case of e.g. ^{30}Na it could be characterized by the occurrence of ^{28}Mg as a product of the β -decay process.

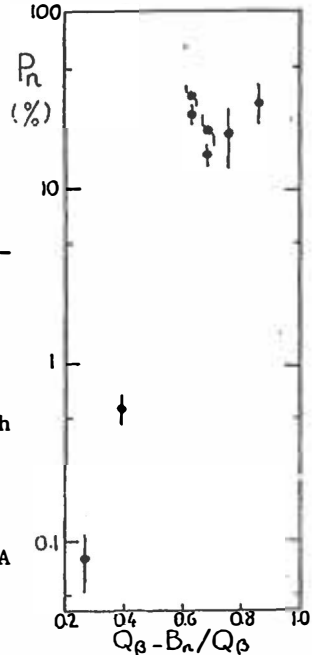


Fig. 1 - P_n values (from ref^{1,6}) for Na isotopes

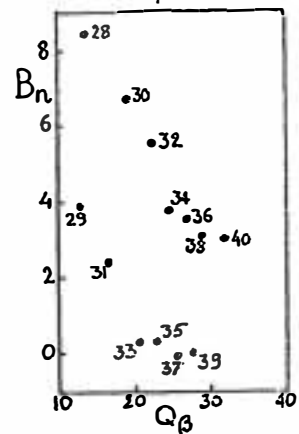


Fig. 2 - Diagram of $Q_{\beta}(\text{Na} \rightarrow \text{Mg})$ and $B_n(\text{Mg})$ values

TABLE 1 - Energy windows for delayed particle emission from Na isotopes

A	Q_{β}	$Q_{\beta} - B_n$	$Q_{\beta} - B_{2n}$	$Q_{\beta} - B_{\alpha}$	$Q_{\beta} - B_t$
28	13.9	5.4	- 1.0	2.6	-4.7
29	12.9	9.0	0.5	1.6	-4.1
30	18.0	11.3	7.4	6.0	1.2
31	16.5	14.1	7.4	3.8	0.7
32	22.4	16.9	14.5	8.5	5.9
33	20.6	20.3	14.7	6.3	5.5
34	24.6	20.8	20.5	9.6	9.5

3) delayed α emission : This is a well documented β -decay mode for neutron-deficient nuclei, although six β^- decaying nuclei close to the valley of stability are known to be delayed α emitters⁴. Mass calculations show that it can become a systematic phenomenon for light neutron-rich nuclei well before the neutron drip line is reached. In the case of Na isotopes, this phenomenon could be observed from ³⁰Na on (table 1) and seems within reach of the experimental methods of ref.1.

4) delayed triton emission : It was suggested by Berlovich⁵ that it could systematically occur before the neutron drip line is reached. At least for light nuclei, as exemplified in table 1, it seems unlikely that delayed triton emission, which becomes energetically possible for heavier isotopes than α delayed emission, could be observed.

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