

Multi-stage virtual nuclear decays

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Using the technique of Feynman diagrams and the R - matrix theory of nuclear reactions, as well as the results of articles [1-4], general formulae for the amplitudes of multi-stage decays of parent nucleus A_0 of the type $A_0 \rightarrow b_1 + A_1 \rightarrow b_1 + b_2 + A_2 \rightarrow \dots \rightarrow b_1 + b_2 + \dots + b_n + A_n$ with the appearance of real (observed) states of finite nucleus A_n and particles b_1, b_2, \dots, b_n were constructed. By introducing the internal energies $E(A_i)$ and $E(b_i)$ of nuclei A_i and particles b_i , the heats $Q_i = E(A_i) - E(A_{i+1}) - E(b_{i+1})$ of binary nuclear decays $A_i \rightarrow A_{i+1} + b_{i+1}$ that appear in the analyzed multi-stage decays were calculated. In the case of positive values of $Q_i > 0$ these decays and states of nuclei A_{i+1} can be really observed. However, at negative values $Q_i < 0$ the states of nuclei A_{i+1} lie outside the mass surface of the considered multi-stage decays and therefore have a virtual character. The experimental observation of such decays is possible only in its combinations with the decays of intermediate nuclei formed at the subsequent stages of the analyzed multi-stage decays with sufficiently larger positive values of heats. Using the introduced above formulae for experimentally observed nuclear decays the multi-stage virtual decays were distinguished and their characteristics were successfully described.

It is shown that the group of two-stage virtual nuclear decays includes the double beta-decays of nuclei [5–7], two-proton decays of nuclei [1,3], as well as spontaneous and low-energy induced ternary fission of nuclei with the escape of alpha particles from the neck of the fissile nuclei [4]. It is demonstrated that the group of three-stage virtual nuclear decays includes the spontaneous and low-energy induced quaternary fission of nuclei with the emission of the first and the second alpha particles from the neck of the fissile nuclei [8].

In conclusion, it should be noted that the concept of the multi-stage virtual nature of ternary and quaternary fission of nuclei with the emission of tritons and a large group of light nuclei as light particles is valid too.

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