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A new semiempirical formula for the alpha decay half-lives

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Abstract. — A new semiempirical relationship for the alpha decay life-time was derived on the ground of the fission theory of alpha decay. It takes into consideration explicitly not only the dependence on the proton number but also on the neutron number and their difference from magicity. In comparison with other formulae it gives a better agreement with experimental data for 116 even-even alpha emitters.

A relatively reliable estimate of the alpha decay partial half-life $T$, can be made by using some semiempirical relationships [1-6], if the kinetic energy of the emitted particle $E_s$ is known. Some of these formulae were derived only for a limited region of $Z$ and $N$ (proton and neutron numbers), but each has some parameters determined by fitting a given set of experimental data. In spite of the strong influence of the neutron shell effects, mainly the $Z$ dependence was stressed. In the meantime the precision of some measurements was increased and new alpha emitters were discovered. On the other hand, new effects can be introduced.

Our new equation is based on the fission theory of alpha emission [7]. The action integral $K$ allowing to calculate the WKB penetrability is split in two terms $K = K_s + K_i$, corresponding to the overlapping and to the separated fragments respectively. The main contribution $K_s$ comes from the separated fragments and this can be solved leading to an analytical relationship. For the small contribution of the overlapping region, $K_i$, which is usually computed numerically, we assume a proportionality with $K_s$, hence $K = \chi K_s$. The coefficient $\chi$ is expressed as a second order expression of the argument $N$ and $Z$ with six parameters $B_i$ ($i = 1, 2, \ldots, 6$) determined from a fit with experimental data. Finally we obtain

$$\log T = (B_1 + B_2 y + B_3 z + B_4 y^2 + B_5 yz + B_6 z^2) K_s / \ln 10 - 20.446$$

where $y$ and $z$ are reduced variables expressing the relative distance of $N$ and $Z$ from the closest magic-plus-one number of neutrons and protons $N_i, Z_i:

$$y = (N - N_i)/(N_{i+1} - N_i); \quad N_i < N \leq N_{i+1}; \quad N_i = \ldots, 51, 83, 127, 185, \ldots$$
$$z = (Z - Z_i)/(Z_{i+1} - Z_i); \quad Z_i < Z \leq Z_{i+1}; \quad Z_i = \ldots, 51, 83, 115, 121, \ldots$$

In the equation (1) $T$ is obtained in s when $Q = E_s A/A_d$ is in MeV.

The experimental data for $Q$-values [8] and partial half-lives [9] of 116 even-even nuclei allowed us to obtain the following parameters: $B_1 = 0.988662$ ; $B_2 = 0.016314$ ; $B_3 = 0.020433$ ; $B_4 = 0.027896$ ; $B_5 = -0.003033$ and $B_6 = -0.16820$.

A comparison of the dispersion of the calculated life-times relative to the experimental ones $T_{\text{exp}}$ for our case (Fig. 1b) and for a typical result obtained...
with other [6] equation, is presented in figure 1. As in figure 1a, all other expressions have an increased error in the vicinity of the magic number of neutrons \( N = 126 \). This is practically smoothed out by the present relationship. In this way, one can expect an increased accuracy for the life-time prediction in a new region of alpha emitters.

Fig. 1. — The errors of life-time predictions with the equation from reference [6] (a) and with our formula (b).

References