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Résumé. — La désintégration d'un état nucléaire métastable par émission d'une particule légère peut être considérée comme un processus de fission très asymétrique. Une approximation de la barrière de potentiel dans la région de recouvrement des deux fragments conduit à une relation analytique pour la durée de vie, permettant de traiter un grand nombre de cas dans une recherche de nouveaux modes de radioactivité. On découvre ainsi que certains noyaux ayant $Z = 83$-92, $N = 127$-137 et 97-105, 145-157 peuvent émettre spontanément des particules ^{5}He. D'après une estimation optimiste, 15 noyaux seulement ont des durées de vie partielles dans l'intervalle 10^{14}-10^{38} ans ; les autres, à l'exception de quelques noyaux superlourds, vivent un temps encore plus long. Le meilleur candidat est ^{213}Po, conduisant à un noyau doublement magique. Quelques émetteurs ^{5}He-β retardés, comme par exemple ^{155}Yb, ^{175}Pt, $^{209-217}$Ra, $^{9-11}$Be, $^{13-14}$B, $^{13-17}$C et $^{19-21}$O, ont des durées de vie plus brèves, et une meilleure chance de confirmation expérimentale.

Abstract. — The disintegration of a metastable nuclear state by emission of a light particle can be considered to be a very asymmetric fission process. An approximation of the potential barrier in the overlapping region of the two fragments leads to an analytic relationship for the life-time, allowing us to handle a large number of cases to search for new kinds of radioactivities. In this way, it is predicted that some nuclei with $Z = 83$-92, $N = 127$-137 and 97-105, 145-157 are able to decay spontaneously by emission of ^{5}He particles. A tentative optimistic estimation leads to the result that only 15 radionuclides should have partial life-times in the range 10^{14}-10^{38} years ; all others, except some superheavies, are longer lived. The best candidate is ^{213}Po for which the daughter is a double magic nucleus. Smaller life-times, with a better chance to be experimentally confirmed have some β-delayed ^{5}He emitters, as for example ^{155}Yb, ^{175}Pt, $^{209-217}$Ra, $^{9-11}$Be, $^{13-14}$B, $^{13-17}$C and $^{19-21}$O.

1. Introduction.

The stability of a particular nucleus (A, Z) with respect to the split into a heavy (A_1, Z_1) and a light (A_2, Z_2) fragment, can be studied [1] by using the deformation energy curve $E(R)$ of the system *vs.* separation distance, R, between fragments.

If the energy of the two nuclei at infinite separation is taken as the origin of the potential, the initial energy $E(R_i)$ is equal to the Q-value which can be computed from the experimental masses [2] :

$$Q = M(A, Z) - M(A_1, Z_1) - M(A_2, Z_2), \qquad A = A_1 + A_2 ; \quad Z = Z_1 + Z_2 . \quad (1)$$

A negative value, $Q < 0$, means that the split is prevented by an infinitely thick barrier ; the nucleus is stable.

For $Q > 0$, there are two distinct cases : instability or metastability. The nucleus is unstable if $E(R)$ is monotone decreasing. The radioactive nuclei are metastable. The fragments are held together temporarily by the potential barrier. There is a finite probability, P, per unit time, of penetrating this barrier by the quantum-mechanical tunnelling effect.

We have performed a systematic investigation of the stability of about 2 000 nuclei, with known masses tabulated by Wapstra and Bos [2], for the emission of He isotopes ($Z_2 = 2$) with various mass numbers $A_2 = 3, 4, ..., 10$. It was possible to consider this large number of cases (about 16,000) by using a model leading to analytical results both for the statics (potential energy) and the dynamics (barrier penetrability) of the process.

The model was derived from the well known Strutinsky's [3] macroscopic-microscopic method successfully used in fission [4-9] under the assumption that alpha decay [10, 11], or any other particle evaporation [12] could be considered a very asymmetric fission. In its initial form, it was used only for alpha decay from almost spherical ground states [13] or from very deformed shape isomeric states [14]. In the following we would like to present, on one hand, an extended version allowing us to account for angular momentum and nuclear excitation effects and, on the other hand, an approximation which help us to obtain analytical relationships both for potential energy and the life-time. This version can be used to find new kinds of radioactivities, as will be shown in the example of ^{5}He.

The figure 1 illustrates the fact that for some Po isotopes, besides the well known alpha decay, the exotic ^{5}He spontaneous emission from the ground state is also energetically possible. All other He isotopes (A_2 = 3, 6, 7, 8, 9, 10) could be emitted only from excited states, because $Q < 0$.

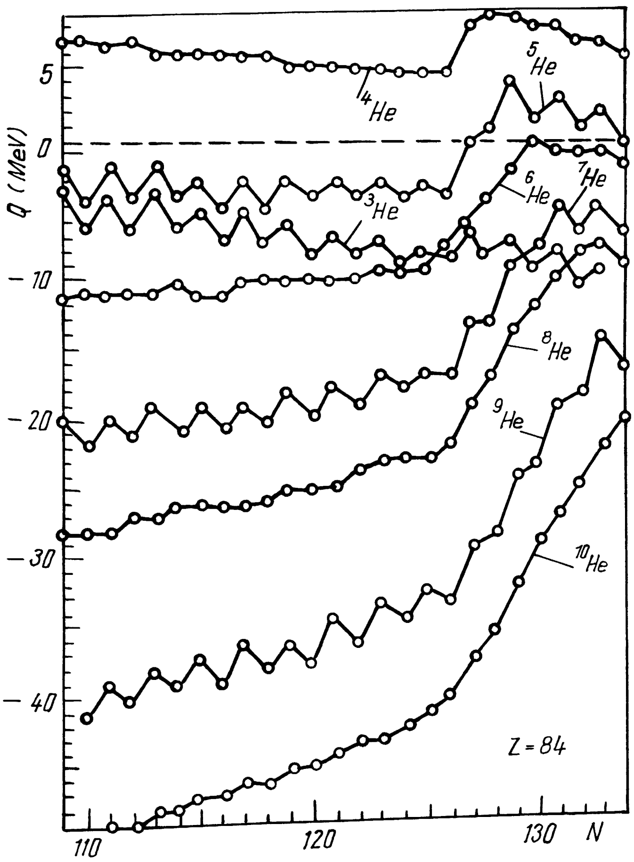

Fig. 1. — Q-values for the emission of various He isotopes from Z = 84 nuclides with different neutron numbers.

Unfortunately ^{5}He is not stable (see Ref. [15] and the references cited therein). Its ground state has a width, $\Gamma = 600 \pm 20$ keV [16]. Consequently the ^{5}He radioactivity could be experimentally determined by α-particles or the neutron, produced by its own disintegration, as well as by the presence of the daughter nucleus. In this respect it is encouraging that recently [17] the existence of two-proton radioactivity predicted a long time ago [18] was experimentally confirmed. Of course, the diproton, like ^{5}He, is not a stable particle, but from the analysis undertaken by Goldansky [18] it seems that the two protons separate practically only after the passage of the cluster through the potential barrier. We presume that the same is true for ^{5}He, i.e. it disintegrates into a neutron and an alpha particle after tunnelling.

2. The potential barrier.

In the two centre spherical parametrization [13] of shapes during the deformation from the parent nucleus with a radius $R_0 = r_0 A^{1/3}$, to the touching point of the fragments, the separation distance, R, is varied between $R_i = R_0 - R_2$ and $R_t = R_1 + R_2$, where $R_i = r_0 A_i^{1/3}$ (i = 1, 2) and r_0 = 1.2249 fm [18].

Initially [13] we used either Myers and Swiatecki's [19] liquid drop model (LDM) or the folded Yukawa-plus-exponential model [20], generalized for nuclei with different charge-to-mass ratio [21], to compute numerically [22] the macroscopic energy in the overlapping region, $R_i < R < R_t$, of the two fragments. Then, a phenomenological shell correction allowed us to reproduce exactly the Q-values.

In the framework of LDM for separated spherical fragments, $R \geqslant R_t$, only the Coulomb interaction energy $Z_1 Z_2 e^2/R$ has been considered for alpha decay of even-even nuclei. The maximum of the potential energy at $R = R_t$ was

$$E_c = Z_1 Z_2 e^2/R_t \tag{2}$$

where e is the electron charge. In this way, a barrier shape like that shown in figure 2 was obtained.

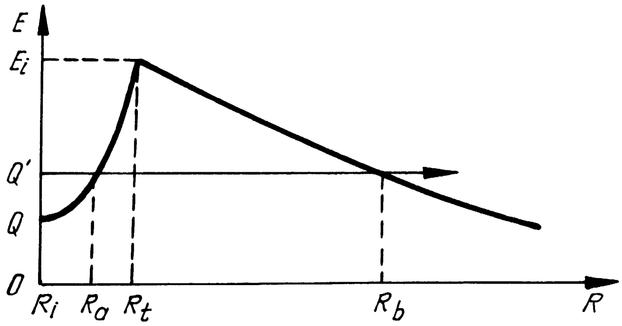

Fig. 2. — The barrier shape for light particle emission from heavy nuclei.

Now, for ^{5}He, which has a spin $I_2 = 3/2$, the spin (I) and parity (π) conservation conditions must be fulfilled :

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{l}, \qquad \pi = \pi_1 . \pi_2 . (-1)^l . \tag{3}$$

Any quantity belonging to the parent nucleus is written without subscript; those of the daughter and emitted particle have the subscript 1 and 2 respectively.

To the Coulomb interaction E_c one has to add also the contribution of the angular momentum $l\hbar$ — the centrifugal term

$$E_l = \hbar^2 \, l(l+1)/(2 \, \mu R_t^2) \tag{4}$$

where $\mu = mA_1 A_2/A$ is the reduced mass and m is the nucleon mass. By substituting the numerical values one obtains, for $R = R_t$ in fm, the total interaction energy at $R = R_t$, in MeV :

$$E_i = E_c + E_l = 1.43998\, Z_1 Z_2/R_t + 20.735\, l(l+1)\, A/(A_1 A_2 R_t^2)\,. \quad (5)$$

In the overlapping region, a convenient analytical approximation of the potential energy curve $E(R)$, going from $E(R_i) = Q$ to $E(R_t) = E_i$, suggested by the potential barrier shape (Fig. 2) which allows us to get a closed formula for the life-time T (see the next section), is a second order polynomial in R. Finally, one has

$$E(R) \simeq \begin{cases} Q+[(E_i-Q)]\,[(R-R_i)/(R_t-R_i)]^2\,; & R \leqslant R_t \\ Z_1 Z_2 e^2/R+\hbar^2\, l(l+1)/(2\,\mu R^2)\,; & R \geqslant R_t \end{cases} \quad (6)$$

where E_i is given by equation (5).

For a nonzero excitation energy (a nuclear temperature τ), the Coulomb energy is only slightly reduced [23], being multiplied by the factor $(1 - 10^{-3}\,\tau^2)$, where τ is expressed in MeV. Consequently, at relatively small excitation energies, it remains practically unchanged.

3. The life-time.

Like in fission [4, 8] the half-life of a metastable system is given by

$$T = \hbar/\Gamma = \ln 2/(\nu P) \quad (7)$$

where Γ is the reduced width, $\nu = \omega/(2\,\pi) = 2\,E_{\mathrm{vib}}/h$ represents the number of assaults on the barrier per second (the characteristic frequency of the collective mode) and $E_{\mathrm{vib}} = \hbar\omega/2$ is the zero point vibration energy.

According to the WKB theory, the probability per unit time of penetration through the barrier is expressed as

$$P = 1/[1 + \exp(K)] \quad (8)$$

and the action integral, K, is given by

$$K = \frac{2}{\hbar}\int_{R_a}^{R_b} \{\, 2\,\mu[E(R) - Q']\,\}^{1/2}\, \mathrm{d}R \quad (9)$$

in which $Q' = Q + E_{\mathrm{vib}} + E^*$, and $E^* < E_i - (Q + E_{\mathrm{vib}})$ is the fraction of the excitation energy concentrated in the separation degree of freedom. This barrier transmission model, used in the present work, describes only low excitations [9]. Statistical equilibrium among all the degrees of freedom of the nucleus is reached for high excitation energies U. In this case $E^* = U - (E^{\mathrm{i}} + E_{\mathrm{rot}})$ where $U = a\tau^2$; $a \simeq A/10\ \mathrm{MeV}^{-1}$ is the level density parameter; E^{i} is the internal energy available for other degrees of freedom; E_{rot} is the rotational energy. In a hot nucleus the energy concentrated on motion in the deformation mode is of the order of the nuclear temperature. Hence the residual nucleus is usually left in a highly excited state too. According to the statistical model [24] the probability of exciting a collective state of E^* energy is roughly proportional to $\exp(-\,E^*/\tau)$. Due to the fact that $E(R_a) = E(R_b) = Q'$, from equations (2), (4), (6) it follows that

$$R_a = R_i + (R_t - R_i)\,[(E_{\mathrm{vib}} + E^*)/E_b^0]^{1/2} \quad (10)$$

$$E_b^0 = E_i - Q \quad (11)$$

$$R_b = (R_t\, E_c/Q')\,[0.5 + (0.25 + Q'\, E_l/E_c^2)^{1/2}]\,. \quad (12)$$

According to equation (6), one can split the action integral into two terms $K = K_{\mathrm{ov}} + K_{\mathrm{s}}$, by integrating from R_a to R_t in the overlapping region and from R_t to R_b for separated fragments :

$$K_{\mathrm{ov}} = \frac{2}{\hbar}\sqrt{2\,E_b^0}\cdot\frac{1}{b}\int_{R_a}^{R_t} [(R - R_i)^2 - a^2]^{1/2}\, \mathrm{d}R \quad (13)$$

$$K_{\mathrm{s}} = \frac{2}{\hbar}\sqrt{2\,\mu Q'}\,.\,R_b\, \mathfrak{J}_{cm}\,;$$

$$\mathfrak{J}_{cm} = \int_r^1 \left(\frac{c}{x} + \frac{m}{l^2} - 1\right)^{1/2} \mathrm{d}x \quad (14)$$

where

$$a = R_a - R_i = b[(Q' - Q)/E_b^0]^{1/2}\,; \quad b = R_t - R_i \quad (15)$$

$$c = rE_c/Q'\,; \quad m = r^2\, E_l/Q' \quad \text{and} \quad r = R_t/R_b\,. \quad (16)$$

By expressing the time in seconds, the energies in MeV and the lengths in fm, one obtains, after replacing the numerical constants, the following relationships :

$$T = \frac{1.4333 \times 10^{-21}}{E_{\mathrm{vib}}}\,[1 + \exp(K)]\,; \quad K = K_{\mathrm{ov}} + K_{\mathrm{s}} \quad (17)$$

$$K_{\mathrm{ov}} = 0.1296(E_b^0\, A_1\, A_2/A)^{1/2}\left[\sqrt{b^2 - a^2} - \frac{a^2}{b}\ln\frac{b + \sqrt{b^2 - a^2}}{a}\right] \quad (18)$$

$$K_{\mathrm{s}} = 0.4392(Q'\, A_1\, A_2/A)^{1/2}\, R_b\, \mathfrak{J}_{cm} \quad (19)$$

$$\mathfrak{J}_{cm} = (c + m - 1)^{1/2} - [r(c - r) + m]^{1/2} + \frac{c}{2}\left(\arcsin\frac{c - 2\,r}{\sqrt{c^2 + 4\,m}} - \arcsin\frac{c - 2}{\sqrt{c^2 + 4\,m}}\right) + \sqrt{m}\,\ln\left\{\frac{2\sqrt{m}\,[r(c - r) + m]^{1/2} + cr + 2\,m}{r[2\sqrt{m}(c + m - 1)^{1/2} + c + 2\,m]}\right\}. \quad (20)$$

If $l = 0$, one has $c = 1$, $m = 0$ and the well known formula

$$\mathfrak{J}_{10} = \arccos \sqrt{r} - \sqrt{r(1-r)} \tag{21}$$

is obtained.

The zero point vibration energy, $E_{\mathrm{vib}} = 0.51$ MeV, was determined by fit with experimental data, T^{exp}, on 376 alpha emitters, the same given as input data in the computer program described in reference [25]. In the variation with E_{vib} of the r.m.s. deviation of $\log T$ values defined by

$$\sigma = \left\{ \frac{1}{375} \sum_{i=1}^{376} [\log (T_i/T_i^{\mathrm{exp}})]^2 \right\}^{1/2} \tag{22}$$

there is a minimum $\sigma_{\min} = 1.02$ at $E_{\mathrm{vib}} = 0.51$ MeV. For $E_{\mathrm{vib}} = 0.2$ and 0.9 MeV, one has $\sigma = 2.20$. It is assumed that the optimum value for alpha decay could be used also for ^{5}He radioactivity. Of course, this assumption which presumably is an « optimistic » one, needs further theoretical (or experimental) support. Consequently, the absolute values for T given in the following sections should be taken only as tentative lower limits.

4. Ground state spontaneous emission.

The variation of Q-values for the emission of ^{5}He from the ground states of nuclei with masses tabulated in 1977 by Wapstra and Bos [2] is plotted in figure 3. Due to the pronounced odd-even effect, which is present for all odd-mass He isotopes (see Fig. 1), we have selected, for illustration in this figure, even Z-odd N nuclei.

There are two islands (in fact two archipelagos due to odd-even effects) of ^{5}He radioactivity — the hatched areas on figure 3 where $Q > 0$. The figure 4 shows the detailed position of ^{5}He emitters, relative to the Green approximation for the line of beta stability. The main archipelago, formed from two islands involves the medium-mass nuclei with Z = 83-92 and N = 127-137. The enhanced Q of the $N = 129$, $Z = 84$ nucleus, leading to the double magic daughter $N_1 = 126$, $Z_1 = 82$, is a strong shell effect, disturbing the smooth LDM-like trend, toward larger Q-values of the neutron deficient nuclei. This trend is manifested in the second archipelago of 4 islands of heavy transcurium nuclei with Z=97-105, N = 145-157.

Similarly, the neutron subshell $N_1 = 152$ explains the larger Q-values for $N = 155$, which are clearly seen on figure 5. In this figure only the positive Q-values are shown; some even-N nuclei have $Q < 0$ and the corresponding points are joined with dotted lines.

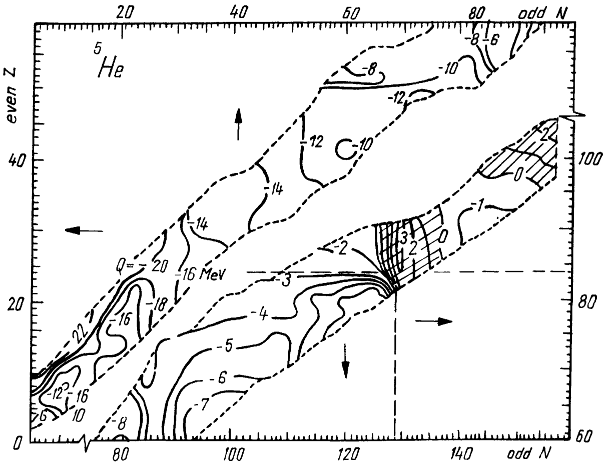

Fig. 3. — Q-values for ^{5}He decay of even Z, odd N nuclei tabulated by Wapstra and Bos [2].

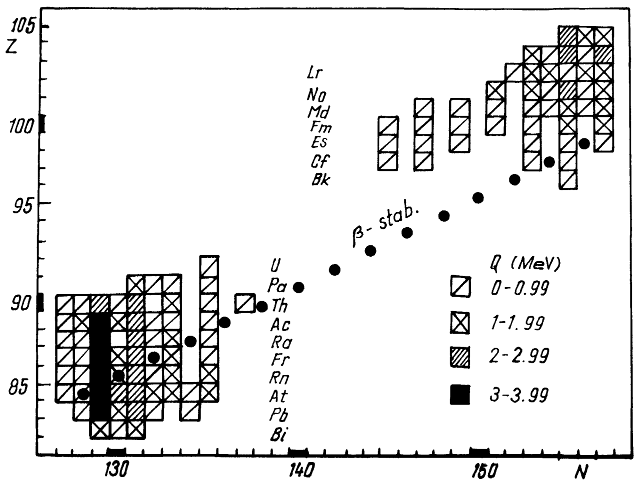

Fig. 4. — The ^{5}He emitters. The heavy dots correspond to the Green approximation for the line of beta stability.

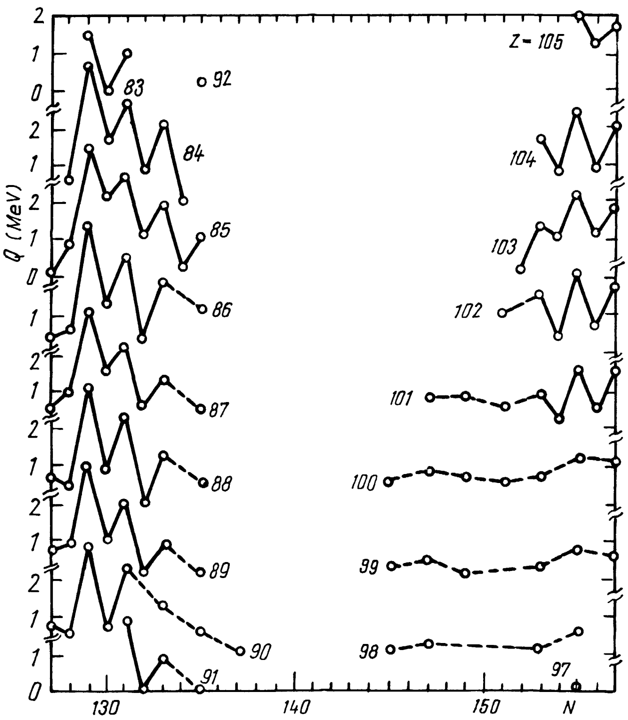

Fig. 5. — Positive Q-values of the two regions of ^{5}He radioactive nuclei.

Unfortunately the life-times for ^{5}He spontaneous emission from the ground states of the above mentioned nuclei, are very long even with the optimistic assumption mentioned above. Only 15 of all 110 emitters have the disintegration period, T, smaller than 10^{45} s (see Fig. 6). Such a reduced probability, as in the case of spontaneous fission of some actinides, will make difficult to observe experimentally this phenomenon, in the presence of other competing decay modes. For example the partial life-time, for ^{5}He radioactivity of ^{213}Po is $10^{20.9}$ s, but its total half-life due to α emission is only 4.2 μs.

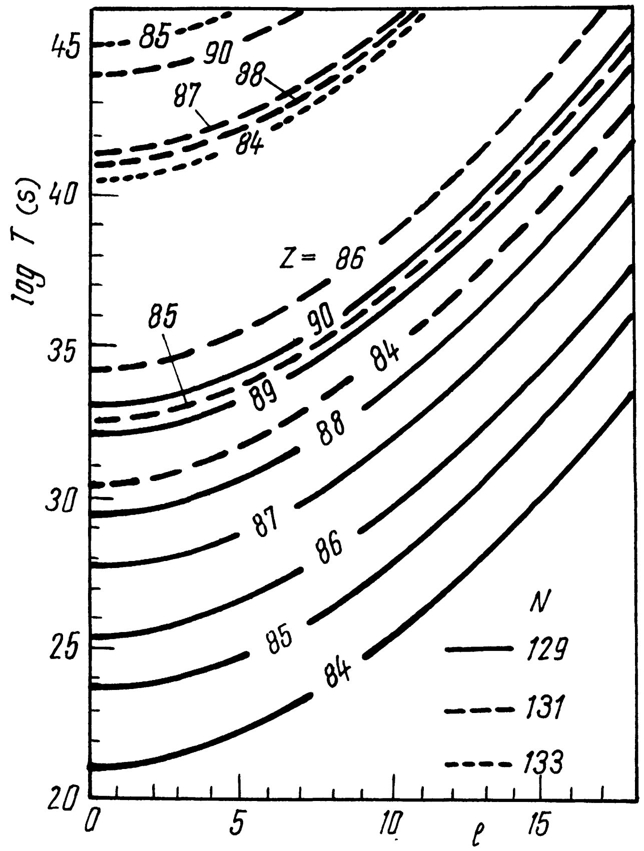

Fig. 6. — Variation of the life-times of some ^{5}He emitters with the angular momentum.

One has to consider also the contribution of the angular momentum $l\hbar$, rising the potential barrier. This is determined from the spin and parity conservation condition (see Eq. (3)). For example when ^{5}He is emitted from ^{213}Po, one obtains $l = 3$ or 5, because $I = 9/2^+$, $I_1^{\pi_1} = 0^+$ and $I_2^{\pi_2} = 3/2^-$. Five units of angular momentum produce an increase of about an order of magnitude of the life-time as is shown in figure 6. In the opposite direction acts the energy E^*, as will be shown in the next section.

Shorter life-times are expected to be met in the region of superheavy nuclei. The results presented in

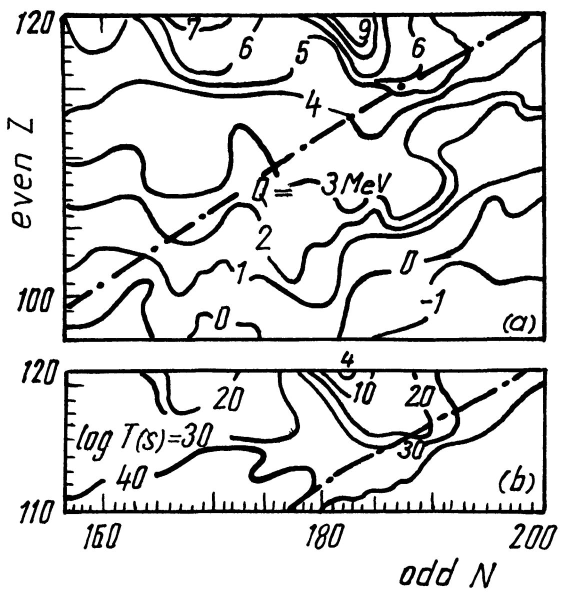

Fig. 7. — Q-values (a) and life-times (b) for some superheavy nuclei with binding energies predicted in reference [26].

figure 7a, obtained by using the binding energies calculated in reference [26], show that the island of ^{5}He radioactive heavy nuclei continues into the superheavy region. Larger Q-values lead to shorter life-times (Fig. 7b). Of course, the partial half-lives of ^{5}He disintegration computed in this work has to be compared with the life-times of other competing decay modes like α or β decay, spontaneous fission etc., in order to obtain the total disintegration period T_t.

5. Emission from excited states. Beta-delayed ^{5}He radioactivity.

The variation of T with the energy E^* (fraction of the excitation energy concentrated in this collective mode), plotted in figure 8 for some nuclei, suggests that a convenient method to obtain shorter life-times is to excite the ^{5}He emitters. The energy E_t^* required to obtain $T = T_t$ — the total half-life of a given nucleus, is the abscissa of the point given on each of the curves of figure 8. This ranges from 4.8 to 9.7 MeV (see Fig. 9) for analysed nuclei.

As it was expected from the beginning, the odd-N nuclei are better candidates for ^{5}He emission than their even-N neighbours. At $E^* = 6$ MeV energy, the life-times of some ^{5}He emitters become measurable. This can be seen from the figure 10, given only to illustrate that in principle, by raising the tunnelling energy, the partial half-lives for ^{5}He emission could be conveniently diminished. A more detailed analysis of both probabilities to excite the nuclear states and to compete with other disintegration modes of these states should be undertaken in order to plan an experiment. Such an analysis can

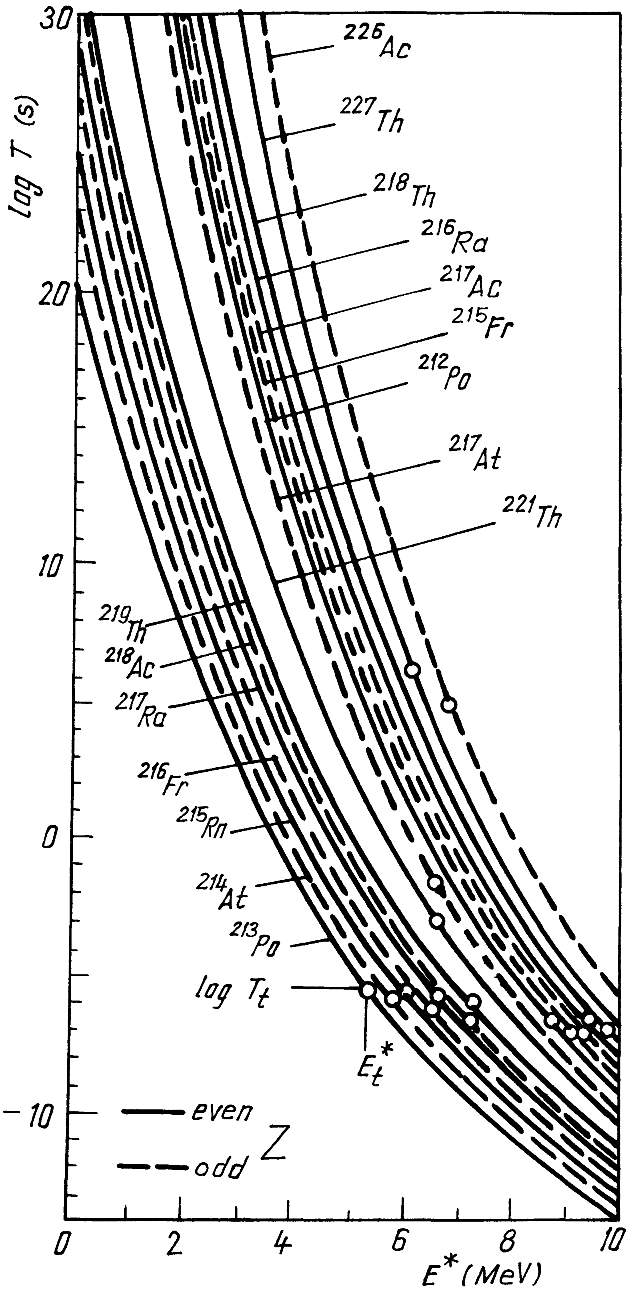

Fig. 8. — Variation of the partial half-lives of some ^{5}He emitters, with the energy E^*. The total life-time T_t of each isotope is given on the curves.

be done similarly to that of a β-delayed proton emission [27-30].

One way to excite the parent nucleus is to populate some of its excited levels by the β-decay of a precursor. The β-delayed ^{5}He radioactivity has a better chance to be experimentally determined. In this respect, from the available energy of the analysed nuclei, one can say that ^{155}Yb, ^{175}Pt and $^{209\text{-}217}$Ra after β^+-decay, as well as $^{9\text{-}11}$Be, $^{13\text{-}14}$B, $^{13\text{-}17}$C, $^{19\text{-}21}$O, etc., after β^- decay, are in a privileged position.

The ^{5}He decay of the ^{9}Be excited states fed by the β^- decay of the ^{9}Li precursor have been already experimentally determined [16].

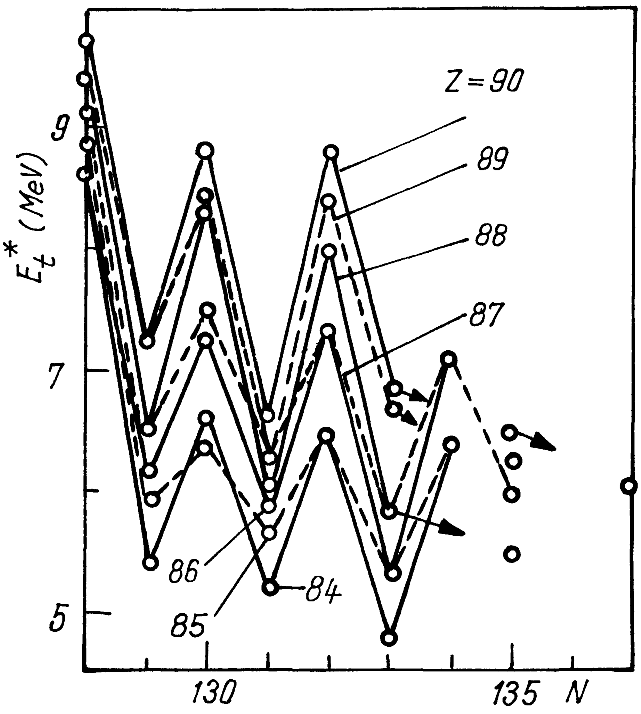

Fig. 9. — The energy E_t^* required to obtain a partial life-time for ^{5}He emission equal to the total half-life.

Up to now we have considered only the nuclei with masses tabulated in 1977 by Wapstra and Bos [2]. Taking into account that the beta decays of exotic nuclei (far off the β-stability line [31]) have high Q-values and can populate a large number of excited levels, it is expected that many other β-delayed ^{5}He radioactive nuclei could be found in the yet unexplored regions.

We are looking for neutron deficient β^+- or neutron abundant β^--precursors with high enough positive Q_β value, which are able to populate, with large probability, excited states E leading to $E + Q_5 \gtrsim 5$ MeV in the (A, Z) nucleus, that is $Q_\beta + Q_5 \gtrsim 5$ MeV (where $Q_5 \equiv Q(^5\text{He})$). This gives a measure of the energy available for ^{5}He emission. Hence, the atomic masses for the $(A, Z+1)$ β^+-precursor obey to one of the equations

$$M(A, Z+1) - M(A-5, Z-2) - M(5, 2) \gtrsim 5 \text{ MeV} \tag{23}$$

$$M(A, Z+1) - M(A-5, Z-2) - M(5, 2) \gtrsim 6 \text{ MeV} \tag{24}$$

when the decay mechanism involves the electron capture or the positon emission, respectively. Similarly, for the $(A, Z-1)$ β^--precursor, one has :

$$M(A, Z-1) - M(A-5, Z-2) - M(5, 2) \gtrsim 5 \text{ MeV}\,. \tag{25}$$

The partial β decay rates are determined [29, 32] by the allowed phase space and the kinematic effects

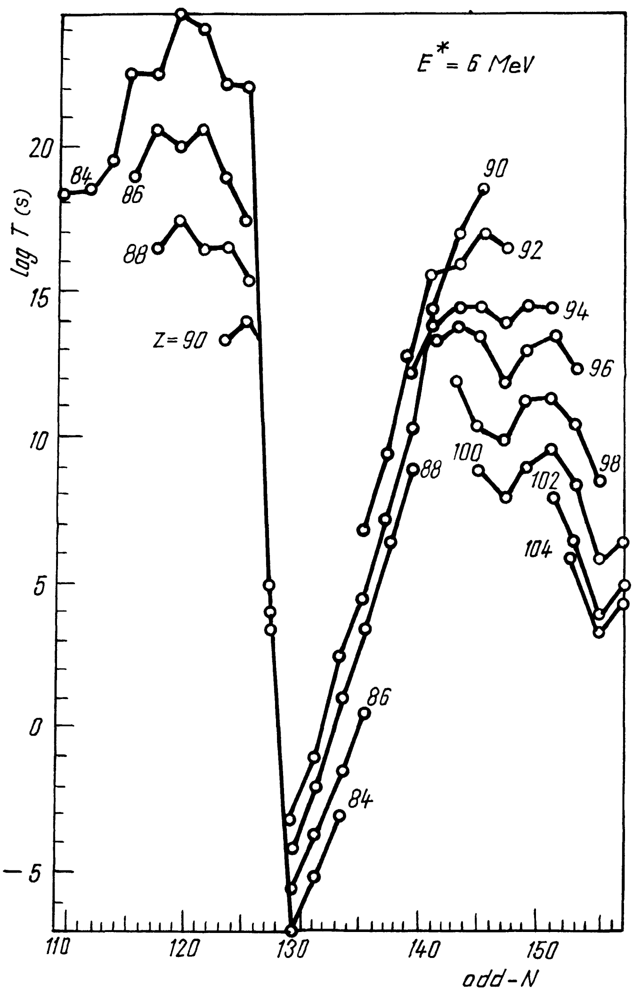

Fig. 10. — Partial life-times for ^{5}He emission from excited states with $E^* = 6$ MeV. E^* is the fraction of the excitation energy concentrated in the separation degree of freedom.

of the emitted fermions, which are accounted for in the statistical rate function $f(Q_\beta - E, Z)$ and the nuclear structure (the overlap between the initial state in the parent nucleus and the final state with energy E populated in the daughter) which is contained in the β-strength function $S_\beta(E)$. The absolute β-intensity per unit interval of the excitation energy in the daughter (in MeV^{-1}) is given by :

$$I_\beta(E) = S_\beta(E).f(Q_\beta - E, Z).T_\beta \qquad (26)$$

where T_β is the beta decay half-life. This quantity is directly related to the Gamow-Teller and Fermi transition matrix elements, characterized by the following selection rules for the nuclear spin I, parity π and isospin T : $\Delta I = I_i - I_f = 0, \pm 1 \; (0 \not\to 0)$; $\pi_i = \pi_f$ and $\Delta I = 0$, $\pi_i = \pi_f$, $\Delta T = T_i - T_f = 0$, respectively.

The superallowed Fermi transition, populating the isobar analog state in the daughter nucleus, has a low fT_β value, of the order of $\log(fT_\beta) \simeq 3$, and the corresponding β-strength function $S_\beta(E)$ has the shape of a narrow resonance [27]. The Fermi transition is interesting only for $N < Z$, β^+-decaying precursors because for β^--decay the analog state is in the region of energetically forbidden transitions.

The typical value for allowed transitions is $\log(fT_\beta) = 5$, and for forbidden ones $\log(fT_\beta) \gtrsim 9$. In the case of the Gamow-Teller transitions, according to the « gross-theory » [33, 34], the β-strength function has the shape of a giant resonance (several MeV width) with a maximum displaced from the analog state.

Usually, the increasing part of the β-strength function *vs.* excitation energy takes place below the ^{5}He binding energy; only the decreasing tail corresponds to the significant ^{5}He kinetic energies, E_5. On the other hand, the ratio Γ_5^{if}/Γ^i of the partial width, Γ_5^{if}, for the ^{5}He decay from the state i of the emitter (A, Z) to the state f of the daughter $(A - 5, Z - 2)$ nucleus, to the total decay width, Γ^i, of the state i, is expected to increase with E_5.

For the mean ^{5}He intensity one can write a similar equation with that given for β-delayed protons [29] :

$$I_5(E_5) = \sum_{if} \langle I_\beta^i \rangle_{E_5} \cdot \left\langle \frac{\Gamma_5^{if}}{\Gamma^i} \right\rangle_{E_5} \qquad (27)$$

where I_β^i is the intensity of β decays from the precursor to the state i of the emitter, and the total decay width of this state Γ^i, is a sum of the partial widths of all competing processes for which the output channels are open, e.g. : gamma decay Γ_γ^i, proton decay Γ_p^i, alpha decay Γ_α^i, ^{5}He decay Γ_5^i, etc.

The parentheses $\langle \; \rangle$ in equation (27) signify a statistical Porter-Thomas mean value. The sum is extended over all pairs of states i, f between which ^{5}He particles of the energy E_5 could be emitted.

From these considerations, it is expected that a bell shaped ^{5}He energy spectrum will be obtained. Broad alpha spectra from the break up of ^{5}He into an alpha particle and a neutron, have been calculated in reference [16].

It is interesting to evaluate also the chance of ^{5}He to compete with the evaporation of other charged particles in the de-excitation of a compound nucleus. Some percentage of the alpha particles and neutrons produced in nuclear reactions originate from ^{5}He disintegration after its emission.

6. Conclusions.

A systematic investigation of the stability of the nuclei, with masses tabulated by Wapstra and Bos, toward the emission of He isotopes, revealed that a new kind of disintegration ^{5}He-decay is energetically possible for some 110 nuclides grouped in two archipelagos with $Z = 83$-92, $N = 127$-137 and $Z = 97$-105, $N = 145$-157. The last region extends also for superheavy nuclei.

The life-time was estimated by using an analytical relationship derived from the fission theory of light particle emission, extended to account for angular momentum and nuclear excitation effects. In this way it is tentatively predicted that only 15 nuclei have half-lives smaller than 10^{45} s. The most promising candidate is ^{213}Po leading to the double magic daughter nucleus.

Usually the centrifugal barrier is not very important; an angular momentum equal to five units of $\hbar$, produce an increase in the life-time of one order of magnitude.

A better chance, to be experimentally confirmed, has the β delayed ^{5}He radioactivity, i.e. the ^{5}He emission from an excited state populated by β decay of a precursor. Examples of such nuclei are : ^{155}Yb, ^{175}Pt, $^{209-217}$Ra excited after β^+-decay and $^{9-11}$Be, $^{13-14}$B, $^{13-17}$C, $^{19-21}$O excited after β^--decay.

It is suggested that ^{5}He emission from excited states could compete in some cases with the evaporation of other charged particles in the de-excitation of a compound nucleus produced by nuclear reactions.

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