LES MASSES

Données Experimentales :

A.H. Wapstra and Georges AUDI (CSNSM, Orsay) in Nuclear Physics A

dernière référence : Nucl. Phys. A432 (1985) 1-54 part I
Nucl. Phys. A 432 (1985) 55-139 part II
part III, IV
} 1983

2396 noyaux mesurés (07/89)

→ E(A,Z), B(A,Z), M(A,Z), $\Delta M = Q_{\beta^-}, Q_{EC}$ → 1a → $Q^{réf}_{\beta^+,\beta^-,EC}$

→ $S_n, S_p, S_{2n}, S_{2p}, Q_\alpha, Q_{Pa}$ .... → 1b → Q des réactions

Formules de Masse :

dernière compilation : Atomic Data and Nuclear Data Tables vol 39 n°2 (1988) "1986-1987 atomic mass predictions"

nécessaire pour une systematique de tous les noyaux possibles
→ 2 → terminaison des chaines isotopiques pour le processus r

exemples : formules de la goutte liquide (liquid droplet model)

qq auteurs : P. Möller, J.R. Nix, W.D. Myers, W.J. Swiatecki
J. TREINER (IPN, Orsay), François TONDEUR (ULB)

Applications Astrophysiques : 1a, 1b, 2

+ $\Delta M(^{187}Re, ^{187}Os)$ (cf β^-) $Q_{\beta^-} = 2.64$ keV !!

$\Delta M(^{205}Tl, ^{205}Pb)$ $Q_{\beta^-} = 53.5 \pm 1.6$ keV

FORMULES DE MASSE

(modèle de la goutte liquide)

nombreux auteurs : von Weizsäcker 1935
Bethe, Bacher 1936
Myers, Swiatecki 1966, 1969
....
Möller, Nix .... 19..., 1988

la plus simple (toujours bien utile, surtout en astrophysique!)

$$B(A,Z) = a_v . A - a_s A^{2/3} - a_c \frac{Z^2}{A^{1/3}} - a_A \frac{(N-Z)^2}{A}$$

↑↑↑↑ termes macroscopiques

$$+ E_p \quad (+ E_s)$$

← termes microscopiques

par ex. $a_v = 15.68$
$a_s = 18.56$
$a_c = 0.717$
$a_A = 28.1$

$$E_p = \frac{1}{2}\left((-1)^N + (-1)^Z\right)\delta(A)$$

$$\delta(A) = \frac{34}{A^{3/4}} \quad \text{ou} \quad \frac{12}{A^{1/2}}$$

Valentin "old" ed. fig V.1 p 168
"new" ed. fig IV.1 p 129

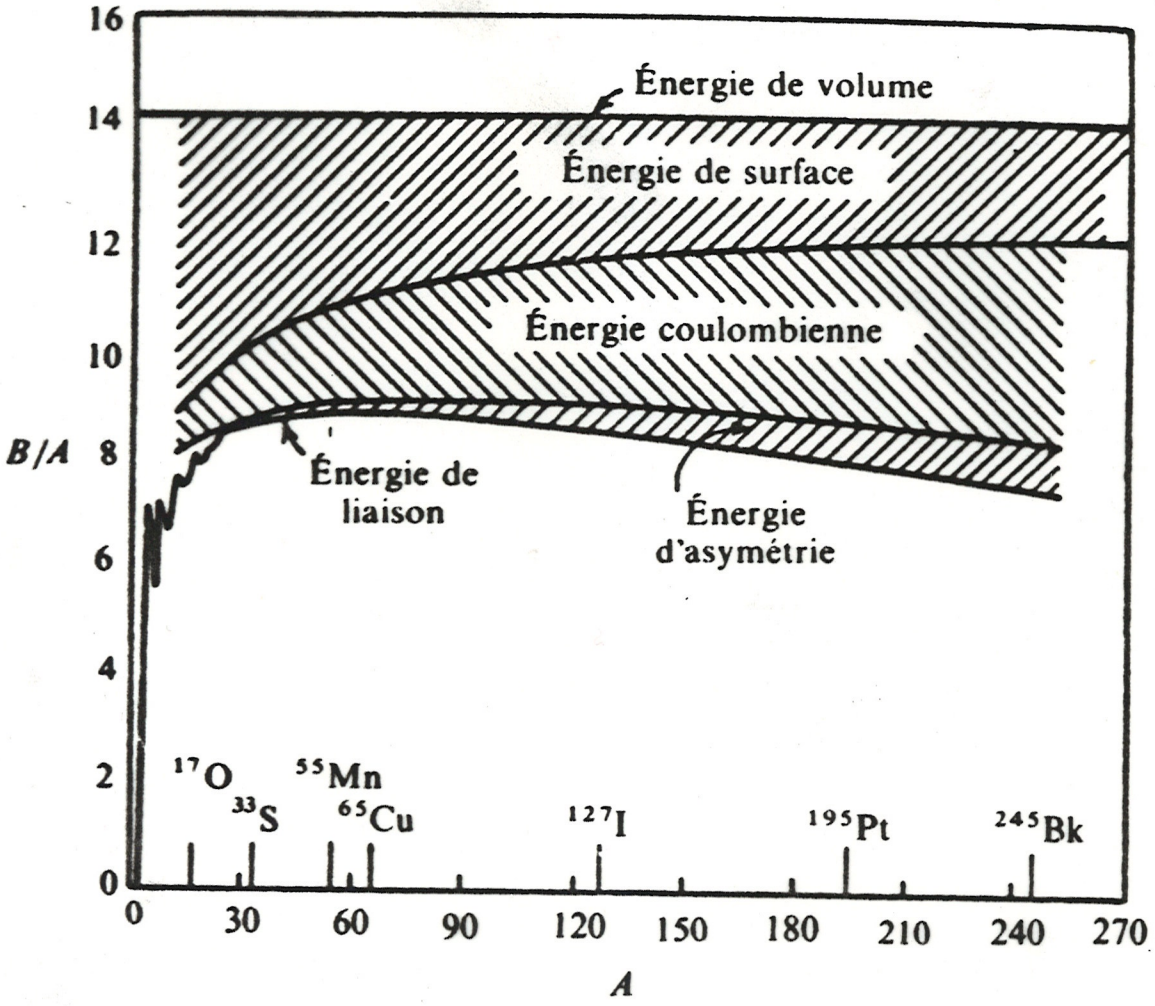


FIGURE IV.1

On constatera qu'il existe un facteur voisin de deux entre l'énergie de volume seule et l'énergie expérimentale. Chacun des termes de surface, coulombien et d'asymétrie contribue à réduire le désaccord que l'on enregistrerait en ne retenant que le terme de volume.

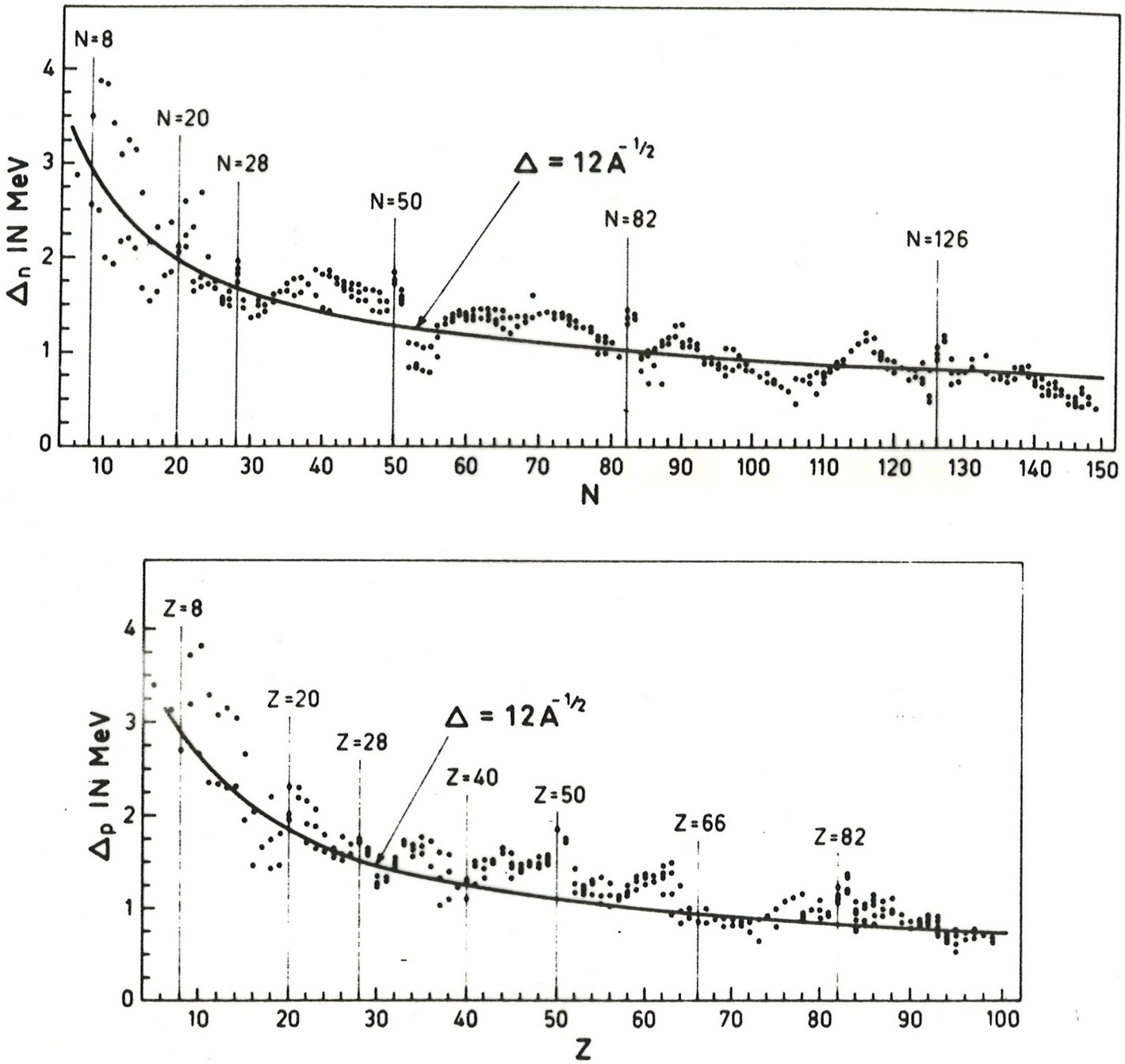


Figure 2-5 The odd-even mass differences for neutrons and protons are based on the analysis of N. Zeldes, A. Grill, and A. Simievic, *Mat. Fys. Skr. Dan. Vid. Selsk.* **3**, No. 5 (1967).

Bohr and Mottelson I p 170

quelques applications :

- parabole de masse

pour A fixé

$$E(A,Z) = C^{te}(A) - Z(m_n - m_H) + a_c \frac{Z^2}{A^{1/3}} + a_A \frac{(A-2Z)^2}{A} - E_p$$

$$E(A,Z) = a + bZ + cZ^2 - E_p$$

- Energies de séparation

$$S_n = \frac{\partial B(N,Z)}{\partial N}\Big|_Z = \frac{\partial B(A,Z)}{\partial A}\Big|_Z$$

$$S_p = \frac{\partial B(N,Z)}{\partial Z}\Big|_N$$

- Isobare le plus stable (vallée de stabilité)

on écrit $\frac{\partial M}{\partial Z}\Big|_A = 0$ (et non $\frac{\partial B}{\partial Z}\Big|_A = 0$)

$$Z = \frac{1+\varepsilon}{2 + \frac{a_c}{2a_A} A^{2/3}} \qquad \varepsilon = \frac{1}{4}\frac{Q_{p^-(n)}}{a_A} \equiv 0$$

$$\frac{A}{Z} = 1.98 + 0.0124\, A^{2/3} \qquad \frac{N}{Z} = 0.98 + 0.0124\, A^{2/3}$$

Lire Z/A au lieu de Z

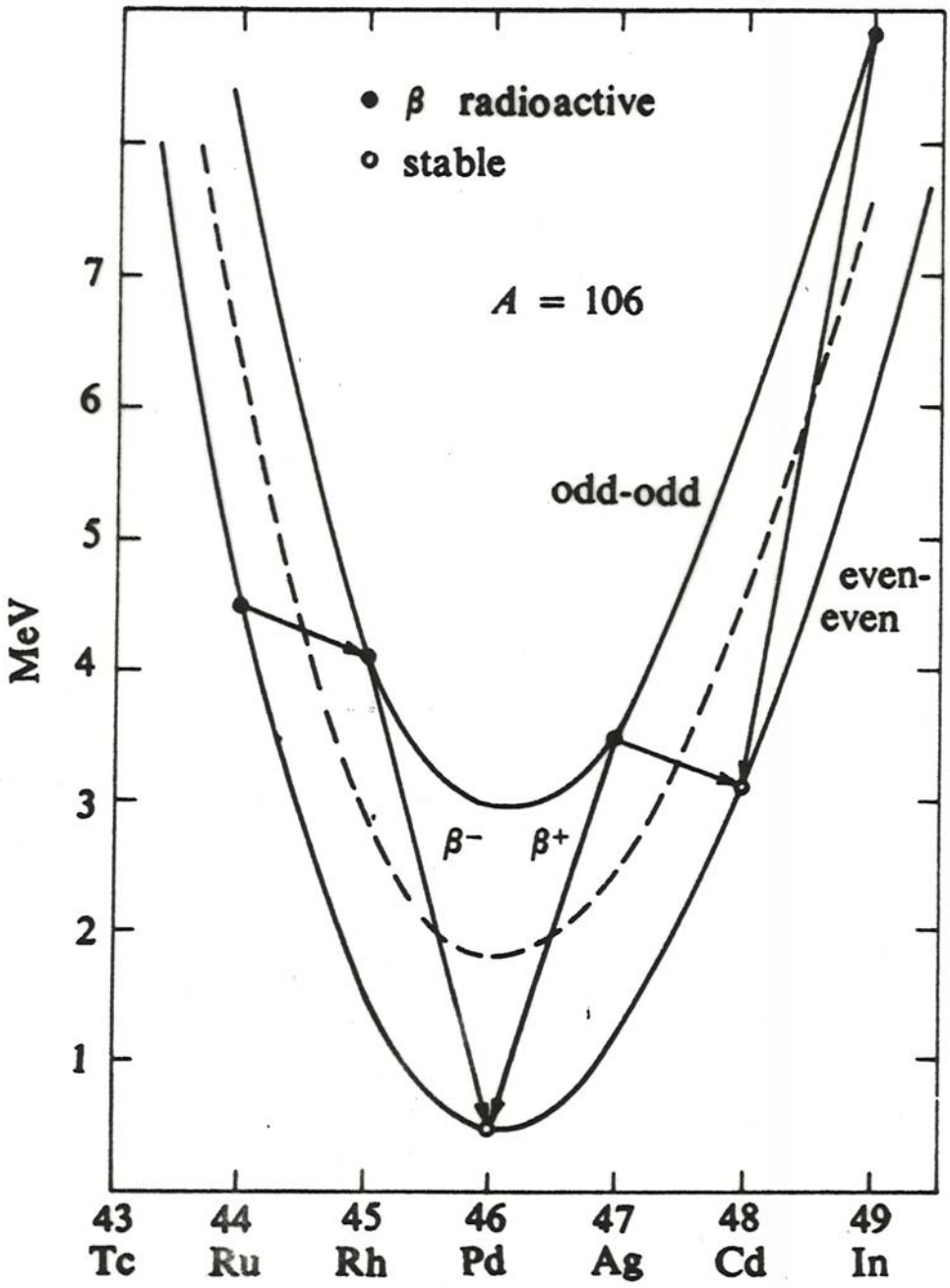


Figure 6-18 Energy (in MeV) of nuclei of mass number 106. The zero point on the energy scale is arbitrary.

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– désintégration alpha

$$Q_\alpha = B_\alpha - \delta B \qquad \delta B = \frac{\partial B(A,Z)}{\partial A}\underbrace{\delta A}_{4} + \frac{\partial B(A,Z)}{\partial Z}\underbrace{\delta Z}_{2}$$

$B_\alpha =$ [illegible]

$$\delta B = 4 a_v - \frac{8}{3} a_s A^{-1/3} - 4 a_c \frac{Z}{A^{1/3}}\left(1 - \frac{Z}{3A}\right) + 4 a_A \left(1 - \frac{2Z}{A}\right)^2$$

$$Q_\alpha \simeq \frac{49.5}{A^{1/3}}\left[1 + 0.057\, Z\left(1 - \frac{Z}{3A}\right)\right] - 112.\left(1 - \frac{2Z}{A}\right)^2 - 35.7$$

et pour l'isotope le plus stable (cf supra)

$Q_\alpha \gtrsim 3.5$ MeV pour $A \gtrsim 190$ ($T_{1/2} \simeq 10^{10}$ ans)

– fission (symétrique)

$$Q_f \equiv 2\, B\left(\frac{A}{2}, \frac{Z}{2}\right) - B(A,Z)$$

$$Q_f = a_s A^{2/3}(1-\delta) + a_c \frac{Z^2}{A^{1/3}}(1-\delta^{-2}) \qquad \delta = 2^{1/3}$$

$$Q_f \simeq (1-\delta) a_s A^{2/3}\left[1 - \frac{a_c}{a_s}\frac{Z^2}{A}\frac{1+\delta}{\delta^2}\right]$$

$$Q_f \simeq -4.82\, A^{2/3}\left[1 - 0.055\frac{Z^2}{A}\right]$$

– équation d'état de la matière nucléaire

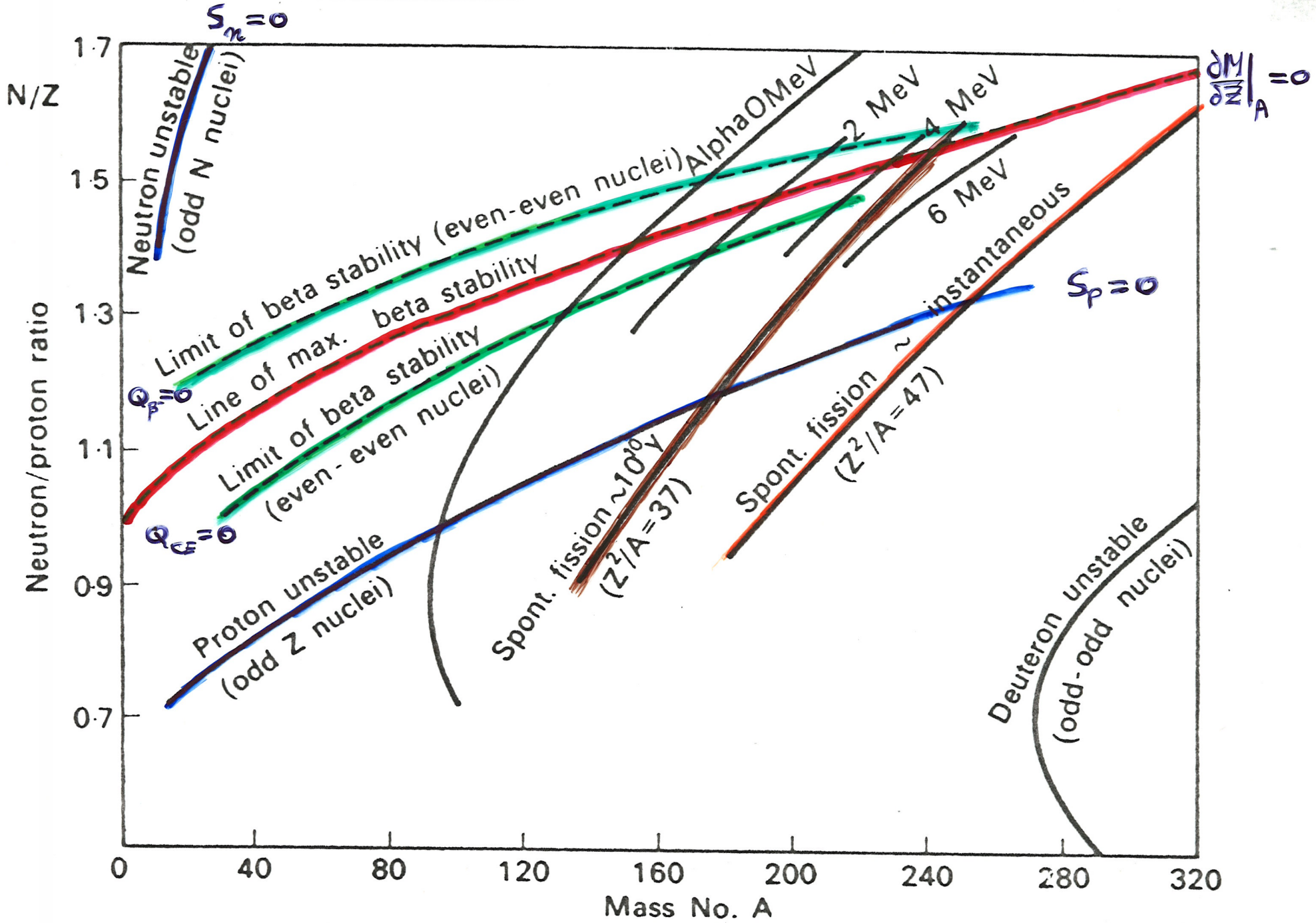


FIG. 14.2. The boundary lines for nuclear stability against various types of decay as predicted by the liquid-drop model.

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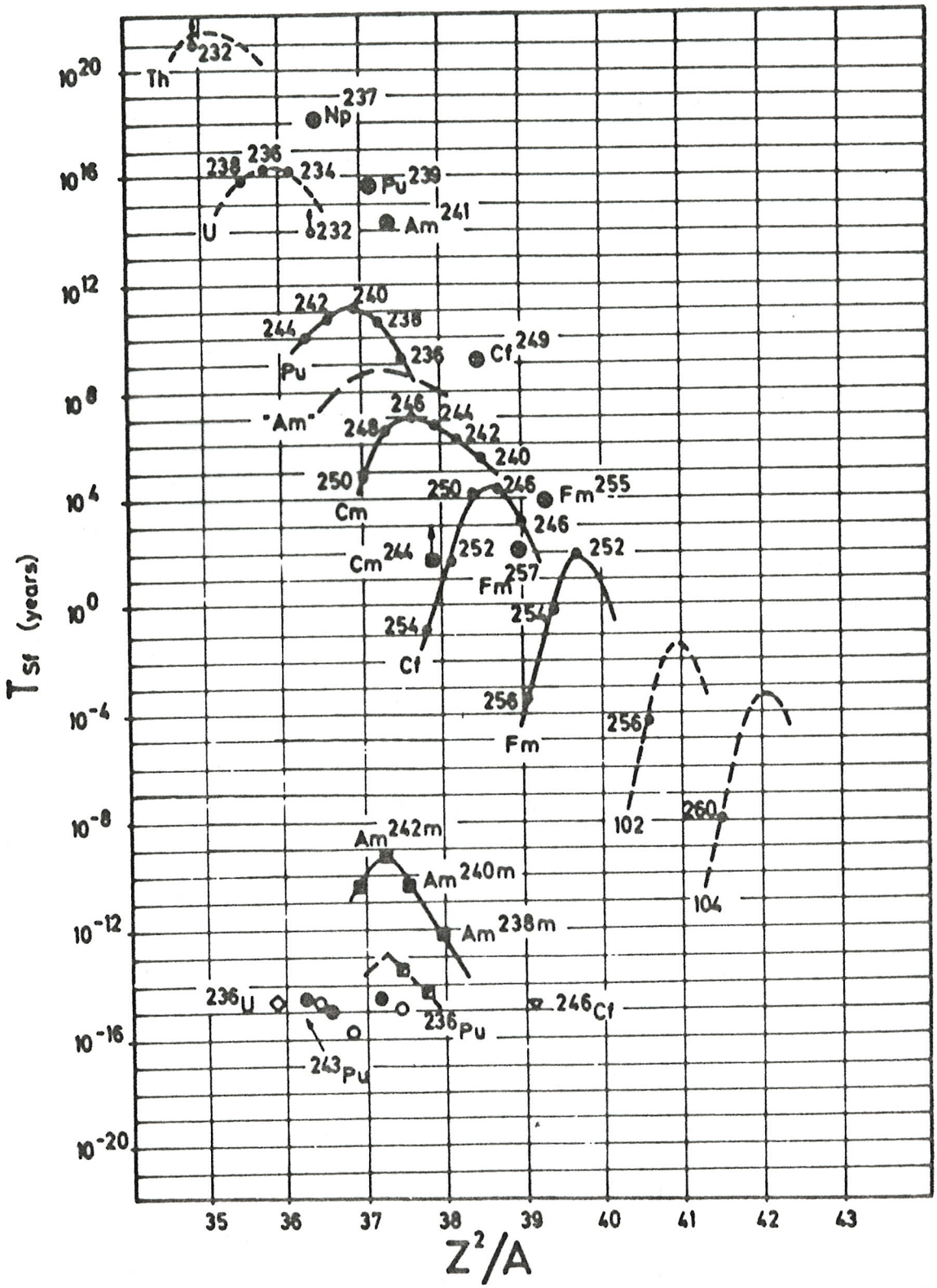


Figure 11-39 Reciprocals of spontaneous fission decay constants multiplied by $\log_e^2$, called spontaneous fission lifetimes. Measured lifetimes for the spontaneous fission isomers are also shown. [From V. M. Strutinsky and H. C. Paul, *Physics and Chemistry of Fission*, p. 157, IAEA, Vienna (1969).]

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$E_{macr}(Z, N, \text{shape}) =$

$M_H Z + M_n N$	mass excesses of Z hydrogen atoms and N neutrons
$+\left(-a_1 + J\bar{\delta}^2 - \frac{1}{2}K\bar{\epsilon}^2\right)A$	volume energy
$+\left(a_2 B_1 + \frac{9}{4}\frac{J^2}{Q}\bar{\delta}^2\frac{B_t^2}{B_1}\right)A^{2/3}$	surface energy
$+ a_3 A^{1/3} B_k$	curvature energy
$+ a_0 A^0$	A^0 energy
$+ c_1 \frac{Z^2}{A^{1/3}} B_3$	Coulomb energy
$- c_2 Z^2 A^{1/3} B_r$	volume redistribution energy
$- c_4 \frac{Z^{4/3}}{A^{1/3}}$	Coulomb exchange correction
$- c_5 Z^2 \frac{B_w B_s}{B_1}$	surface redistribution energy
$+ f_0(k_f r_p)\frac{Z^2}{A}$	proton form-factor correction
$- c_a(N - Z)$	charge-asymmetry energy
$+ W\left[\lvert I\rvert + \begin{cases} 1/A, & Z \text{ and } N \text{ odd and equal} \\ 0, & \text{otherwise} \end{cases}\right]$	Wigner energy
$+ \begin{cases} +\bar{\Delta}_p + \bar{\Delta}_n - \delta_{np}, & Z \text{ and } N \text{ odd} \\ +\bar{\Delta}_p, & Z \text{ odd and } N \text{ even} \\ +\bar{\Delta}_n, & Z \text{ even and } N \text{ odd} \\ +0, & Z \text{ and } N \text{ even} \end{cases}$	average pairing energy
$- a_{el} Z^{2.39}$	energy of bound electrons (3)

P. Möller et al. "Finite-Range Droplet Model" ADNDT 39 (1988) 225-233

P. Möller and J.R. Nix "Unified Macroscopic-Microscopic Model" ADNDT 39 (1988) 213-223

$E_{macr}(Z, N, \text{shape}) =$

$M_H Z + M_n N$	mass excesses of Z hydrogen atoms and N neutrons
$- a_v(1 - \kappa_v I^2)A$	volume and volume-asymmetry energies
$+ a_s(1 - \kappa_s I^2)B_1 A^{2/3}$	generalized surface and surface-asymmetry energies
$+ c_0 A^0$	A^0 energy
$+ c_1 \frac{Z^2}{A^{1/3}} B_3$	direct Coulomb energy
$- c_4 \frac{Z^{4/3}}{A^{1/3}}$	exchange Coulomb energy
$+ f(k_f r_p)\frac{Z^2}{A}$	proton-form-factor correction
$- c_a(N - Z)$	charge-asymmetry energy
$+ W\left(\lvert I\rvert + \begin{cases} 1/A, & Z \text{ and } N \text{ odd and equal} \\ 0, & \text{otherwise} \end{cases}\right)$	Wigner energy
$+ \begin{cases} +\bar{\Delta}_p + \bar{\Delta}_n - \delta_{np}, & Z \text{ and } N \text{ odd} \\ +\bar{\Delta}_p, & Z \text{ odd and } N \text{ even} \\ +\bar{\Delta}_n, & Z \text{ even and } N \text{ odd} \\ +0, & Z \text{ and } N \text{ even} \end{cases}$	average pairing energy
$- a_{el} Z^{2.39}$	energy of the bound electrons (2)