SYSTEMATIQUE NUCLEAIRE

QUELQUES STATISTIQUES :

nombres d'isotopes connus : (depuis 1930)

→ Il doit exister 4000 - 5000 isotopes

dernière table de masse (07/1989) : 2396 isotopes

MISE EN EVIDENCE DES EFFETS DE PARITÉ

Isotopes "pair-pair", "impair", "impair-impair"

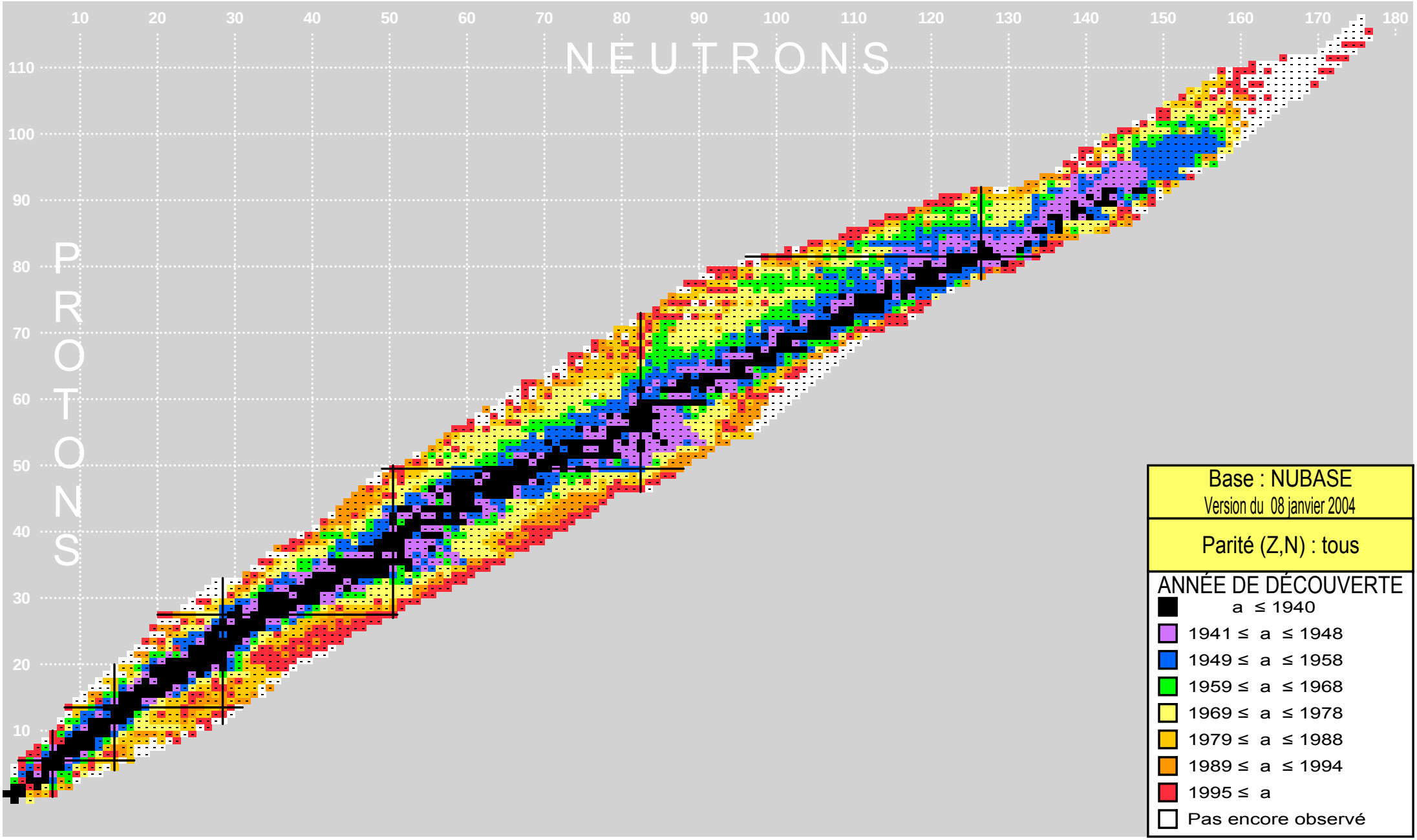
MISE EN EVIDENCE DES NOMBRES MAGIQUES :

(2)	8	20	28	50	82	126
Z → He	O	Ca	Ni	Sn	Pb	

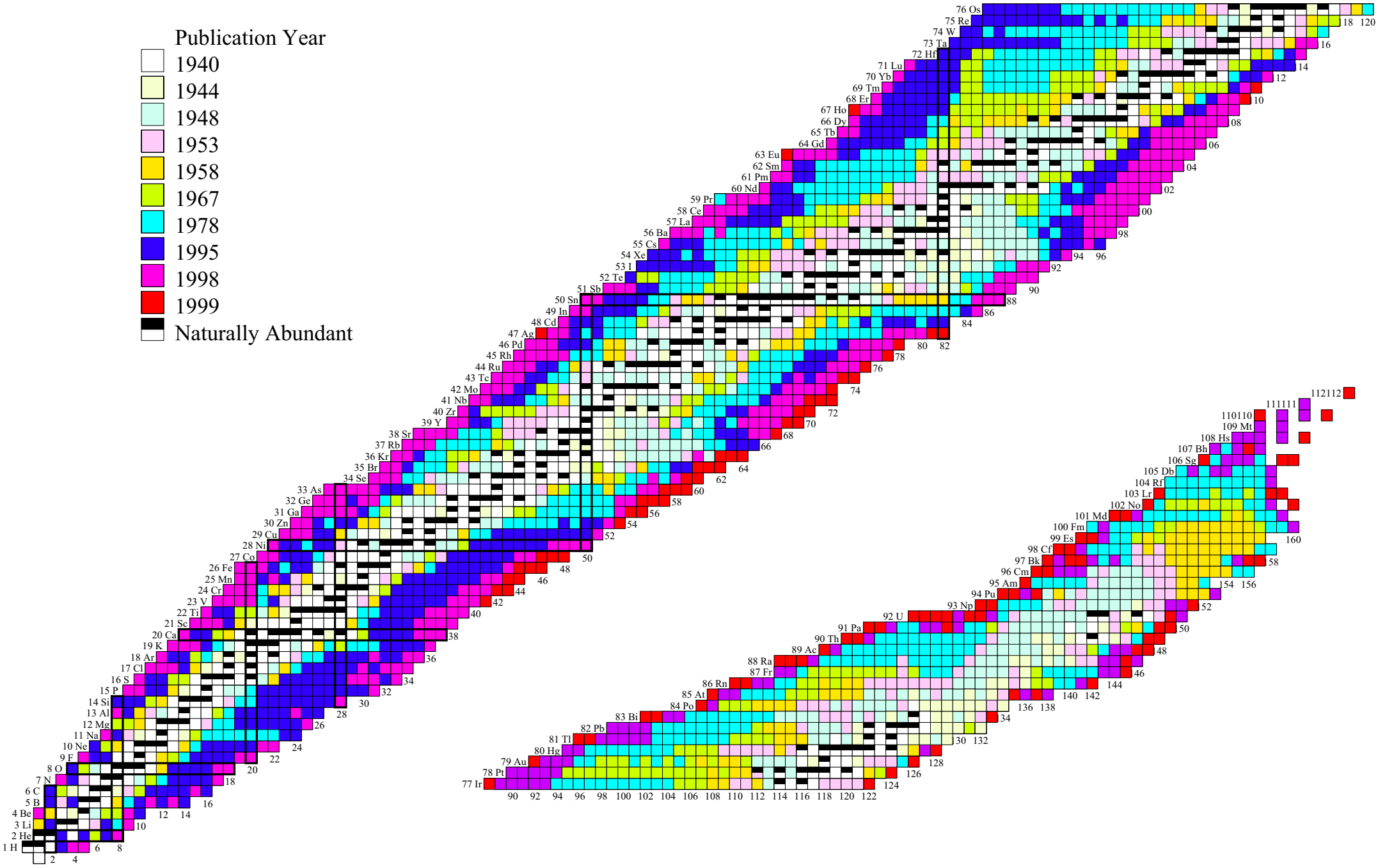
→ noyaux doublement magiques : ^{4}He, ^{16}O, ^{40}Ca et ^{48}Ca, ^{56}Ni, ^{132}Sn, ^{208}Pb, ^{78}Ni, ^{100}Sn
+ evt : ^{10}He

→ cf théorie : Le modèle en couches "shell model"

cf physique atomique : Z = 2 (He), 10 (Ne), 18 (Ar), 36 (Kr), 54 (Xe), 86 (Rn)


NEUTRONS
PROTONS
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Base : NUBASE
Version du 08 janvier 2004
Parité (Z,N) : tous
ANNÉE DE DÉCOUVERTE
a ≤ 1940
1941 ≤ a ≤ 1948
1949 ≤ a ≤ 1958
1959 ≤ a ≤ 1968
1969 ≤ a ≤ 1978
1979 ≤ a ≤ 1988
1989 ≤ a ≤ 1994
1995 ≤ a
Pas encore observé

Evolution of the *Table of Isotopes*



A	Z	N	Appellation	Nombre de noyaux stables
Pair	Pair	Pair	Pair-pair	156
	Impair	Impair	Impair-impair	4 (§) + qq (*)
Impair	Pair	Impair	Impair	53
	Impair	Pair		50

(§) ^{2}H
^{6}Li
^{10}B
^{14}N

(*) Qu'est ce qu'un élément stable ???
e.g. ^{76}Ge ($T_{1/2}$ = 1.58 +/- 0.17 Zy , 7.6% du Ge)

Aussi, selon NuBase (2004) :
284 noyaux de $T_{1/2} > 1$ Gyr
dont 196 noyaux stables

Un élément instable peut aussi être (assez) abondant
e.g. U, ^{40}K,

Une curiosité ^{180}Ta instable ($T_{1/2}$ = 8.152 h)
mais $^{180}Ta^*$ (E^* = 75.3 +/- 1.3 keV, $T_{1/2} > 1.2$ Py, 0.012% du Ta)

Noyau radioactif primaire	Période radioactive (secondes)	Pourcentage dans l'élément naturel	Modes de désintégration
$^{40}_{19}K$	$0{,}410\ 10^{17}$	0,0118	β^-, CE
$^{50}_{23}V$	$0{,}189\ 10^{24}$	0,24	β^-, CE
$^{87}_{37}Rb$	$0{,}148\ 10^{19}$	27,85	β^-
$^{115}_{49}In$	$0{,}158\ 10^{23}$	95,72	β^-
$^{123}_{52}Te$	$0{,}379\ 10^{21}$	0,87	CE
$^{138}_{57}La$	$0{,}347\ 10^{19}$	0,089	CE, β^-
$^{142}_{58}Ce$	$0{,}158\ 10^{24}$	11,07	α
$^{144}_{60}Nd$	$0{,}757\ 10^{23}$	23,95	α
$^{147}_{62}Sm$	$0{,}335\ 10^{19}$	14,97	α
$^{148}_{62}Sm$	$0{,}379\ 10^{21}$	11,24	α
$^{149}_{62}Sm$	$0{,}126\ 10^{23}$	13,83	α
$^{152}_{64}Gd$	$0{,}347\ 10^{22}$	0,200	α
$^{156}_{66}Dy$	$0{,}631\ 10^{22}$	0,052	α
$^{176}_{71}Lu$	$0{,}694\ 10^{18}$	2,59	β^-
$^{174}_{72}Hf$	$0{,}136\ 10^{24}$	0,18	α
$^{187}_{75}Re$	$0{,}126\ 10^{19}$	62,93	β^-
$^{190}_{78}Pt$	$0{,}221\ 10^{20}$	0,0127	α
$^{192}_{78}Pt$		0,78	α
$^{204}_{82}Pb$	$0{,}442\ 10^{25}$	1,48	α
$^{232}_{90}Th$	$0{,}445\ 10^{18}$		α, FS
$^{235}_{92}U$	$0{,}225\ 10^{17}$	0,72	α, FS
$^{238}_{92}U$	$0{,}142\ 10^{18}$	99,27	α, FS

Radioéléments primaires

NUBASE data on 180Ta

SECOND ISOMERIC STATE

Excitation Energy : 1451.0 (1.0) keV
Half life : 45 (2) us
Jπ : 15^-
Decay Mode(s) :

FIRST ISOMERIC STATE

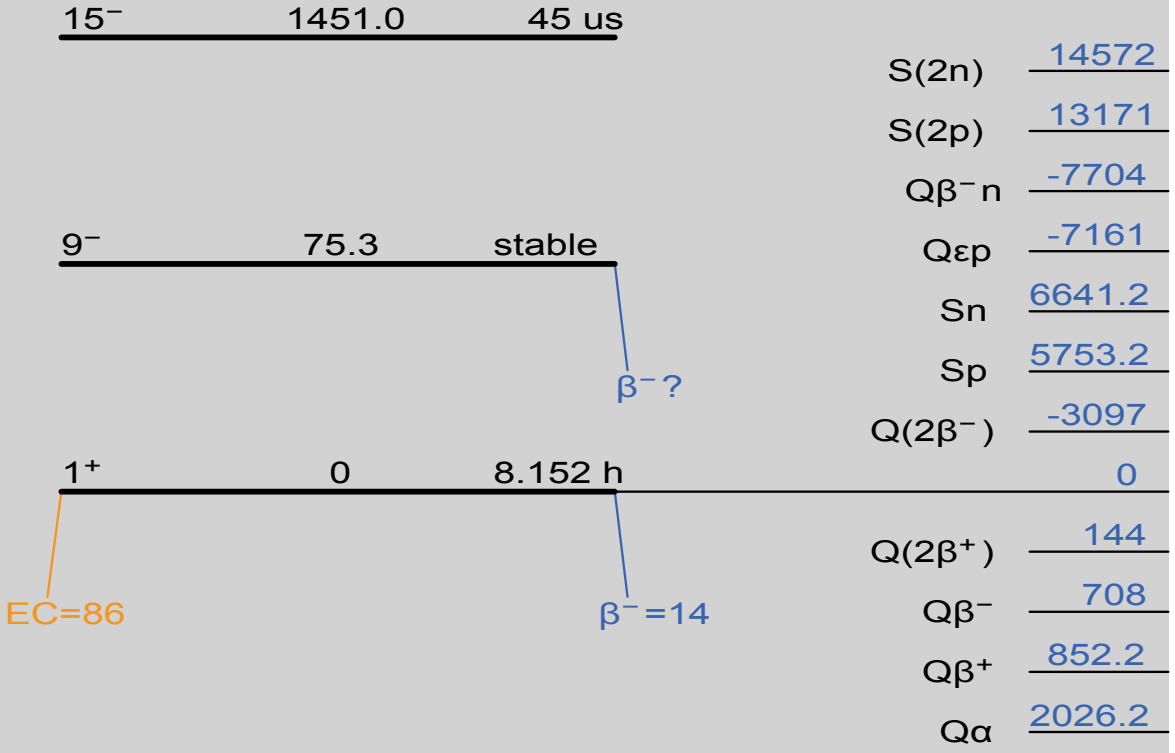
Excitation Energy : 75.3 (1.3) keV from RQ
Half life : stable (>1.2Py)
Jπ : 9^-
Abundance=0.012 (2)%, β^-?

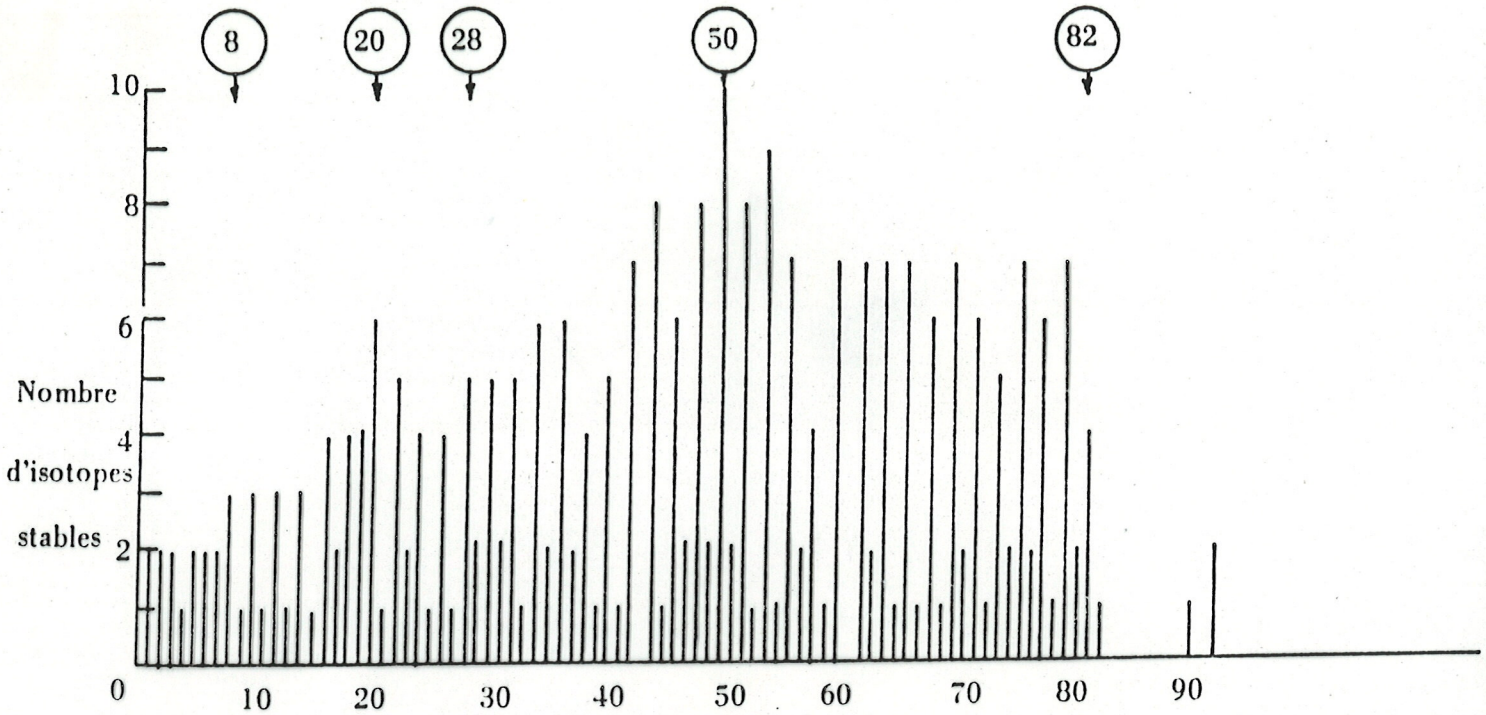
GROUND STATE

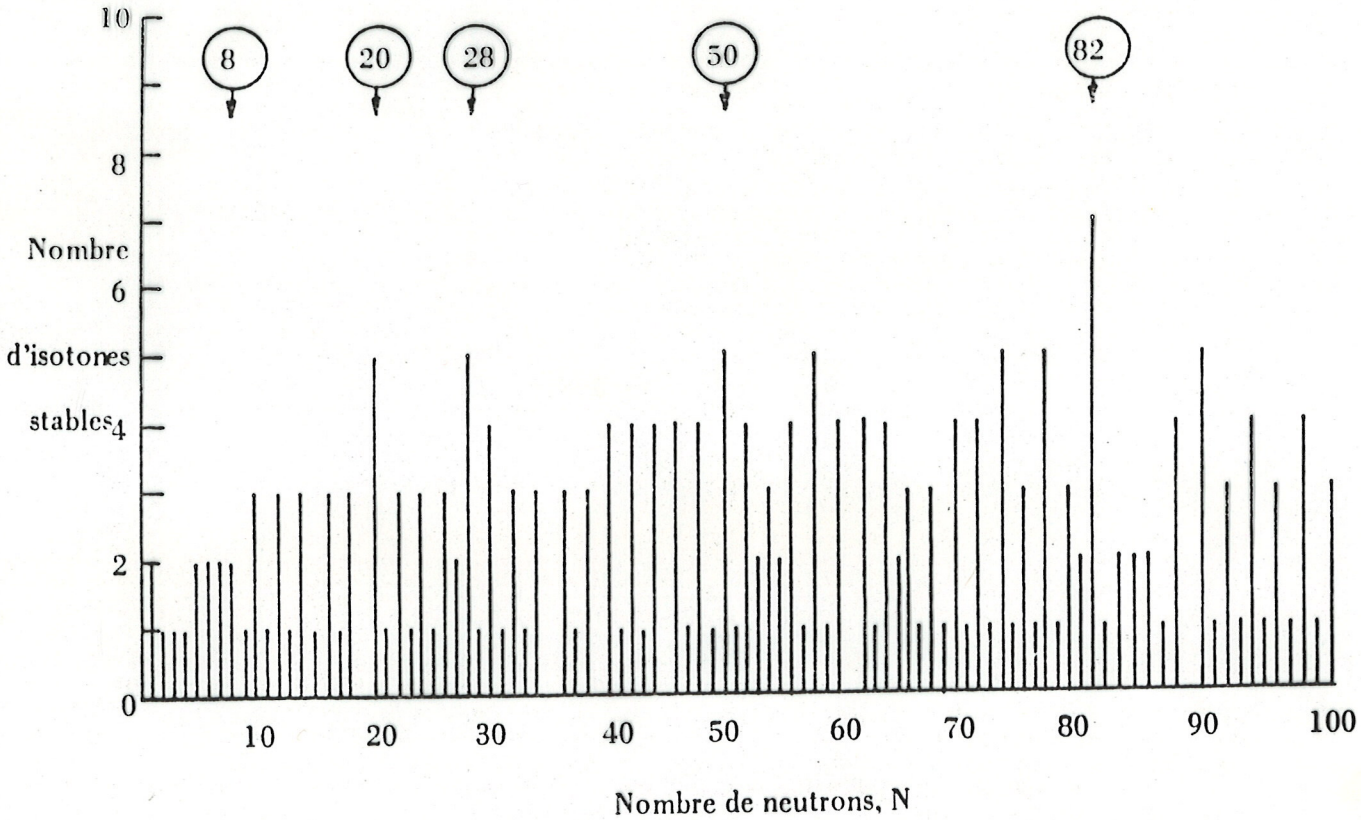
Mass Excess : −48936.2 (2.2) keV
Half life : 8.152 (0.006) h
Jπ : 1^+
Decay Mode(s) : EC=86 (3)%, β^-=14 (3)%

Sn = 6641.2 (2.5)
Sp = 5753.2 (2.5)
Qα = 2026.2 (2.6)
Qβ⁻ = 708 (4)
Qβ⁻n = -7704 (16)
Qβ⁺ = 852.2 (2.5)
Qεp = -7161 (6)

S(2n) = 14572 (15)
S(2p) = 13171 (3)
Q(2β⁻) = -3097 (22)
Q(2β⁺) = 144 (4)



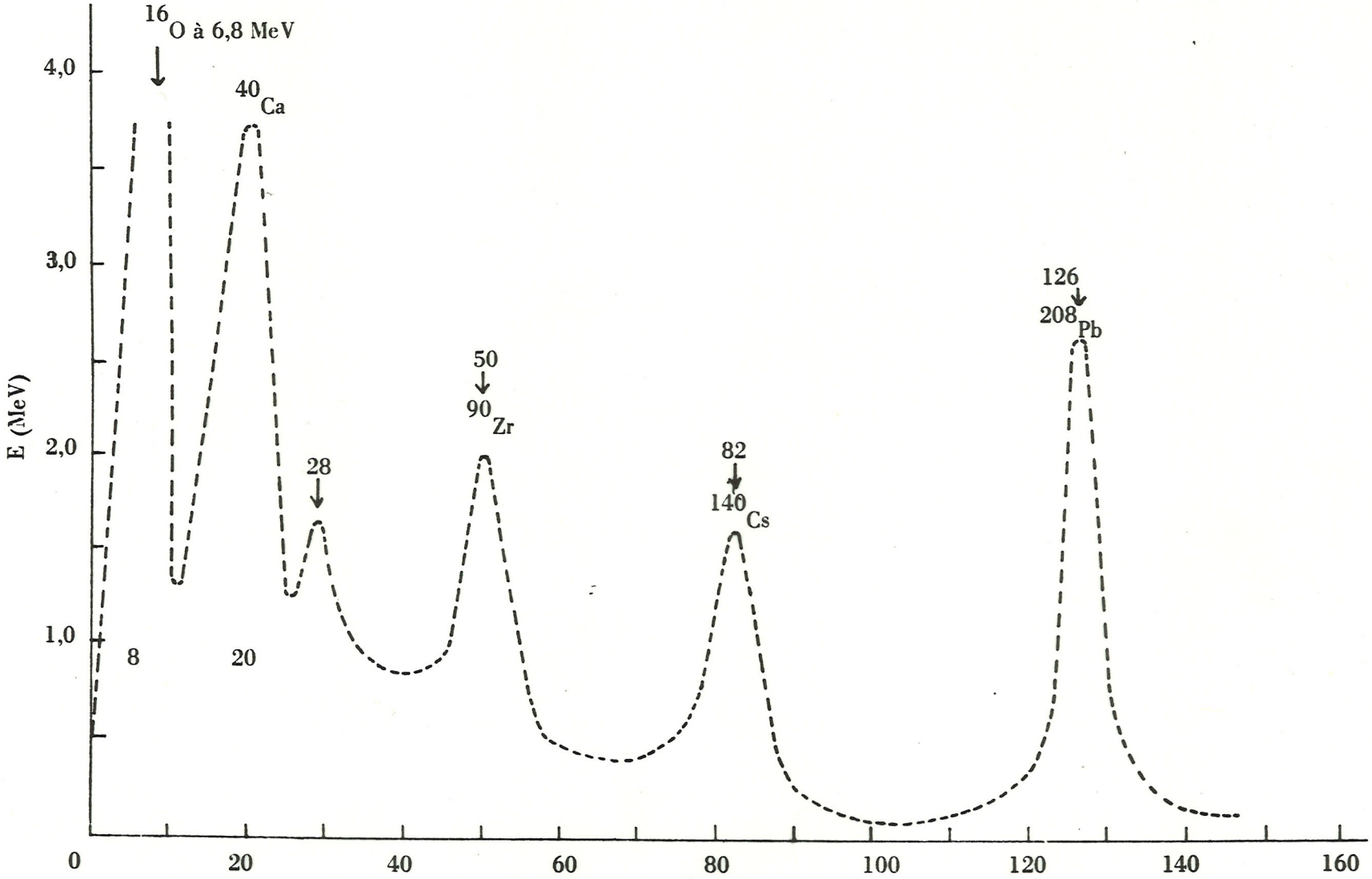




Nombre de noyaux stables en fonction du nombre de protons et du nombre de neutrons.

→ Remarquer aussi les effets dus à la parité de Z ou de N

EAMSA 40 I p 111.15 oeocter



Energie du 1er état excité des noyaux pair - pair

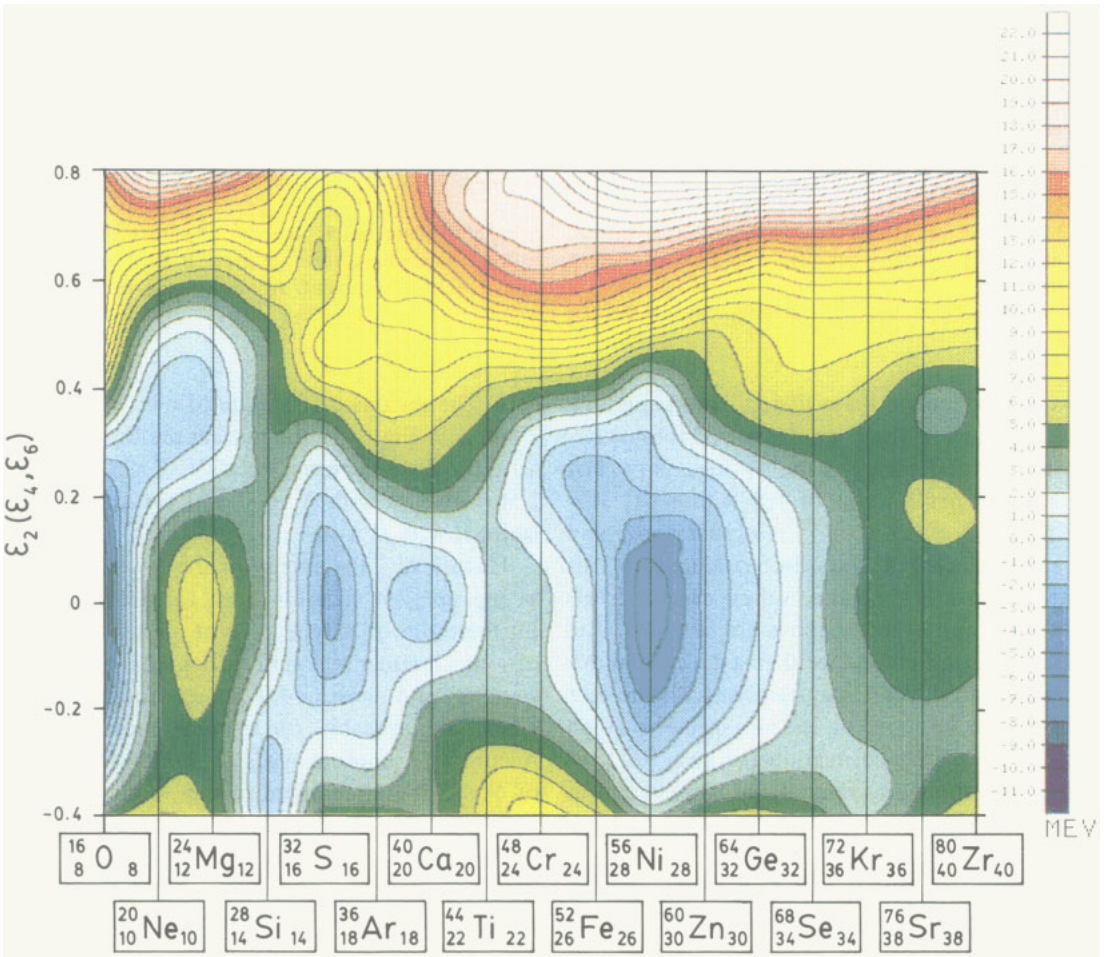


Fig. 5. Contour map of the total energy including Coulomb, surface, shell and pairing energies as a function of proton number and elongation. The elongation coordinate is parametrized by ϵ_2 and for each ϵ_2-value, the energy is minimised with respect to a waist-line coordinate which is a linear combination of ϵ_4 and ϵ_6. The Myers–Swiatecki parameters of the liquid drop model [15] have been used but with the surface symmetry term κ_s equal to 2.53 instead of 1.78 [16]. The parameters of the modified oscillator are given in Table I. The main effect of the pairing energy is to smooth the shell energy fluctuations of Figs. 3 and 4. The figure is calculated for proton rich nuclei along the upper path of dots shown in Fig. 1. It follows the $N = Z$ line up to ^{100}Sn while for large Z-values is passes through element 108 with neutron number 152 which is in the region of the heaviest elements being produced today. In agreement with experimental masses (Fig. 2), the spherical minimum for ^{32}S is deeper than for ^{40}Ca as seen in the plot with an expanded scale for light nuclei. Furthermore, the fact that ^{40}Ca is experimentally considered to be a "better closed shell nucleus" than ^{32}S is consistent with the fact that the energy is stiffer in the ϵ_2-direction for ^{40}Ca than for ^{32}S. The path of nuclei chosen passes straight through the possible region of deformed nuclei donoted 8 in Fig. 1, but still, in the present figure, no deep minima develops for $N = Z$ nuclei with $Z \approx 36$–40. This suggests that in the nuclear ground states this region of deformation is not very well developed. Stable deformations are predicted for $Z \approx 56$–66 (region 5 of Fig. 1). For heavier nuclei, we first pass the outskirts of region 6 with at most only very modest indications of deformaton and then also the outskirts of the classical "actinide region" with large deformations around $Z = 106$ and $N = 150$. It is also interesting to observe the shape isomeric state which is calculated around the very neutron deficient $Z \approx 88$–94 nuclei and around $\epsilon \approx 0.4$.

MISE EN EVIDENCE DES ELEMENTS S, P, R :

cf. astrophysique

éléments s (pair) : 35
éléments r (pair) : 44
éléments sr : 88
éléments p : 35

(pour $Z \gg 33$)

ref : E. Anders and N. Grevesse

QUELQUES "CURIOSITES"

astrophysique ↓

- ^{56}Fe isotope le plus lié (8.7904 MeV/A) "pic du Fer"
- pas d'isotopes β-stable pour $Z = 43$ (Tc) → observation dans les étoiles → nucléosynthèse en cours
- pas d'isobares particule-stable pour $A = 5$ cf Big-Bang
- " " " " " " " " " " $A = 8$ cf réaction 3-α
- pas d'isotones β-stable pour $N = 35, 39, 45, 61, 89, 115, 123$ et 127 cf processus s

- noyaux impair-impair β-instable de très longue période : $^{180}_{73}Ta$, $^{138}_{57}La$, $^{176}_{71}Lu$ nucléocosmochronomètre ?

- autres curiosités : $^{186}_{75}Re^{m}$

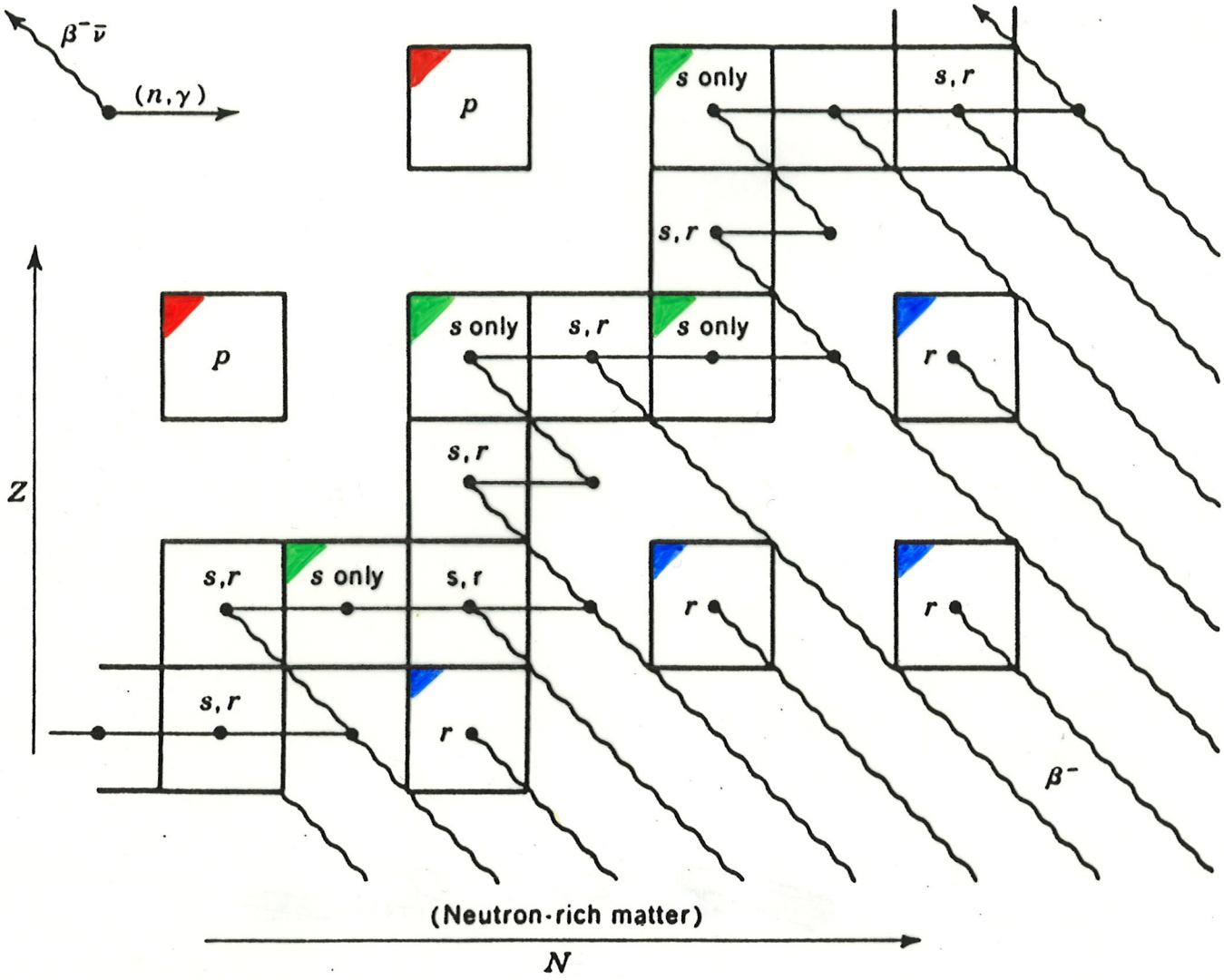


Fig. 7-14 A characterization of a portion of the chart of nuclides showing the assignment of nuclei to the classes *s*, *r*, and *p*. The *s*-process path of (n,γ) reactions followed by quick beta decays enters at the lower left and passes through each nucleus designated by the letter *s*. Neutron-rich matter undergoes a chain of beta decays terminating at the most neutron-rich of the stable isobars, which are designated by the letter *r*. Those nuclei on the *s*-process path which are shielded from *r*-process production are labeled "*s only*." The rare proton-rich nuclei which are bypassed by both neutron processes are designated by the letter *p*.

Clayton p 547

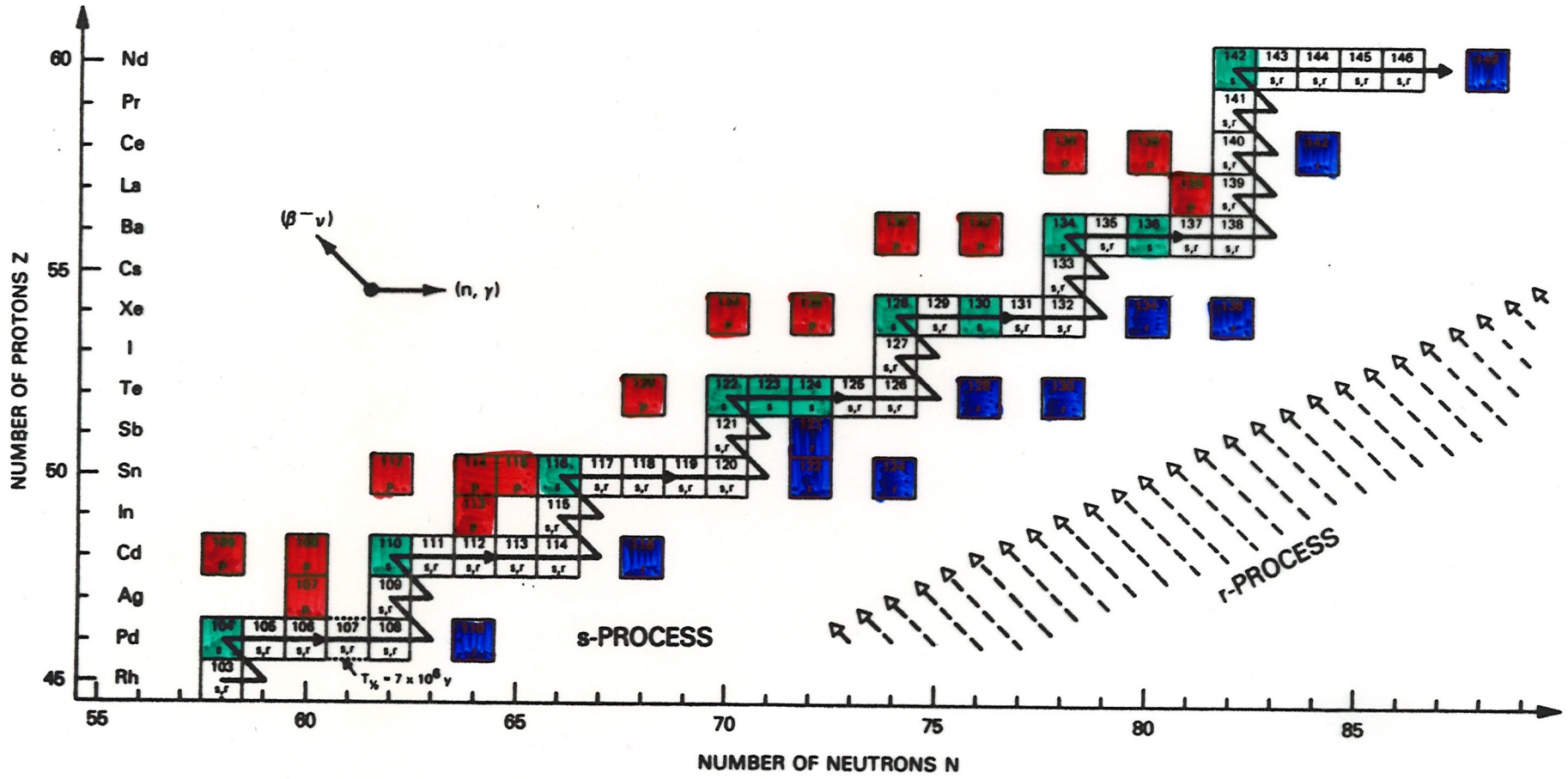


FIGURE 9.7. A section of the chart of nuclides and the *s*-process path through the elements in this mass region. Note that the path bypasses the *p*- and *r*-process nuclei. The *r*-process nuclei are the end products of an isobaric β-decay chain, the flow of which is indicated by the inclined arrows, from neutron-rich progenitors produced in an intense neutron flux. When this flux ceases, the progenitors "rain" down to the valley of stability via β-decay.

Rolfs and Rodney p 459

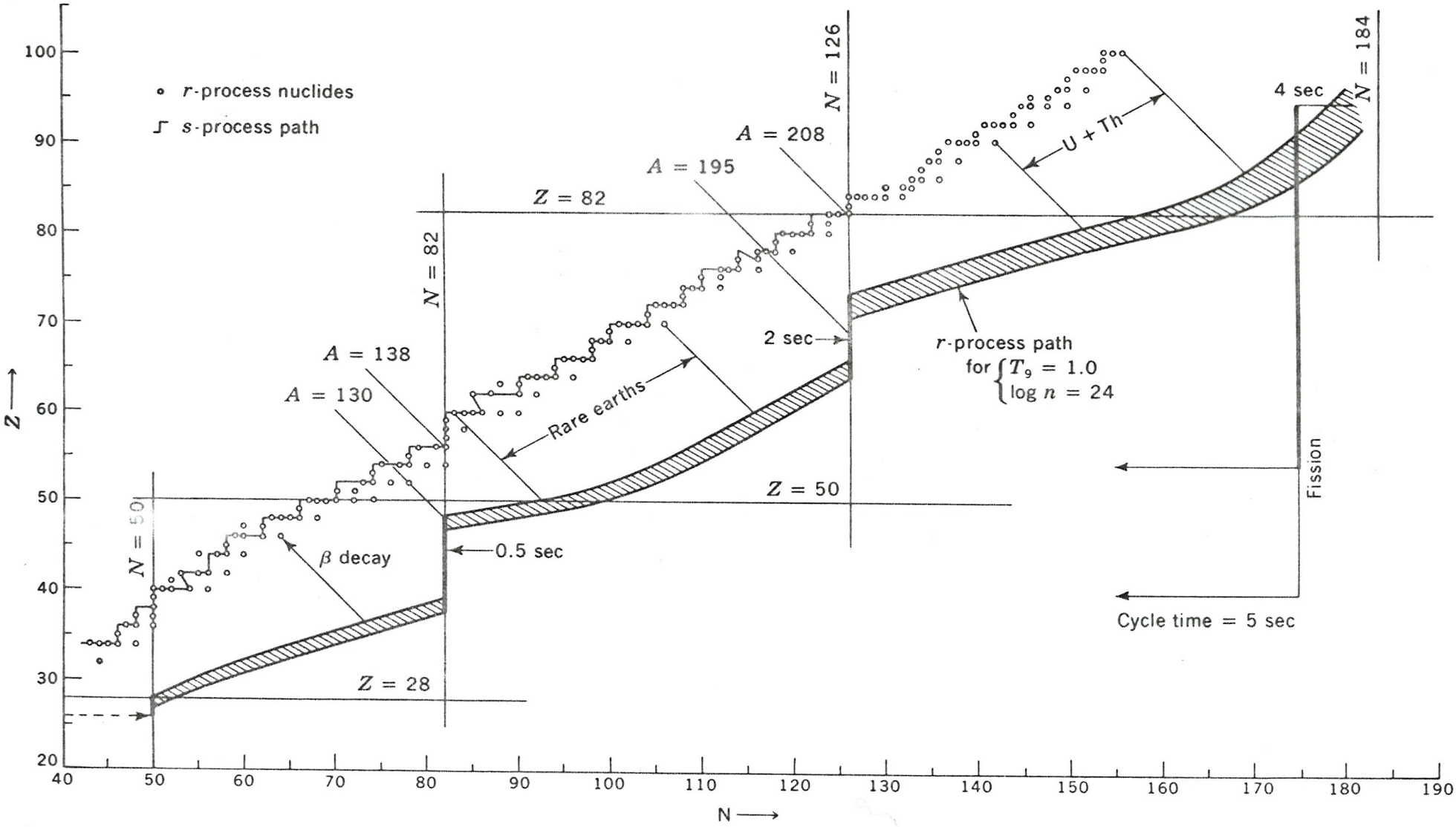


Fig. 7-30 Neutron-capture paths for the *s* process and the *r* process. The *s* process follows a path in the NZ plane along the line of beta stability. The neutron-rich progenitors to the stable *r*-process nuclei, which are here shown as small circles, are formed in a band in the neutron-rich area of the NZ plane, such as the shaded area shown here. This *r*-process path was calculated for the case $T_9 = 1.0$ and $\log n_n = 24$. After the synthesizing event the nuclei in this band beta-decay to the stable *r*-process nuclei. The abundance peaks at $A = 80$, 130, and 195 are attributed to abundance peaks in the neutron-rich progenitors having $N = 50$, 82, and 126. Neutron capture flows upward from the lower left-hand corner along the shaded band until neutron-induced fission occurs near $A = 270$. [*P. A. Seeger, W. A. Fowler, and D. D. Clayton, Astrophys. J. Suppl.*, **11**:121 (1965). *By permission of The University of Chicago Press. Copyright* 1965 *by The University of Chicago.*]

D.D. Clayton p 586

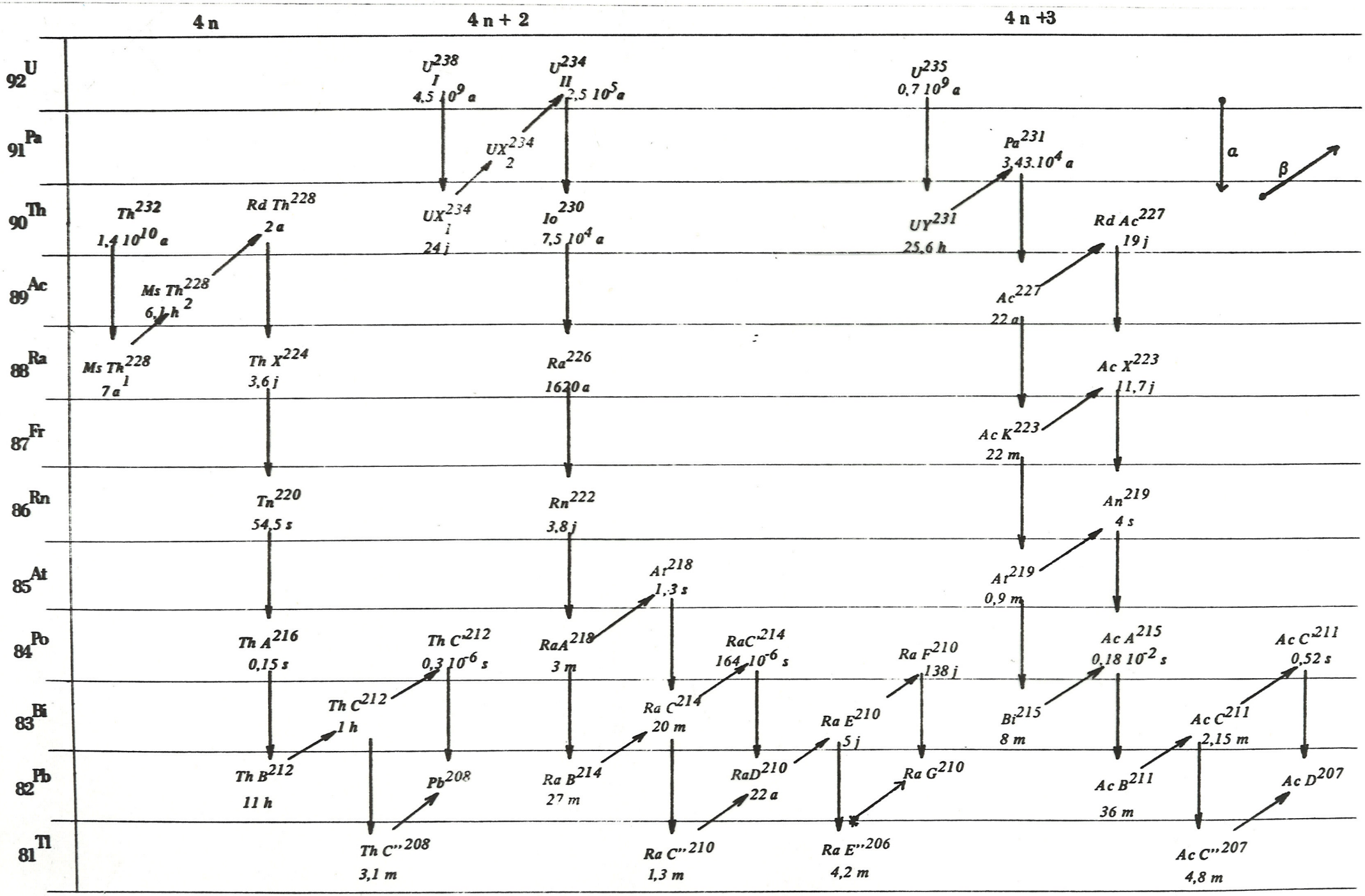
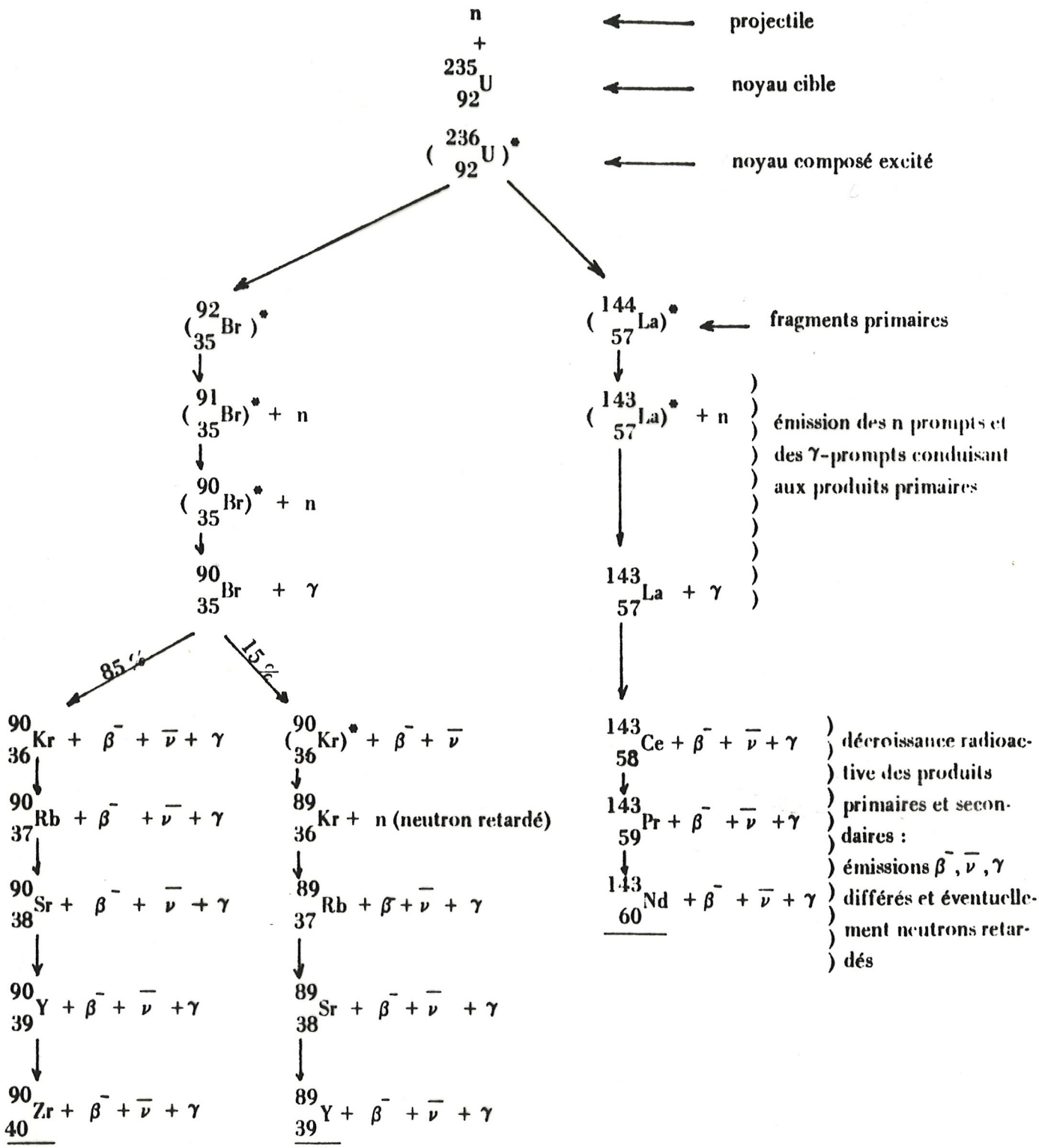


FIGURE 4 : Familles radioactives naturelles

EAMEA CVII p IV.8 bis



Exemple de fission.

Les noyaux soulignés sont des noyaux stables.

Le processus envisagé peut se résumer par :

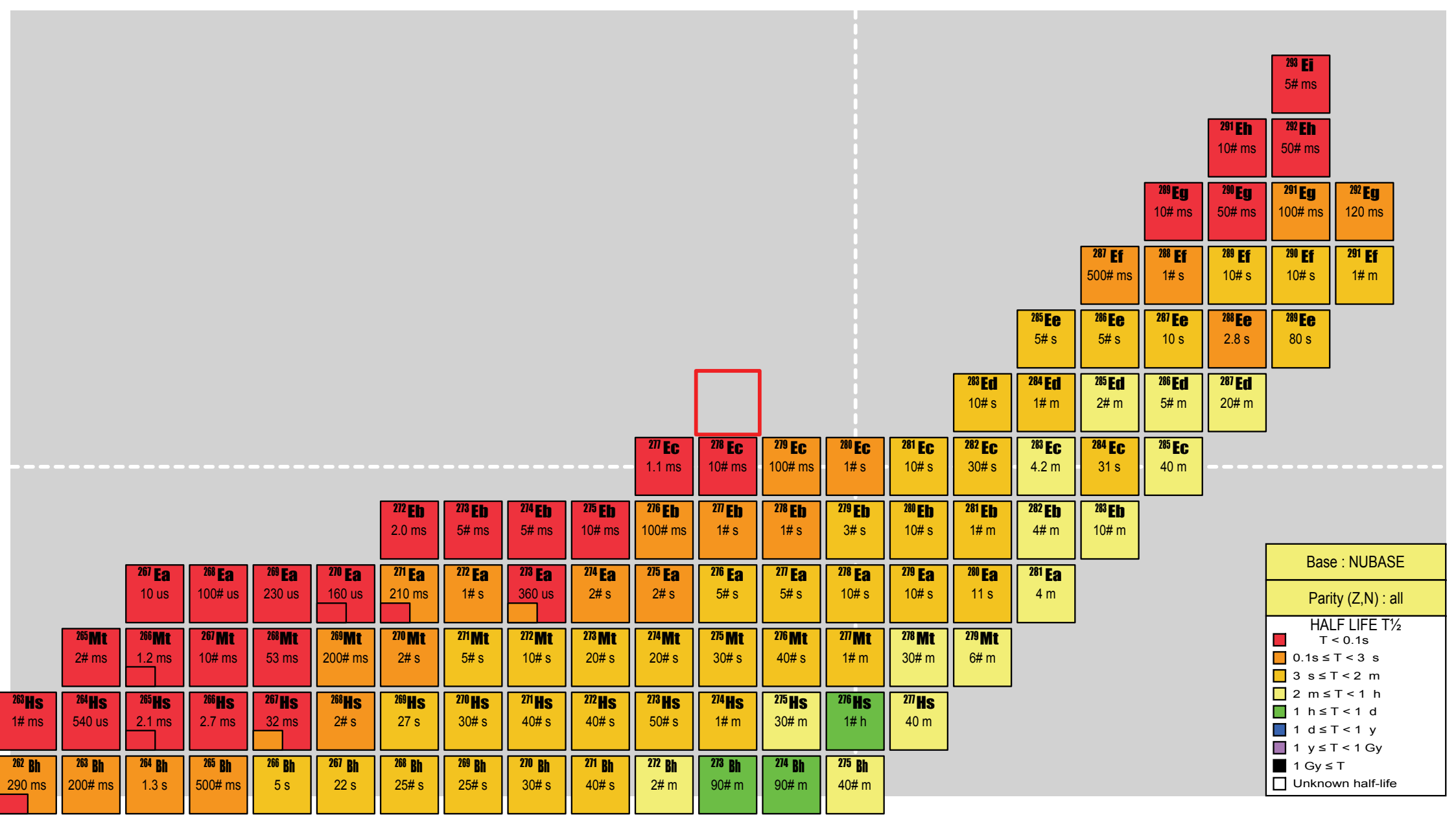
$$n + {}^{235}_{92}U \rightarrow ({}^{236}_{92}U)^* \begin{cases} \rightarrow {}^{90}_{40}Zr + {}^{143}_{60}Nd + 3n + 8\beta^- + 8\bar{\nu} + x\gamma \\ \text{(ou)} \\ \rightarrow {}^{89}_{39}Y + {}^{143}_{60}Nd + 4n + 7\beta^- + 7\bar{\nu} + y\gamma \end{cases}$$

EANEA CU III p.x.15

Les « nouveaux » éléments

Rappel : Les actinides du La (Z=89) au Lr (Z=103)

Z	Symbole	Nom	Année découverte	Année baptême	Isotopes
104	Rf	Rutherfordium	1964	1997	253 – 268
105	Db	Dubnium	1967	1997	255 – 270
106	Sg	Seaborgium	1974	1997	258 – 273
107	Bh	Bohrium	1981	1997	260 – 275
108	Hs	Hassium	1984	1997	263 – 277
109	Mt	Meitnerium	1982	1997	265 – 279
110	Ds	Darmstadtium	1994	2003	267 – 281
111	Rg	Roentgenium	1994	2004	272 – 283
112	Cn	Copernicium	1996	2010	277 – 285
113	Uut ou Ed	Ununtrium	2004		283 – 287
114	Uuq ou Ee	Ununquadium	1999		285 – 289
115	Uup ou Ef	Ununpentium	2004		287 – 291
116	Uuh ou Eg	Ununhexium	2000		289 – 292 303 et 304 !!
117	Uus ou Eh	Ununseptium	2010		291 et 292 *(293 et 294 ?)*
118	Uuo ou Ei	Ununoctium	2006		293 *(294 ?)*


293 Ei 5# ms
291 Eh 10# ms
292 Eh 50# ms
289 Eg 10# ms
290 Eg 50# ms
291 Eg 100# ms
292 Eg 120 ms
287 Ef 500# ms
288 Ef 1# s
289 Ef 10# s
290 Ef 10# s
291 Ef 1# m
285 Ee 5# s
286 Ee 5# s
287 Ee 10 s
288 Ee 2.8 s
289 Ee 80 s
283 Ed 10# s
284 Ed 1# m
285 Ed 2# m
286 Ed 5# m
287 Ed 20# m
277 Ec 1.1 ms
278 Ec 10# ms
279 Ec 100# ms
280 Ec 1# s
281 Ec 10# s
282 Ec 30# s
283 Ec 4.2 m
284 Ec 31 s
285 Ec 40 m
272 Eb 2.0 ms
273 Eb 5# ms
274 Eb 5# ms
275 Eb 10# ms
276 Eb 100# ms
277 Eb 1# s
278 Eb 1# s
279 Eb 3# s
280 Eb 10# s
281 Eb 1# m
282 Eb 4# m
283 Eb 10# m
267 Ea 10 us
268 Ea 100# us
269 Ea 230 us
270 Ea 160 us
271 Ea 210 ms
272 Ea 1# s
273 Ea 360 us
274 Ea 2# s
275 Ea 2# s
276 Ea 5# s
277 Ea 5# s
278 Ea 10# s
279 Ea 10# s
280 Ea 11 s
281 Ea 4 m
265 Mt 2# ms
266 Mt 1.2 ms
267 Mt 10# ms
268 Mt 53 ms
269 Mt 200# ms
270 Mt 2# s
271 Mt 5# s
272 Mt 10# s
273 Mt 20# s
274 Mt 20# s
275 Mt 30# s
276 Mt 40# s
277 Mt 1# m
278 Mt 30# m
279 Mt 6# m
263 Hs 1# ms
264 Hs 540 us
265 Hs 2.1 ms
266 Hs 2.7 ms
267 Hs 32 ms
268 Hs 2# s
269 Hs 27 s
270 Hs 30# s
271 Hs 40# s
272 Hs 40# s
273 Hs 50# s
274 Hs 1# m
275 Hs 30# m
276 Hs 1# h
277 Hs 40 m
262 Bh 290 ms
263 Bh 200# ms
264 Bh 1.3 s
265 Bh 500# ms
266 Bh 5 s
267 Bh 22 s
268 Bh 25# s
269 Bh 25# s
270 Bh 30# s
271 Bh 40# s
272 Bh 2# m
273 Bh 90# m
274 Bh 90# m
275 Bh 40# m
Base : NUBASE
Parity (Z,N) : all
HALF LIFE T½
T < 0.1s
0.1s ≤ T < 3 s
3 s ≤ T < 2 m
2 m ≤ T < 1 h
1 h ≤ T < 1 d
1 d ≤ T < 1 y
1 y ≤ T < 1 Gy
1 Gy ≤ T
Unknown half-life