A Guide to the *TABLE OF ISOTOPES*, Firestone and Shirley, Editors

The 7th edition of the "Table of the Isotopes" contains so much material that it is difficult to read (even more so with the 8th). This guide describes ^{60}Co in some detail, with the relevant tables and charts for ^{60}Co reproduced and attached to this write-up. Short comments are supplied for other commonly encountered isotopes, namely, ^{137}Cs, ^{57}Co, ^{22}Na, ^{24}Na, ^{106}Ru, and ^{228}Th, with selected entries for them also attached. Be sure to examine the introductory section of the "TABLE" for detailed descriptions of format, notation, and abbreviations. Please note that the program "PCNudat" contains much of this information in electronic format. Also do familiarize yourself with the 8th edition CD-ROM (1998 Update). The WWW version of this guide provides some graphical examples from the CD-ROM.

^{60}Co - [γ-rays, β spectrum, Conversion Electrons]

There are several entries for each isotope, both tables of data and diagrams. The first useful data is at the beginning of the Mass = 60 section. It is a simple diagram that tells you which of the A=60 nuclei exist or have been artificially produced. It also gives some information about the decay of each system; for example, ^{60}Co decays to ^{60}Ni and is about 2.8 MeV/c^2 more massive (as can been seen by reading the scale to the left of the diagram or reading the Q_{β^-} values). This diagram also tells you that an excited, isomeric level of ^{60}Co decays to ^{60}Ni with a half-life of 10.47 minutes, while the ground state decay has a half life of 5.271 years. The isomeric level decays 99.76% of the time to the ^{60}Co ground state via an isomeric transition, IT, and only .24% of the time to ^{60}Ni. (References: (1) pp. 369-373, (2) pp. 229-234, (3) p. 274)

Now you want to look at the diagrams for the daughter isotope, ^{60}Ni. (Reference (3), p. 277). There are three diagrams, do not look at the main entry (part 2). We are interested in the diagram which lists the isotopes decaying to this one (part 1). It includes the parent and daughter nuclei, the levels in the daughter which are the final product of the decay, and the subsequent gamma-ray (γ-ray) emissions. The decays are labeled by the type of decay [e.g., beta - (β^-), beta + (β^+), and electron capture (EC)] and the relative probability of each mode. The ^{60}Co level with the 10.47 minute half life is labeled as a meta-stable state **m**, which means that it is not the ^{60}Co ground state but is a long - lived excited state. The bold entry over the gamma-ray transitions are their energies, the italic entries are the branching ratios for the decay if more than one gamma decay is possible. The spin, and parity of each level in ^{60}Ni is listed on the left side of the line (e.g.,. 0+, 2+ etc.). If the lifetime of a level is known it will also be listed. This diagram is not complete. It only includes the levels in the daughter which can be reached by the radioactive decay of ^{60}Co and ^{60}Cu. There may be other levels in-between those shown. You will have to look at the main entry if you want a complete listing of levels.

The main diagram for ^{60}Co does not list any information about radioactive decay (ref. (3), p. 275). It does list the nuclear levels, their energies, spins, parities, and lifetimes. The vertical lines connecting states identify the known gamma ray transitions; their energies, if not given, can be calculated by taking the difference between the energies of the levels. We are seldom interested in this information because long lived radioactive decays come from the ground state of the parent nucleus. The higher energy states have very short lifetimes (pico-seconds, femto-seconds, or shorter) unless they are meta-stable, but even these will have decayed in a few minutes.

^{137}Cs - [γ-ray, X-ray, Conversion Electrons, β-spectrum]

^{137}Cs has an additional subtlety that you must be aware of. You can start in the usual way, which is to look at the A=137 diagram (ref. (3), p. 1242). From this you will find that ^{137}Ba is the daughter and the important decay information will be listed there. The diagram lists the various decays and their branching ratios, but it does not point out that the de-excitation of the .661 MeV level in Ba is rather unusual. It involves a large spin change ($11/2^-$ to $3/2^+$) and will be hindered so that another de-excitation mechanism, Internal Conversion, is possible. Instead of emitting a gamma-ray, the nucleus de-excites by knocking out one of the atomic electrons with kinetic energy equal to the decay energy. It is usually the K shell electron that is internally converted because it has the greatest wave function overlap with the nucleus. The hole that is left behind will be repopulated by an electron from a higher atomic shell, usually the L shell, and this L to K transition is accompanied by an X-ray. To find out how probable internal conversion is you have to look at the tabular information for ^{137}Ba under ~prod~ or products of the decay. The .662 MeV gamma-ray is a product of the decay and is produced 90.11 % of the time. The remaining 10% goes into internal conversion, listed under e/gamma.

^{134}Cs - [γ-rays]

^{134}Cs beta decays to ^{134}Ba with a half-life of 2.065 years. Because the ground state of ^{134}Cs is 4+, it decays predominantly to the 4+ states of ^{134}Ba. 27.28% of the decays go to the 1.970 MeV level, and 70.23% to the 1.401 MeV level. These levels subsequently decay by γ-ray emission, yielding strong lines at 0.569, 0.802, and 0.796 MeV. (The 4+, 2+, 0+ sequence is a very common decay sequence in nuclei. look for it in the attached diagram. ref. (3), p. 1208)

^{57}Co - [γ-rays, X-rays, Conversion Electrons]

^{57}Co decays by electron capture to the 136.47 keV level of ^{57}Fe. This level subsequently decays by gamma emission 10.68% of the time to the ground state, and 85.60% of the time to the 14.4 keV level. The de-population of the 14.4 keV level proceeds by a combination of gamma emission and internal conversion (e/gamma = 8.2) yielding an X-ray with each electron. This is a standard Mössbauer Effect source, and that is also frequently used for excitation of X-ray fluorescence. Reference (3), p. 254.

^{22}Na - [γ-rays, Positronium/Annihilation Radiation]

^{22}Na decays by positron emission and electron capture yielding a single gamma-ray at 1.274 MeV. ^{22}Na in vacuum is an excellent source of positrons, otherwise (especially when in close proximity to material) the positrons annihilate and produce .511 MeV gamma-rays. [See Experiment 14] Reference (3), p. 43.

^{24}Na - [γ-rays]

^{24}Na is made by neutron activation, (^{23}Na + n $\rightarrow$ ^{24}Na). Only the ground state lives long enough to be used as a calibration source (14.96 hours). It is a source of a uniquely high energy gamma ray ($E\gamma$ = 2.754 MeV). Reference (3), p. 52.

^{207}Bi - [electrons and γ-rays]

^{207}Bi decays by electron capture to ^{207}Pb with a half-life of 31.55 years. The decay leads to an unusual level in ^{207}Pb that is almost stable, even though it is the excited state of the nucleus. This isomer of ^{207}Pb has an 0.805 second lifetime due to its unusual spin (13/2 +). The γ-ray decay to the ground state is hindered because it is an M4 transition. Instead of emitting a γ-ray, the isomeric level decays by Internal Conversion (See ^{137}Cs) and generates a monoenergetic electron which has 1.06366 MeV of kinetic energy. ^{207}Bi also produces γ-rays at 0.569 and 1.770 MeV, but these are of less interest than the electron line.

Radioactive Series - ^{106}Ru and ^{228}Th

^{106}Ru and **^{228}Th** are examples of radioactive decay series. The parent has a long half life, but may not directly yield any interesting (useful) emissions. The daughters, on the other hand, produce useful decay products. In the case of ^{106}Ru, the daughter's (^{106}Rh) half life is only 29.8 seconds (ref. (3), p. 802), so short that it is frequently overlooked in the Table of Isotopes. ^{228}Th, another parent of a decay series, is a long lived daughter (1.91 years) of yet an even longer decay series starting with ^{232}Th (1.405x10^{10} y). ^{238}U (4.468x10^{9} y) is still another series. The Uranium and Thorium series are shown in the attached diagrams. The ^{238}U series involves a sequence of 16 daughters before it reaches an end point at ^{209}Pb. The ^{232}Th series has 9 daughters (including ^{228}Th) and terminates at ^{208}Pb. The parent nuclei each have very long half-lives (> a billion years). but the daughters have a wide variety of half-lives (milli-seconds to years), and are found in the environment in various equilibrium concentrations. The Uranium and Thorium series are responsible for the Radon gas that emanates from stone and concrete buildings, and are responsible for most of the naturally occurring lead found on the earth.

^{106}Ru - [β^- spectrum, γ - rays]

^{106}Ru beta decays 100% of the time to the ground state of ^{106}Rh and does not yield any useful particles other than very low energy electrons. But the daughter, ^{106}Rh, is unstable and decays to ^{106}Pd yielding electrons, with a maximum end-point energy of 3.54 MeV, which can be used for calibration of plastic scintillators and spectrometers. Reference (3), p. 807.

In this decay, a neutron inside the nucleus is decaying to a proton + an electron + an anti-neutrino ($n \rightarrow p + e^- + \overline{\nu}_e$). The total energy released in the decay will depend on the difference in binding energy between the parent and daughter nuclei with this energy manifested as the kinetic energy of the electron and anti-neutrino. (The proton also receives part of the decay energy but is so massive in comparison to the electron that the recoil energy is negligible.) The spectrum of energies available to the electron ranges between 0 and the total energy of the decay (3.54 MeV). It is most probable for the neutrino and electron to carry away about the same amount of energy and so the spectrum is peaked at mid-energies.

^{228}Th - [γ - rays and α-particles]

^{228}Th decays with a half life of 1.91 years, proceeding through a chain of five α and two β decays before arriving at stable ^{208}Pb. All of the intermediate daughters have short half-lives (the longest being 10.6 hours), so that their abundance is not determined by their half lives, but rather by the abundance of the parent ^{228}Th (i.e., the daughters are in equilibrium - they are produced at the same rate that they decay.) A detailed review of the radiations emanating from a ^{228}Th source requires that each and every daughter be looked up in the Table of Isotopes.

Briefly, the main γ-rays emitted occur at the following energies (energies in MeV and percent abundance):

0.084 (25%), 0.115 (5%), 0.239 (88%), 0.300 (5%), 0.510 (8%), 0.583 (30%), 0.727 (3%), 0.860 (8%), and 2.615 (36%).

The alpha-particles are emitted at the following energies:

5.6856 (95%), 6.06 (35%), 6.2883 (99%), 6.7785 (100%), and 8.7844 (64%).

GLOSSARY OF TERMS:

β^- (Beta -) emission: a neutron decaying inside of the nucleus emits a proton, electron, and an anti-neutrino. The electrons produce the β^- (Beta -) particle spectrum. (Reference: (2) pp. 536-541)

β^+ (Beta +) emission: a proton decaying inside of the nucleus emits a neutron, positron (anti-electron), and a neutrino. The positrons produce the β^+ (Beta +) particle spectrum. (Reference: (2) pp. 536-541)

ELECTRON CAPTURE: When a proton decays inside of the nucleus it must conserve charge. It can do this by positron emission (Beta + decay) or by capturing an orbital electron. The captured electron may come from any of the atomic orbitals and so K capture, L capture, M capture, etc. may all occur. The decay scheme is that a proton and an electron decay to a neutron and a neutrino. (Reference: (2) pp. 23-25)

INTERNAL CONVERSION *(often labeled e/Y or ek/Y):* an excited state of the nucleus usually de-excites by gamma-ray emission. It may also de-excite by knocking out one of the orbital electrons, this is called *internal conversion*. It usually only occurs when the energy of the excited level is small, ~ 100 keV, or the change in spin between the initial and final state is large. Radioactive decays that lead to low energy levels in the daughter are often good sources of internal conversion electrons, which are monoenergetic, and can be used to calibrate electron detectors. (Reference: (2) pp. 23-25)

ISOMER: nuclei with the same Z and same A, but with differing energy states. (Reference: (2) p.229-234

Q: The mass difference between the parent and daughter isotopes is called the Q value. It is usually quoted in units of MeV/c^2. (Reference: (1) p. 502)

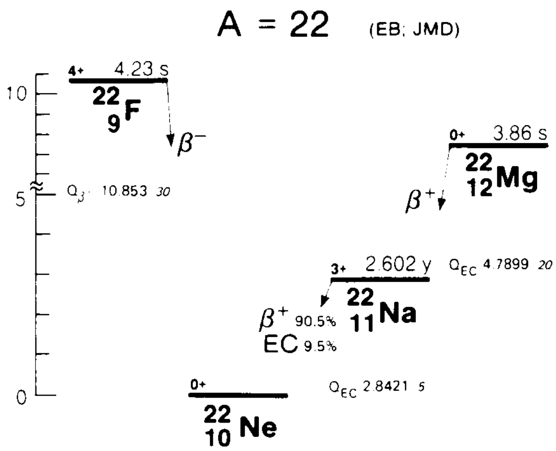
REFERENCES:

(1) E. Segre, *Nuclei And Particles*, 2nd Edition, (Benjamin/Cummings Publishing Company, 1977).

(2) R. D. Evans, *The Atomic Nucleus*, (McGraw-Hill Book Company, New York, 1955).

(3) R. B. Firestone and V. S. Shirley, Editors, *Table Of Isotopes*, 2 - volume set including CD-ROM, 8th Edition, (John Wiley & Sons, New York, 1996) The 6th (1967) and 7th (1978) editions are also available in the laboratory.

The following decay schemes are from the 7th edition of the *Table of Isotopes.* Check the latest literature for updated numbers.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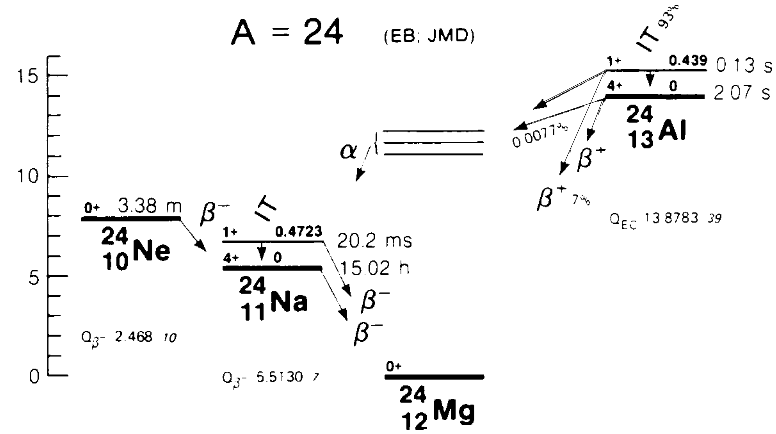
22 12 Mg
22 11 Na
22 10 Ne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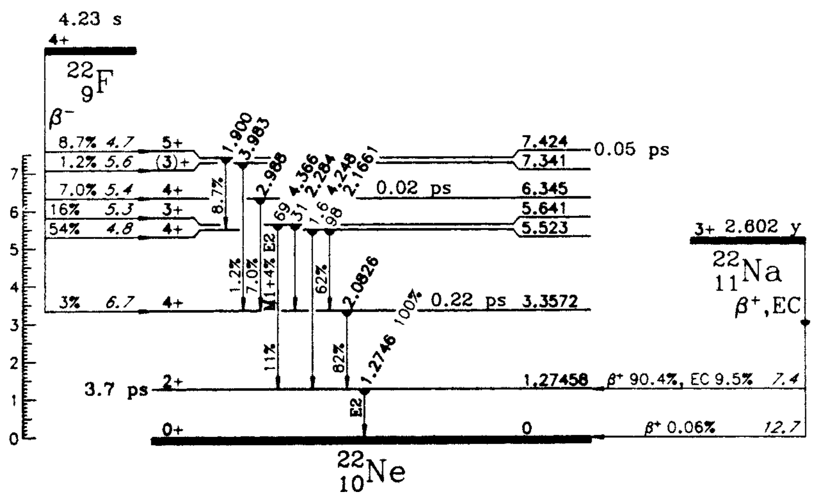
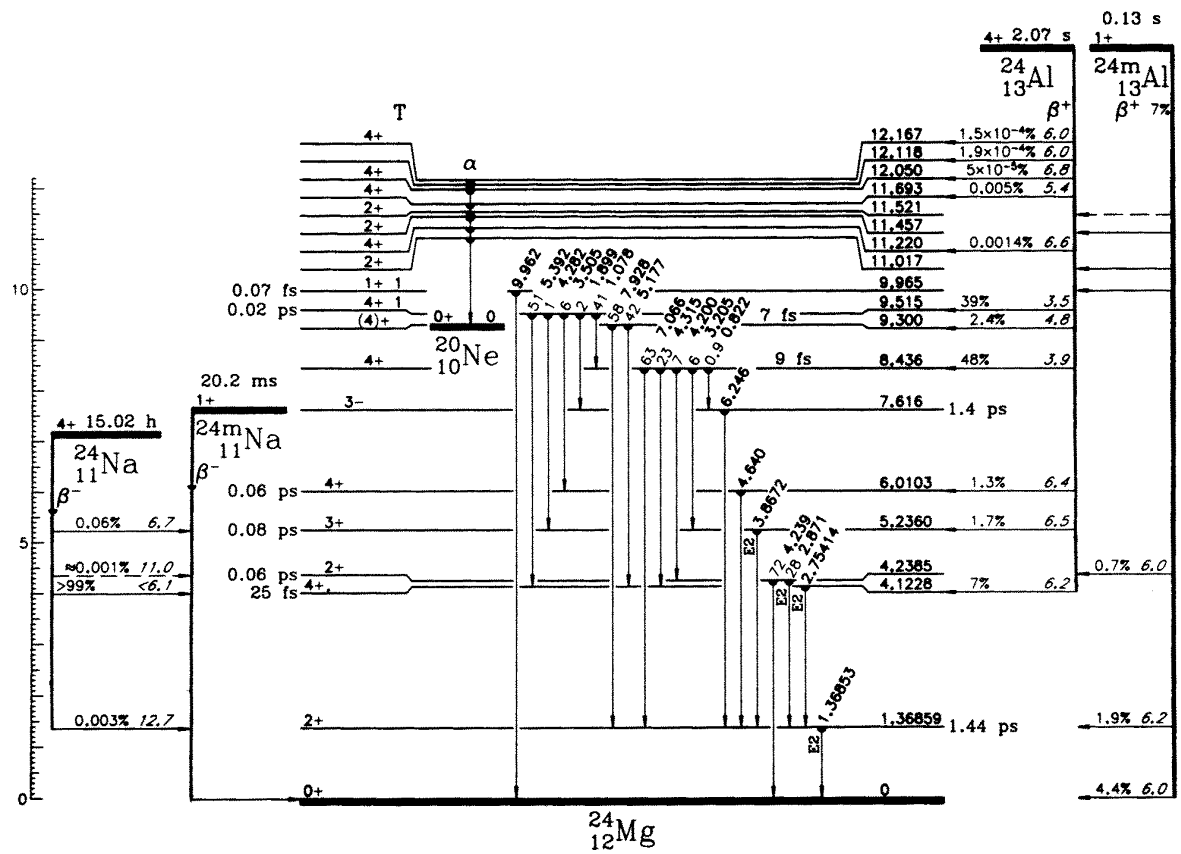
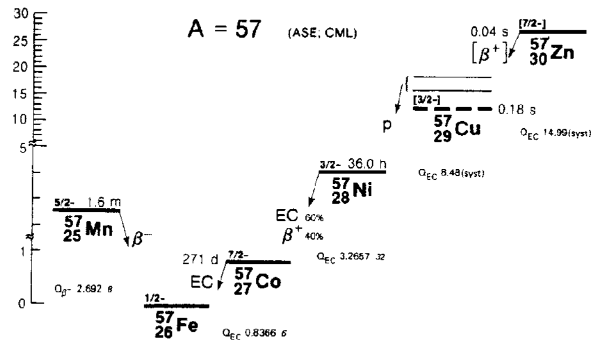
24 10 Ne
24 11 Na
24 13 Al
24 12 Mg

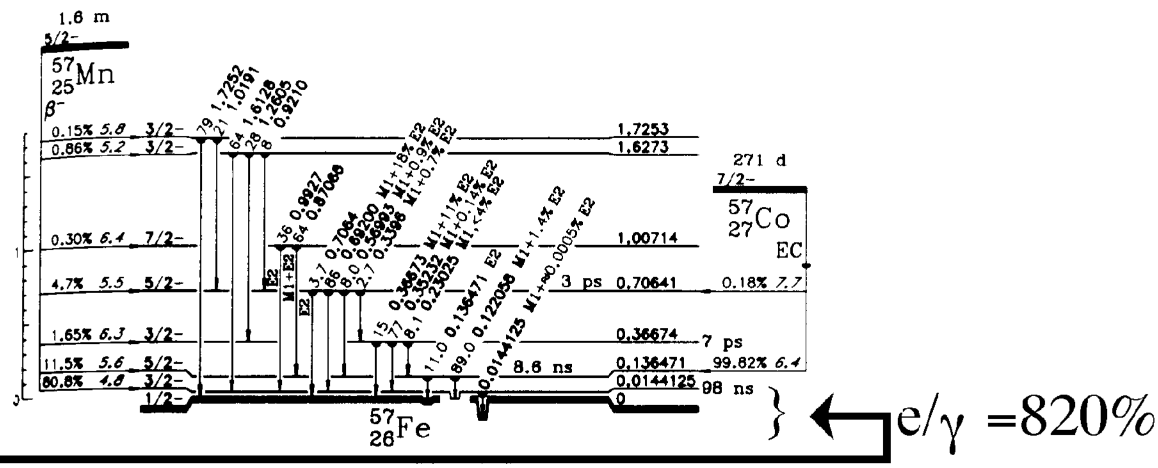

22 9 F
22 11 Na
22 10 Ne


24 11 Na
24m 11 Na
20 10 Ne
24 13 Al
24m 13 Al
24 12 Mg

$^{57}_{26}$Fe

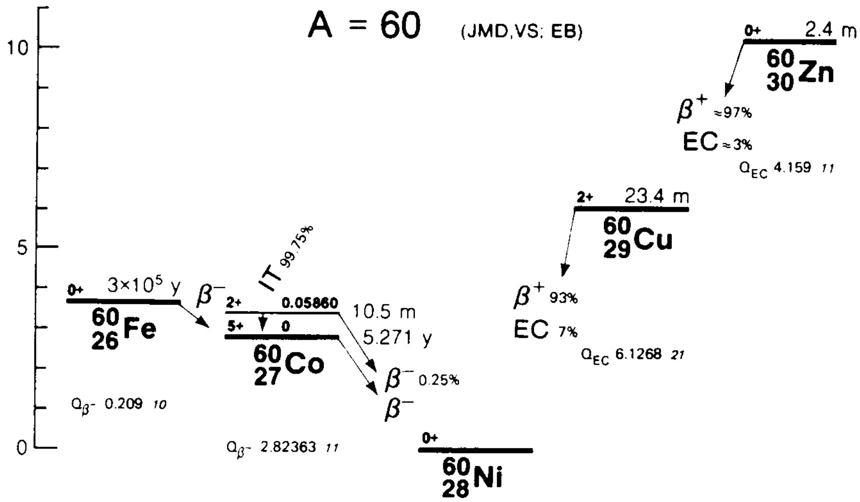
%: 2.15 {BNL-NCS-50605(77)}
Δ: −60.1790 14 {ANDT 19 175(77)}
I: 1/2 *EPR* {Dokl 113 1243(57), PRL 1 295(58)}
σ_0: 2.4 3 (reactor spectrum) {PC77 Holden}
$t_{1/2}$(levels): **0.014:** 97.7 2 ns *delay coinc* {PPSL 89 187(66)}, 99.3 3 ns *delay coinc* {PR 184 298(69)}, ≈0.02 to 0.06% variation of $t_{1/2}$ with chemical environment *delay coinc* {PL 39B 620(72), HPAc 46 165(73)}
0.136: 8.5 4 ns *delay coinc* {NIM 71 29(69)}, 8.8 4 ns *delay coinc* {PR 121 1464(61)}
0.367: 6.9 14 ps *Doppler* {NP A137 658(69)}, 7.6 17 ps *Coulomb excit* {NP A137 658(69)}
0.706: 2.7 4 ps *Coulomb excit* {NP A137 658(69), ASE}, 4.1 10 ps *Doppler* {NP A137 658(69)}
2.355: ≤0.42 ps *Doppler* {PScr 6 11(72)}
2.879: ≤0.46 ps *Doppler* {PScr 6 11(72)}
others: {NIM 104 93(72), NP A137 658(69), PIAS A65 25(67), PR 139 B295(65), PR 129 826(63), IzF 26 992(62), NP 17 9(60), NP 17 1(60), Phca 21 897(55), PPSL 68A 701(55), PR 77 139(50)}

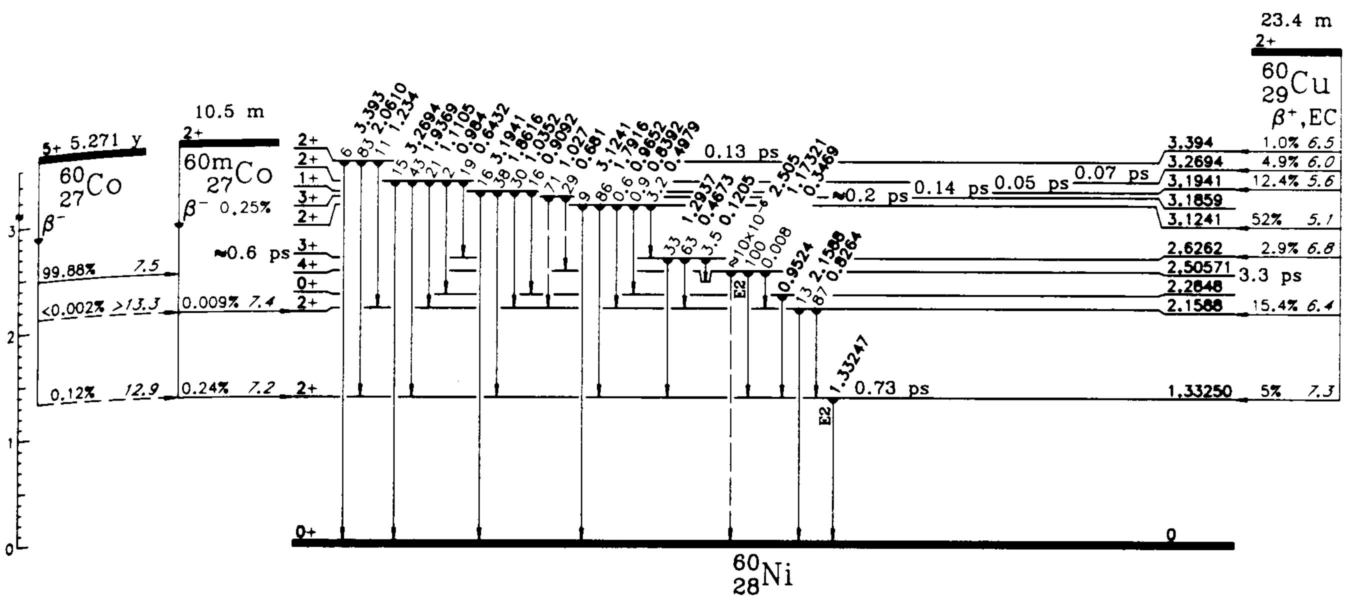


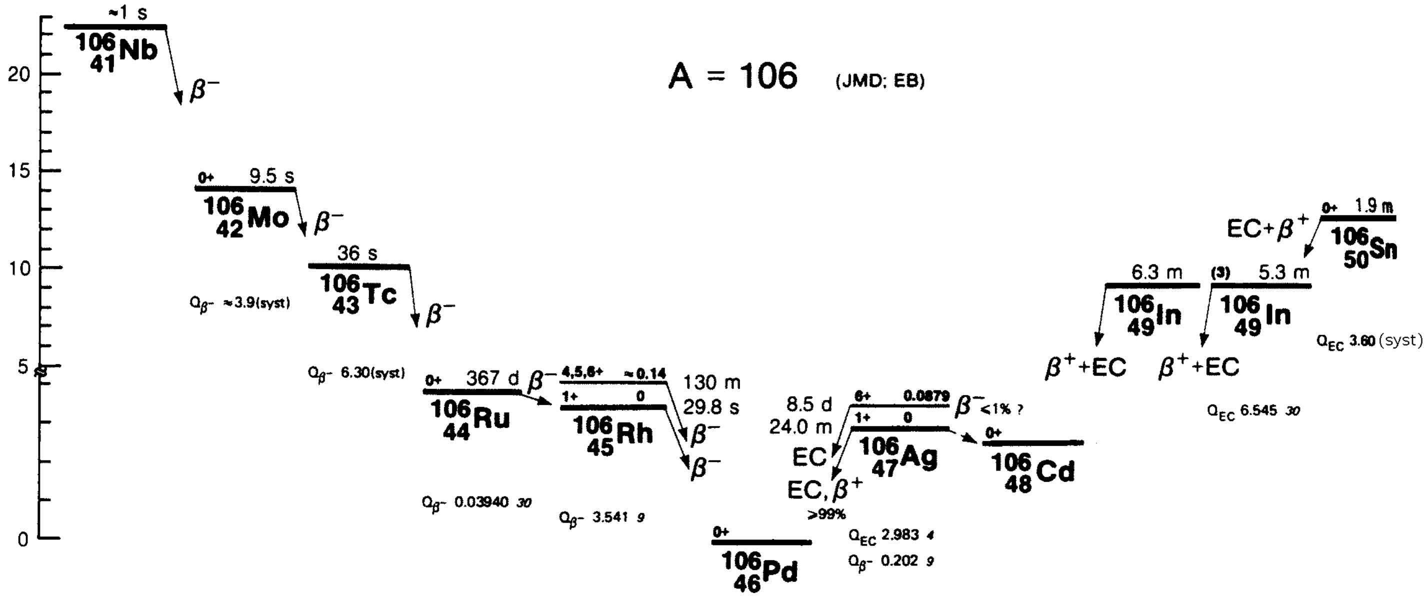


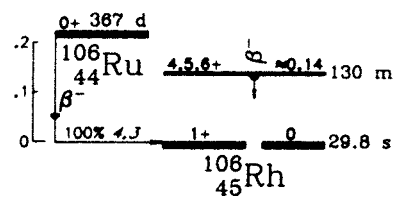
$^{57}_{27}$Co

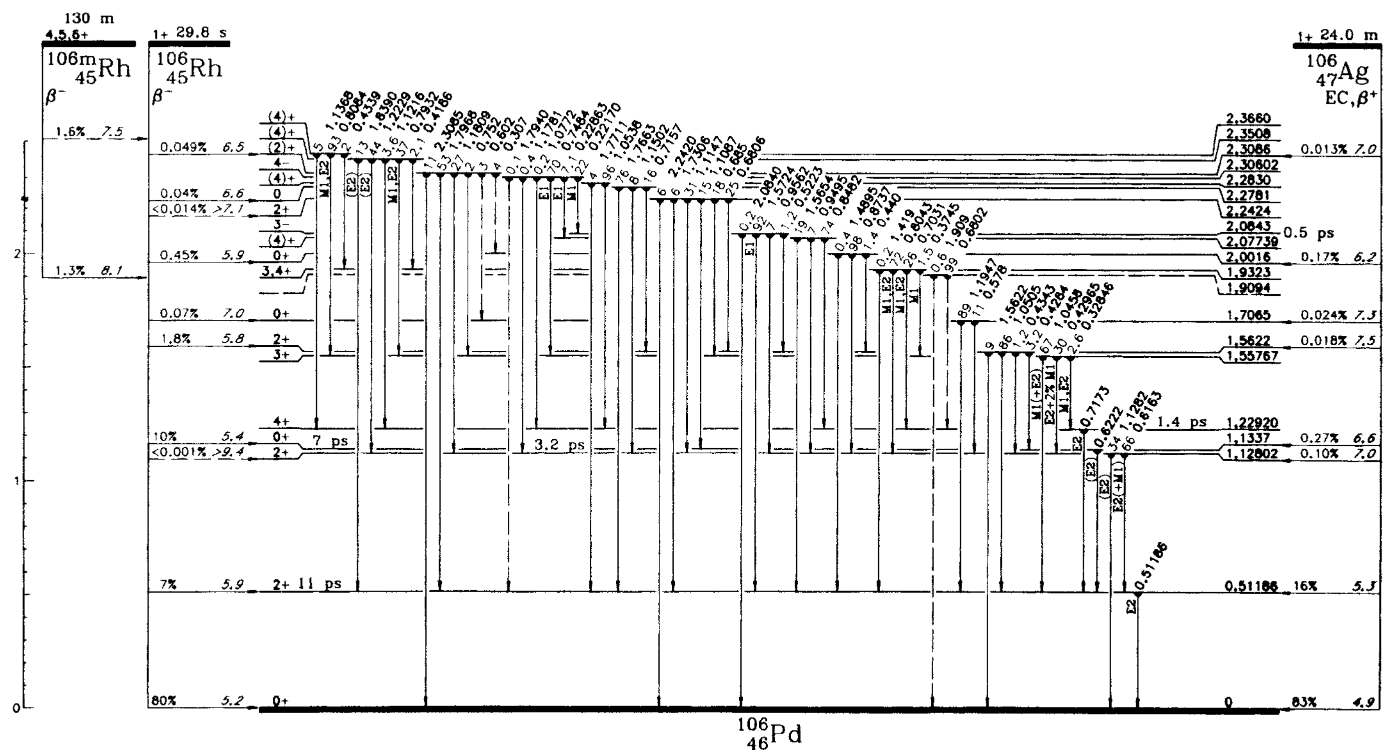
Δ: −59.3424 15 {ANDT 19 175(77)}
I: 7/2 *EPR* {PPSL 69A 353(56)}
ψ: EC {PR 98 66(55)}
$t_{1/2}$: 271.65 13 d {NP−15663(65)}; 271.23 63 d {IIso 23 219(72)}; 269.8 4 d {NSEg 48 319(72)}; **others:** {PR 99 703(55), PR 60 913(41)}
Class: A; **Ident:** chem, excit, cross bomb {PR 60 913(41)}
Prod: gammas on ^{58}Ni {RaTo 12 60(63)}; ^{56}Fe(d,n) {PR 53 847(38), PR 53 104(38), RicS 10 464(39), PR 60 913(41)}; ^{56}Fe(p,γ) {PR 60 913(41)}; ^{55}Mn(α,2n) {PR 88 887(52)}
γ: **0.01441247** 29 *cryst* {RMP 39 78(67), ZNat 27a 1861(72)}
0.1220583 21, **0.1364709** 23 *cryst* {ZNat 31a 387(76)}
0.1220638 30, **0.1364785** 35 *cryst* {ZNat 27a 1861(72)}
0.122063 4, **0.136473** 4 *Ge(Li)* {NIM 96 173(71)}
(norm: $\gamma_{0.122}$ (γ 85.6 4%), from level scheme) $\gamma_{0.014}$ ($\dagger_\gamma$1.141 50×10^4), **0.122062** ($\dagger_\gamma$1×10^5), **0.136473** ($\dagger_\gamma$1.30 4×10^4), **0.23046** ($\dagger_\gamma$0.5 5), **0.33968** 28 ($\dagger_\gamma$4.5 4), **0.35223** 27 ($\dagger_\gamma$3.7 4), **0.36705** ($\dagger_\gamma$1.5 4), **0.57004** 28 ($\dagger_\gamma$19.4 11), **0.69244** 6 ($\dagger_\gamma$183 11), **0.70646** 34 ($\dagger_\gamma$6.2 6) *Ge(Li)* {NIM 94 389(71)}
$\gamma_{0.014}$ ($\dagger_\gamma$1.00×10^4), $\gamma_{0.122}$ ($\dagger_\gamma$1×10^5), $\gamma_{0.136}$ ($\dagger_\gamma$1.29×10^4), **0.2306** 6 ($\dagger_\gamma$0.6), **0.3397** 5 ($\dagger_\gamma$5.6), **0.3524** 5 ($\dagger_\gamma$4.4), **0.3667** 5 ($\dagger_\gamma$0.8), **0.5703** 4 ($\dagger_\gamma$16), **0.6921** 3 ($\dagger_\gamma$188), **0.7068** 4 ($\dagger_\gamma$7.9) *Ge(Li)* {NP 74 177(65)}
$\gamma_{0.014}$ (e/γ 8.25 46), $\gamma_{0.122}$ ($\dagger_\gamma$ 1×10^5), $\gamma_{0.136}$ ($\dagger_\gamma$ 1.25 8×10^4), **0.2298** 10 ($\dagger_\gamma$0.7), **0.3397** 4 ($\dagger_\gamma$5.6), **0.3525** 4 ($\dagger_\gamma$4.3), **0.3668** 5 ($\dagger_\gamma$0.8), **0.5700** 4 ($\dagger_\gamma$17), **0.6921** 3 ($\dagger_\gamma$187), **0.7064** 4 ($\dagger_\gamma$7.6) *Ge(Li), scint−scint γγ coinc* {PR 139 B295(65)}
$\gamma_{0.122}$ ($\dagger_\gamma$1.00 1×10^5), $\gamma_{0.136}$ ($\dagger_\gamma$1.20 1×10^4), **0.230** ($\dagger_\gamma$0.2 2), **0.340** ($\dagger_\gamma$2.9 3), **0.353** ($\dagger_\gamma$2.0 2), **0.367** ($\dagger_\gamma$0.7 1), **0.570** ($\dagger_\gamma$16 1), **0.693** ($\dagger_\gamma$188 5), **0.707** ($\dagger_\gamma$5.5 6) *Ge(Li)* {NP 72 475(65)}
→ $\gamma_{0.014}$ (e/γ 8.19 18) *Mössbauer* {PR B1 3551(70)}
$\gamma_{0.014}$ (e/γ 8.26 22) *ion ch−ion ch γγ coinc* {PR 170 969(68), ND B3n3 103(70)}
$\gamma_{0.014}$ (K/L_1/L_{2+3}/M+N+... 107 25/10/0.92 7/1.75 2) *mag conv* {NP 19 221(60)}
0.014401 8 (e_K/γ 9.1 8, K/L 8.72 42, L/M 7.1 5), $\gamma_{0.122}$ (e_K/γ 0.0214 12, K/L+M+... 8.3 6), $\gamma_{0.136}$ (e_K/γ 0.122 13, K/L+M+... 8.4 4) *mag, mag conv, mag conv(PL 5 161(63))* {NP A91 495(67)}
$\gamma_{0.014}$ (e/γ 8.5 10), **0.1224** 4 (K/L+M+... 9.5 3), **0.1369** 4 (K/L+M+... 10.0 3) *mag conv, ion ch−ion ch γγ coinc* {CR 261 5438(65)}
$\gamma_{0.122}$ (e_K/γ 0.0245 30), $\gamma_{0.136}$ (e_K/γ 0.151 18) *Ge(Li), Si(Li) conv* {NuoC s10v52B 225(67)}
0.01437 1 ($\dagger_K$666 31, L/K 0.1120 18, M+N+.../K 0.0124 7), **0.12194** 3 ($\dagger_K$15.4 14, K/L+M+... 6.7 6), **0.13631** 3 ($\dagger_K$13.2, K/L+M+... 8.2 5) *mag conv* {JPPa 18 115(57), JPPa 17 532(56), CR 241 1202(55), AnP s13v2 419(57)}
$\gamma_{0.014}$ (K/L 11.4 10, L_{2+3}/L_1 0.093 7, M+N+.../L_1 0.169 9, M_{2+3}/M_1 0.077 7, for metallic-state graphite environment, M_{2+3}/M_1 0.079 7, for oxide-state graphite environment, N_1/M_1 0.034 3, for metallic-state graphite environment, N_1/M_1 0.024 2, for oxide-state graphite environment) *mag conv* {PR C3 2285(71)}
$\gamma_{0.014}$ (no M shakeoff electrons with K conversion), $\gamma_{0.122}$ (L and K shakeoff electrons with K conversion: KL/K ≈0.009, KK/K ≈4×10^{-5} to 2×10^{-4}), $\gamma_{0.136}$ (L shakeoff electrons with K conversion: KL/K ≈0.009) *mag conv* {PR C3 2246(71)}
others: {HypI 1 193(75), NIM 109 509(73), IIso 22 405(71), NIM 92 421(71), ND B3n3 103(70), NIM 77 141(70), NP A107 177(68), NP A91 505(67), NP 68 145(65), PL 17 51(65), NP 44 268(63), PL 5 161(63), ZP 175 506(63), PR 125 2031(62), NP 10 405(59), PR 109 2036(58), Phil s8v1 363(56), PPSL 68A 701(55), PR 99 703(55), PR 98 66(55), PR 97 837(55), PPSL 67A 280(54), PR 77 139(50), PR 64 321(43), PR 62 181(42)}

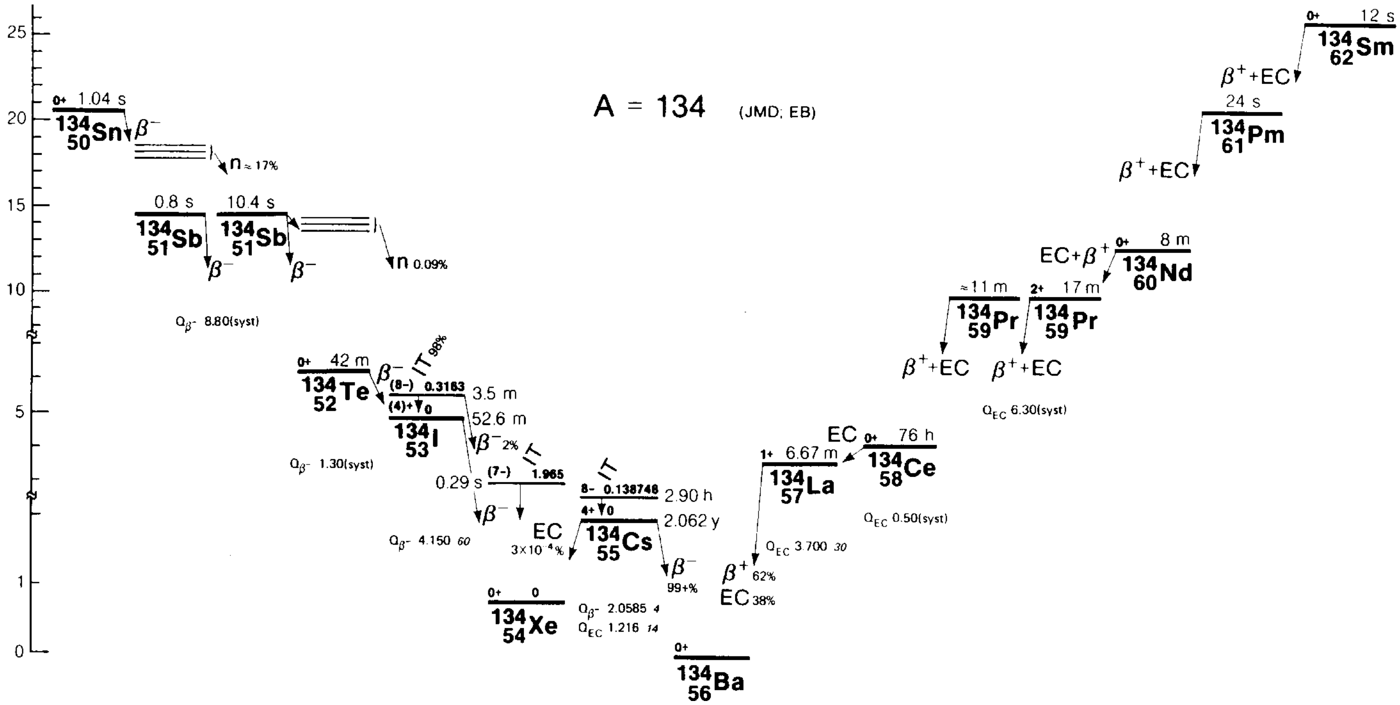

A = 60 (JMD,VS; EB)
0+ 2.4 m
60 30 Zn
β+ ≈97%
EC ≈3%
QEC 4.159 11
2+ 23.4 m
60 29 Cu
β+ 93%
EC 7%
QEC 6.1268 21
0+ 3×10^5 y
60 26 Fe
Qβ- 0.209 10
β−
IT 99.75%
2+ 0.05860 10.5 m
5+ 0 5.271 y
60 27 Co
β− 0.25%
β−
Qβ- 2.82363 11
0+
60 28 Ni

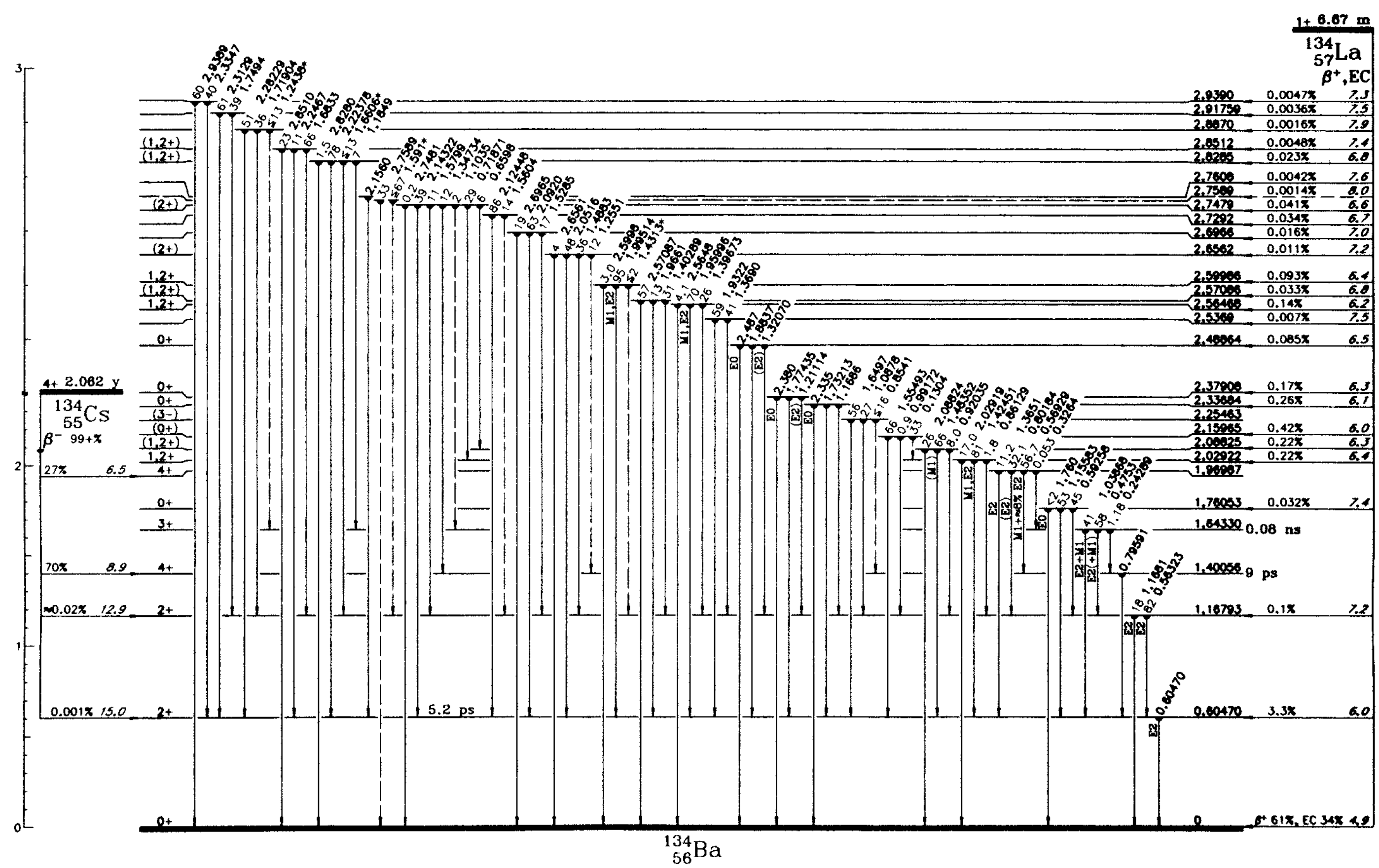

5+ 5.271 y
60 27 Co
β−
10.5 m
2+
60m 27 Co
β− 0.25%
≈0.6 ps
0.13 ps
0.14 ps
0.05 ps
0.07 ps
≈0.2 ps
0.73 ps
3.3 ps
23.4 m
2+
60 29 Cu
β+,EC
3.394 1.0% 6.5
3.2694 4.9% 6.0
3.1941 12.4% 5.6
3.1859
3.1241 52% 5.1
2.6262 2.9% 6.8
2.50571
2.2848
2.1588 15.4% 6.4
1.33250 5% 7.3
0
0+
60 28 Ni

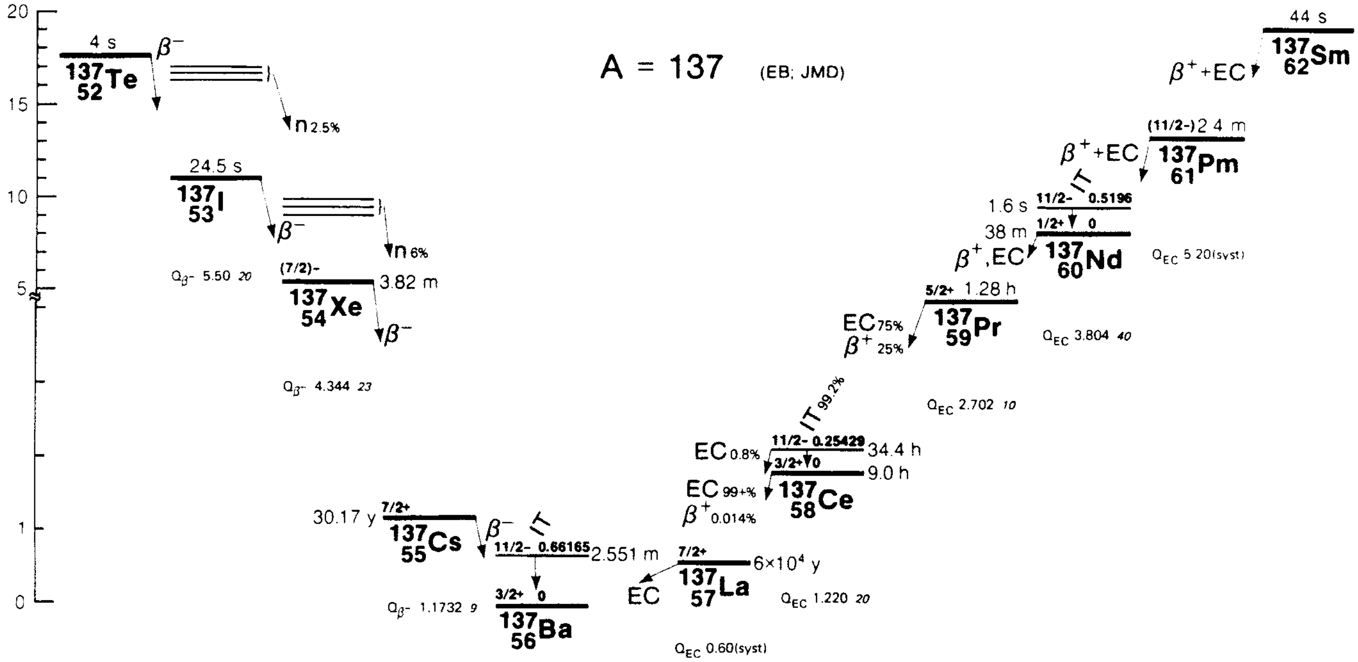

A = 106 (JMD; EB)
106 41 Nb
106 42 Mo
106 43 Tc
106 44 Ru
106 45 Rh
106 46 Pd
106 47 Ag
106 48 Cd
106 49 In
106 50 Sn
Qβ- ≈3.9(syst)
Qβ- 6.30(syst)
Qβ- 0.03940 30
Qβ- 3.541 9
QEC 2.983 4
Qβ- 0.202 9
QEC 6.545 30
QEC 3.60 (syst)


0+ 367 d
106 44 Ru
4,5,6+ ≈0.14 130 m
100% 4.3
1+
0 29.8 s
106 45 Rh


130 m
4,5,6+
106m 45 Rh
1+ 29.8 s
106 45 Rh
1+ 24.0 m
106 47 Ag
EC,β+
106 46 Pd


A = 134 (JMD; EB)
0+ 1.04 s
134 50 Sn
β⁻
n ≈ 17%
0.8 s
10.4 s
134 51 Sb
134 51 Sb
β⁻
n 0.09%
Qβ- 8.80(syst)
0+ 42 m
134 52 Te
(8-) 0.3163 3.5 m
(4)+ 52.6 m
134 53 I
IT 98%
β⁻ 2%
Qβ- 1.30(syst)
(7-) 1.965
0.29 s
IT
Qβ- 4.150 60
EC 3×10⁻⁴%
8- 0.138748 2.90 h
4+ 2.062 y
134 55 Cs
β⁻ 99+%
0+ 0
134 54 Xe
Qβ- 2.0585 4
QEC 1.216 14
0+
134 56 Ba
1+ 6.67 m
134 57 La
β⁺ 62%
EC 38%
QEC 3.700 30
EC 0+ 76 h
134 58 Ce
QEC 0.50(syst)
≈11 m
134 59 Pr
2+ 17 m
134 59 Pr
β⁺+EC
QEC 6.30(syst)
0+ 8 m
134 60 Nd
EC+β⁺
24 s
134 61 Pm
β⁺+EC
0+ 12 s
134 62 Sm
β⁺+EC

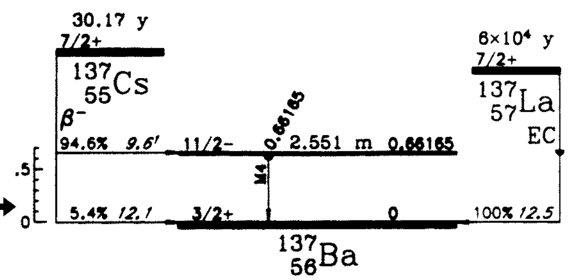

1+ 6.67 m
134 57 La
β⁺,EC
4+ 2.062 y
134 55 Cs
β⁻ 99+%
27% 6.5
70% 8.9
≈0.02% 12.9
0.001% 15.0
5.2 ps
0.08 ns
9 ps
2.9390 0.0047% 7.3
2.91759 0.0036% 7.5
2.8870 0.0016% 7.9
2.8512 0.0048% 7.4
2.8285 0.023% 6.8
2.7808 0.0042% 7.6
2.7589 0.0014% 8.0
2.7479 0.041% 6.6
2.7292 0.034% 6.7
2.6966 0.016% 7.0
2.6562 0.011% 7.2
2.59986 0.093% 6.4
2.57066 0.033% 6.8
2.56468 0.14% 6.2
2.5369 0.007% 7.5
2.48864 0.085% 6.5
2.37906 0.17% 6.3
2.33884 0.26% 6.1
2.25463
2.15965 0.42% 6.0
2.08825 0.22% 6.3
2.02922 0.22% 6.4
1.96987
1.76053 0.032% 7.4
1.64330
1.40056
1.16793 0.1% 7.2
0.60470 3.3% 6.0
0 β⁺ 61%, EC 34% 4.9
134 56 Ba



$^{137}_{56}$Ba

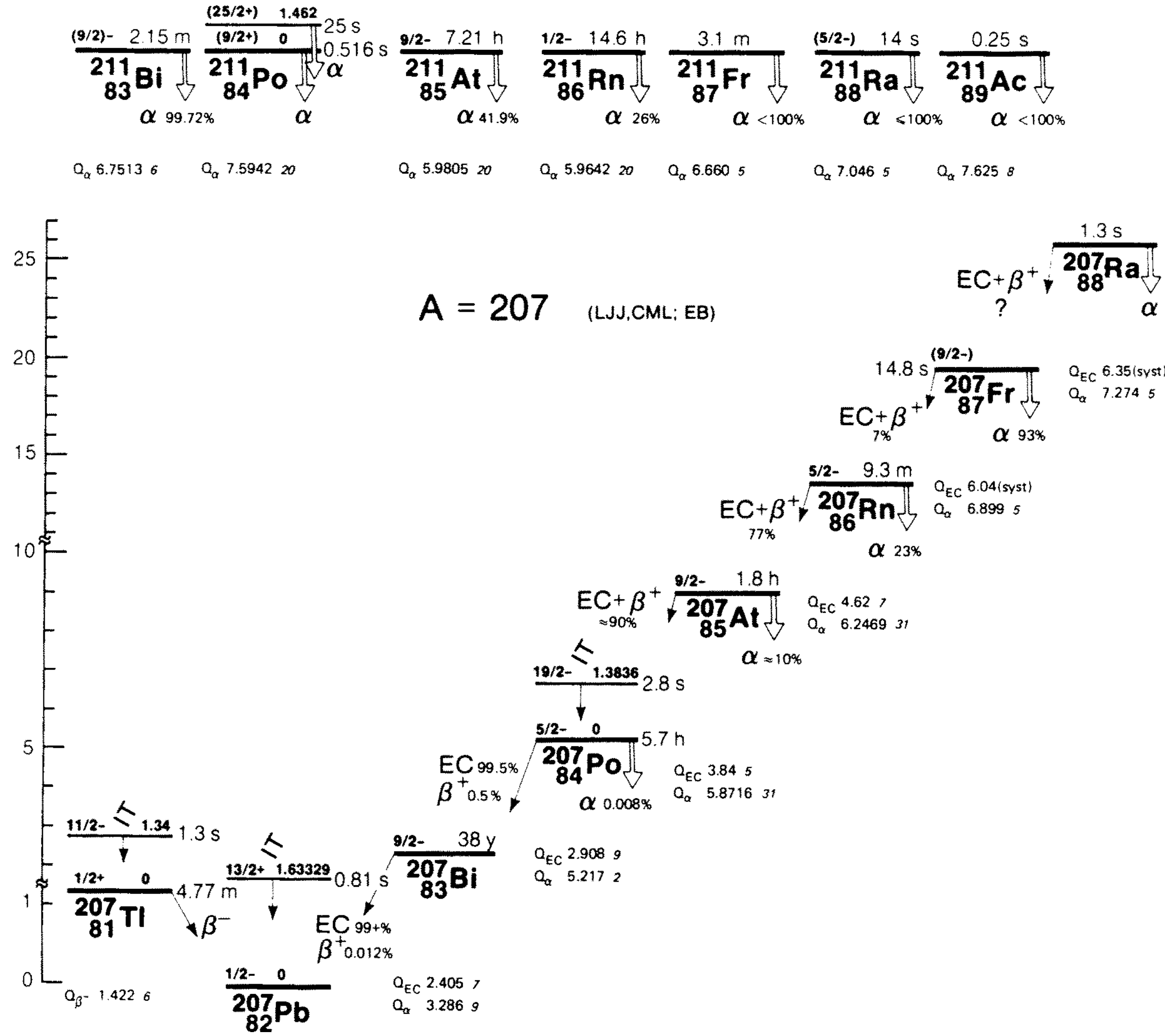
%: 11.2 {BNL-NCS-50605(77)}
Δ: −87.733*7* {ANDT 19 175(77)}
I: 3/2 *O, AB* {PR 52 1127(37), PR 79 836(50), PR 60 75(41)}
σ_0: 5.1*4* *(reactor spectrum)* {PC77 Holden}
$t_{1/2}$(2.349): 0.59 *10 µs delay coinc* {NP A206 245(73)}

e_k/γ =10%

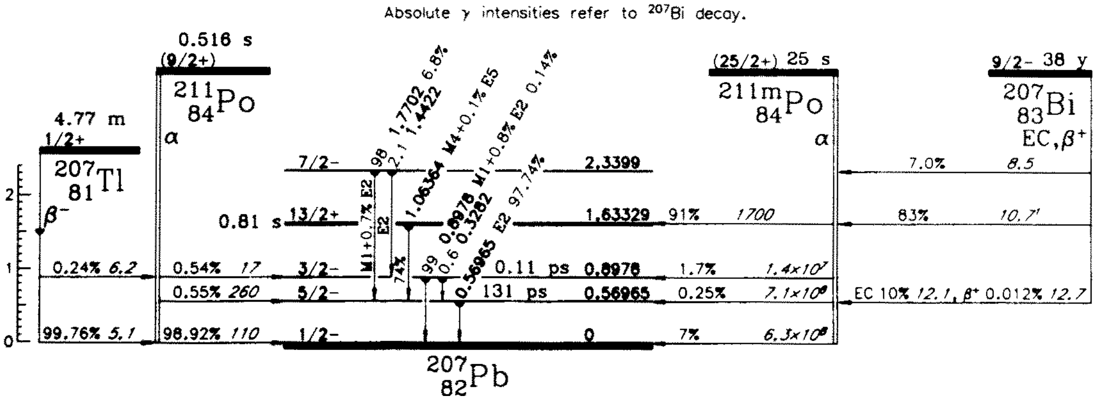


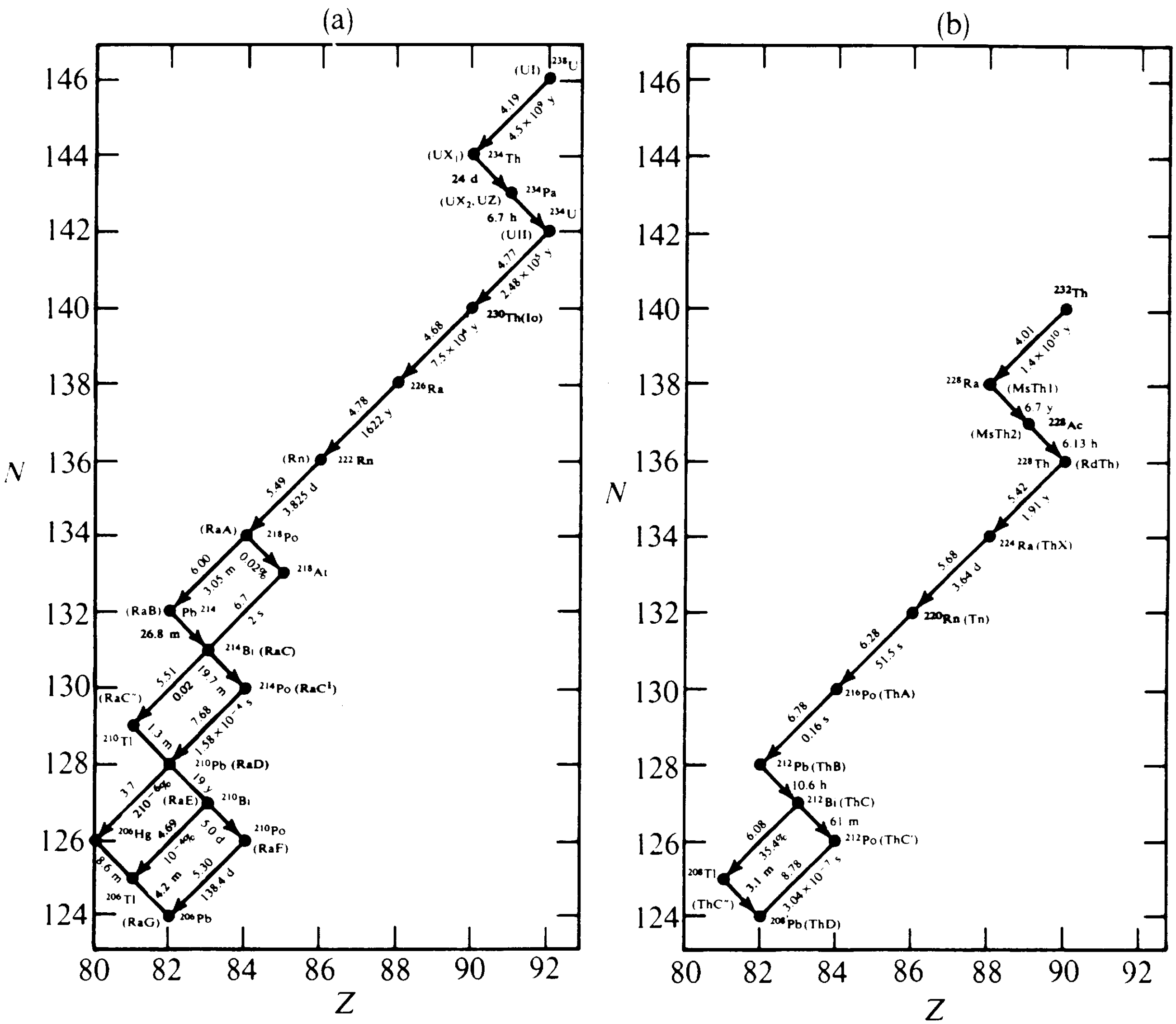
$^{137m}_{56}$Ba

Δ: −87.071*7* {ANDT 19 175(77)}
☢: IT {PR 74 499(48)}
$t_{1/2}$: 2.5513*7* m {JSAC 19 1(66)}; 2.554*3* m {AnaC 37 351(65)}; 2.5577*32* m {KDVM 35n8(66)}; 2.557*5* m {Nat 211 283(66)}; 2.559*6* m {KDVM 36n4(67)};
others: {RaAc 6 216(66), PR 118 242(60), PR 75 197(49), PR 74 499(48)}
Class: A; **Ident:** n-capt {PRSL 149A 522(35)}; chem, genet {PR 74 499(48)}
Prod: daughter ^{137}Cs {PR 74 499(48)}
γ: **0.661649** *12 cryst* {ZNat 31a 387(76)}
0.661638 *19 Ge(Li)* {NIM 96 173(71)}
⟨**norm:** $\gamma_{0.662}$ (γ 89.95%), from level scheme⟩ $\gamma_{0.662}$ (e_K/γ 0.0916*4*, K/L+M+... 4.41*4*) *Si(Li)-mag γe coinc, scint-ion ch γβ coinc* {ZP 218 25(69)}
→ $\gamma_{0.662}$ (e_K/γ 0.0894 *10*, e/γ 0.1100 *11*) *Ge(Li), mag conv, ion ch scint eγγ coinc* {AnaC 37 351(65)}
$\gamma_{0.662}$ ($K/L_1/L_2/L_3$ 1000*20*/151*4*/22*1*/19*1*) *mag conv* {CJP 40 1258(62), NIM 9 245(60)}
$\gamma_{0.662}$ (K/L 5.29*23*, $L_1/L_2/L_3$ 341 *10*/100/50*3*) *mag conv* {YadF 5 901(67)}
$\gamma_{0.662}$ (K/L 5.25*30*, K/M+N+... 12.4 *10*) *Ge(Li), Ge(Li) conv* {HPAc 42 949(69)}
$\gamma_{0.662}$ ($\dagger_{\gamma\gamma}/\dagger_\gamma$ 6.4*3*1×10^{-6}) *scint-scint γγ coinc* {HPAc 33 363(60)}
$\gamma_{0.662}$ (K/L/M 566*4*/100/26.0*3*) *mag conv* {NP 5 122(58)}
$\gamma_{0.662}$ ($\dagger_{K\gamma}/\dagger_K$ 0.0022*2*) *scint-Si(Li) γe coinc* {PR C3 824(71)}
$\gamma_{0.662}$ ($\dagger_{KK}/\dagger_K$ 1.85×10^{-4}, $\dagger_{ee}/\dagger_K$ ≤4.5×10^{-4}) *Si(Li)-Si(Li) ee coinc* {PR C3 831(71)}
others: {IIso 26 490(75), NIM 116 465(74), APNY 78 496(73), PScr 4 15(71), NIM 84 157(70), NIM 76 285(69), Prib 1969-2 33(69), NIM 65 26(68), RaAc 10 1(68), NP 86 47(66), IzF 29 2157(65), NIM 36 261(65), PR 135 B319(64), NIM 24 109(63), NP 44 670(63), ZP 168 292(62), NP 28 471(61), PIAS A53 244(61), NP 18 454(60), ArkF 14 565(59), JPJa 12 738(57), Phca 23 693(57), PR 107 1674(57), IzF 20 896(56), ZETF 30 571(56), IzF 19 324(55), ArkF 7 275(54), CR 239 1374(54), JPJa 9 1(54), PR 95 404(54), Dokl 92 1141(53), PPSL 66B 54(53), PR 89 1159(53), PR 88 775(52), PR 88 344(52), PR 87 195(52), PR 82 906(51), PR 80 489(50), PR 78 74(50), PR 76 345(49), PR 75 197(49), PR 74 499(48)}



Absolute γ intensities refer to ^{207}Bi decay.





The natural radioactive families of (a) ^{238}U and (b) ^{232}Th in a Z-N diagram, with the associated energies and half-lives.