3 Natural Isotopes

3.1 Natural & Np Decay Chains

3.1.1 U-238 Decay and Daughters (Radium Series)

red: long-lived isotope, green: isotope in equilibrium, **blue:** noble gas, cyan: γ-ray reference line, attention half-life

half life $t_{1/2}$	**isotope** decay branch in %	α**-decay** energy, MeV (intensity, %)**	β**-decay/IT** energy, MeV (intensity, %)**	γ**-emission** energy, keV; (intensity, %)*
$4.468*10^9$y	$^{238}_{92}$**U**	α: 4.198 (79)		γ: 49.55 (0.064)
	100⇓ α	α: 4.151 (21)		γ: 113.5 (0.0102)
		α: 4.038 (0.078)		↓Th/Pa in equil. with ^{238}U↓
24.10 d	$^{234}_{90}$**Th**		β: 0.199 (78.0)	γ: 63.29 (3.7)
	100↓ β		β: 0.107 (14.0)	γ: 92.38 (2.13)
			β: 0.106 (6.4)	γ: 92.80 (2.10)
1.159 m	$^{234m}_{91}$**Pa**			
	0.16 99.84		β: 2.269 (97.57)	γ: 1001.03 (0.842)$_{Pm a}$
	IT ↓ ↓ β		β: 1.224 (1.002)	γ: 766.42 (0.317)$_{Pm a}$
6.70 h	$^{234}_{91}$**Pa** $\xrightarrow{\beta^-}$ $^{234}_{92}$**U**	α: 4.7746 (71.38)	β: 0.472 (34)	γ: 131.30 (0.030)$_{Pa}$
$2.455*10^5$y	100	α: 4.7224 (28.42)	β: 0.642 (20.4)	γ: 53.20 (0.123)$_U$
	↙ α			γ: 120.90 (0.035)$_U$
$7.538*10^4$y	$^{230}_{90}$**Th**	α: 4.6870 (76.3)		γ: 67.67 (0.38)$_{Th}$
	100⇓ α	α: 4.6205 (23.4)		
1600 y	$^{226}_{88}$**Ra**	α: 4.7843 (93.84)		γ: 186.21 (3.64)$_{Ra}$
	100⇓ α	α: 4.601 (6.16)		↓in equil. with ^{226}Ra↓
3.8235 d	$^{222}_{86}$**Rn**	α: 5.4895 (99.92)		γ: 510 (0.076)$_{Rn}$
	100⇓ α	α: 4.986 (0.078)		↓and with ^{222}Rn↓(att.^{210}Pb)
3.098 m	$^{218}_{84}$**Po**	α: 6.0024 (99.98)	Po-/At-218: NO	Po-/At-218: NO
	0.020 99.980		β-DATA AVAILABLE	γ-RAYS OBSERVED
	β ↓ ⇓ α			
1.5 s	$^{218}_{85}$**At** $^{214}_{82}$**Pb**	α: 6.693 (89.91)	β: 0.724 (40.2)	γ: 351.93 (35.60)$_{Pb}$
26.8 m	0.10 99.9 100		β: 0.667 (45.9)	γ: 295.22 (18.42)$_{Pb}$
	β ↓ α ↘ ↓ β		β: 1.019 (11.0)	γ: 242.00 (7.251)$_{Pb}$
35 ms	$^{218}_{86}$**Rn** $^{214}_{83}$**Bi**	α: 5.452 (0.0113)$_{Bi}$	β: 3.270 (19.10)	γ: 609.32 (45.49)$_{Bi}$
19.9 m	100 0.02 99.98	α: 5.516 (0.0082)$_{Bi}$	β: 1.540 (17.57)	γ: 1764.49 (15.30)$_{Bi}$
	α ↘ α ↙ ↓ β	α: 7.133 (?)$_{Rn}$	β: 1.505 (16.96)	γ: 1120.29 (14.92)$_{Bi}$
			β: 1.423 (8.14)	γ: 1238.12 (5.78)$_{Bi}$
1.30 m	$^{210}_{81}$**Tl** $^{214}_{84}$**Po**	α: 7.6868 (99.99)		γ: 799.7 (0.0104)$_{Po}$
164.3 μs	100 100		β: 4.22 (30)	γ: 799.6 (0.021)$_{Tl}$
	β ↘ ↙ α		β: 1.868 (24)	γ: 296 (0.0166)$_{Tl}$
22.20 y	$^{210}_{82}$**Pb**		β: 0.017 (84)	γ: 46.54 (4.25)
	100 ↓ β		β: 0.064 (16)	^{210}Bi β-decay: NO γ-RAYS
5.012 d	$^{210}_{83}$**Bi**	α: 4.656(7.9E-5)$_{Bi}$	β: 1.162 (100)$_{Bi}$	γ: 265.5 (6.7E-5)$_{\alpha\ decay}$
	1.32E-4↙ α β ↘100	α: 4.694(5.3E-5)$_{Bi}$		γ: 304.6 (3.7E-5)$_{\alpha\ decay}$
4.202 m	$^{206}_{81}$**Tl** $^{210}_{84}$**Po**	α: 5.3043 (100)	β: 1.532 (99.885)	γ: 803.06 (0.0050)$_{Tl}$
138.376 d	100↘ β α ↙100	α: 4.5166 (0.00104)	β: 0.729 (0.0051)	γ: 803.06 (0.00103)$_{Po}$
stable	$^{206}_{82}$**Pb**			

**α-, β-decay: absolute intensity $\Sigma \approx 100\%$, intensity of branch-isotopes: $\Sigma(\alpha+\beta+IT) \approx 100\%$

*γ-emission in equilibrium with U-238/Ra-226; magenta ↓: main decay branch