

3.2 Natural Isotopes in Detail

3.2.1 Decay of U-238 and their Daughters

** α -, β -decay: absolute intensity $\Sigma \approx 100\%$; * γ -emission: intensity per 100 decays in equilibrium with U-238

isotope/ref. abundance % Q_α, Q_β MeV $t_{1/2}$	α -, β -decay, sf $E_\alpha, E_\beta^{max}, (\bar{E}_\beta)$ MeV	α -, β -, sf branch intens.** %	daughter-nuclide & E_γ γ -ray transition (cascade) to final state in keV	E-list in I-order keV	γ - intens.* %
²³⁸ ₉₂ U NDS,108,681,2007 99.2745 ₁₀ % $Q_\alpha=4.2697_{29}$ 4.468 ₃ * 10 ⁹ y	→ α : 4.198 ₃ → α : 4.151 ₅ → α : 4.038 ₅ → sf : → β - β -:	79 ₃ 21 ₃ 0.078 ₁₂ 5.457E-5 2.27E-10	→ ²³⁴ ₉₀ Th($t_{1/2}=24.10$ d) → γ : 49.55 ^{int} (data set completely) → γ : 113.5 ^{int} , 49.55 ²³⁸ ₉₂ U: $\alpha=100\%$, β -stable, DU:CHAPTER 5.5 nat.soil specif.activity:12.35 ₁ kBq/g U _{nat} [8]	49.55 ₆ 113.5 ₁	0.064 ₈ 0.0102 ₁₅
int= ²²⁷ Th(50.13, 8.0%), ²³⁴ Th(112.81, 0.231%) (44.9)			↓ in equilibr. with U-238 ↓		
²³⁴ ₉₀ Th NDS,108,681,2007	→ β^- : 0.199 ₃ → β^- : 0.107 ₃ → β^- : 0.106 ₃ → β^- : 0.096 ₃ → β^- : 0.086 ₃	$\beta^- = 100\%$ 78.0 ₂₀ 14.0 ₂₀ 6.4 ₁₉ 0.015 ₇ 1.5 ₇	(data set completely) → ^{234m} ₉₁ Pa($t_{1/2}=1.159$ m) ^{73.92} ₉₁ Pa _{0.0133} → γ : 62.86 ^{int,M1,E2} , 29.49 ^{E2} γ : 92.38 ^{int,exc,M1,E2} → γ : 63.29 ^{int,E1} , 29.49 γ : 92.80 ^{int,exc,E1} → γ : 73.92 ^{int,M1,E2} , 29.49 → γ : 112.81 ^{int,E1} γ : 83.30 ^{int,exc,E1} , 29.49 γ : 20.02 ^{int,M1,E2} , 63.29, 29.49	63.29 ₂ 92.38 ₁ 92.80 ₂ 112.81 ₅ 83.30 ₅ 62.86 ₂ 73.92 ₂ 29.49 ₂ 103.35 ₁₀	3.7 ₄ 2.13 ₂₀ 2.10 ₂₀ 0.241 ₂₃ 0.060 ₆ 0.016 ₃ 0.0130 ₁₄ 0.0120 ₁₄ 0.0050 ₂₀ 0.0032 ₁₀
int= ²³² Th(63.83, .263%), ^{234m} Pa(73.92, IT), , Th-K α_1 : (93.35), ²³⁸ U(113.5, .0102%)					
^{234m} ₉₁ Pa ^{234m} ₉₁ Pa NDS,108,681,2007	→ β^- : → IT: → sf: → β^- : 2.269 ₄ → β^- : 1.483 ₄ (0.8114 ₁₈) → β^- : 1.459 ₄ → β^- : 1.224 ₄ → β^- : 1.032 ₄ → β^- : 0.715 ₄ → β^- : 0.488 ₄ → β^- : 0.394 ₄	99.84 ₄ 0.16 ₄ 3.E-9 97.57 ₆ 0.059 ₄ 0.948 ₁₃ 1.002 ₃ 0.0190 ₇ 0.0321 ₆ 0.0355 ₈ 0.0256 ₃	→ ²³⁴ ₉₂ U($t_{1/2}=2.455*10^5$ y) → γ^1 : <10 ^{E3} + 73.92 ^{int} → ²³⁴ ₉₁ Pa(6.70 h) ¹ from 1.159 m level → ²³⁴ ₉₂ U α' s ²²⁶ ₈₈ Ra → γ : 742.81 ^{int,E1} , 43.50 ^{E2} γ : 786.28 ^{int,E1} → γ : 766.42 ^{E2} , 43.50 → γ : 1001.03 ^{E2} , 43.50 → γ : 1193.73 ^{E1} , 43.50 → γ : 1510.20 ^{int} , 43.50 → γ : 1737.75, 43.50 → γ : 1831.36, 43.50	73.92 ₂ 1001.03 ₁₀ 766.42 ₁₀ 742.813 ₅ 258.227 ₃ 786.28 ₁₀ 1737.75 ₁₀ 1831.36 ₁₀ 1193.73 ₁₂ 1510.20 ₁₀ 921.72 ₁₀ 740.10 ₈	0.013 _? 0.842 ₈ 0.317 ₅ 0.1066 ₂₃ 0.0764 ₂₁ 0.0544 ₈ 0.0213 ₃ 0.01742 ₂₄ 0.01358 ₁₆ 0.01287 ₁₆ 0.01278 ₁₆ 0.0109 ₁₇
int= ²¹⁴ Pb(258.87, .524%), ²¹⁴ Bi: (DE 742.49), ²¹² Bi(785.37, 1.10%), ²¹⁴ Pb(785.96, 1.07%), ²¹⁴ Bi(786.10, .31%)					
²³⁴ ₉₁ Pa ²³⁴ ₉₁ Pa NDS,108,681,2007 ENSDF data file and ref. [15],[16]	β^- : → sf: → β^- : 1.171 ₈ → β^- : 0.642 ₈ → β^- : 0.502 ₈ → β^- : 0.472 ₈ → β^- : 0.472 ₈ → β^- : 0.412 ₈	(0.215) $\Sigma \beta^-$:110% 100 3.E-10 4.8 ₈ 20.4 ₁₈ 7.3 ₈ 34 ₄ 12.9 ₁₂ 8 ₃	← intensity balance → ²³⁴ ₉₂ U → ²³⁴ ₉₂ U → γ : 131.30 ^{int} , 226.50, 898.67., → γ : 227.25, 131.30, 226.50, 898.67., → γ : 733.39, 946.00, 43.49 ADDITIONAL ENERGIES SEE NEXT PAGE	131.30 ₁ 946.00 ₃ 880.5 ₁ 883.24 ₄ 569.5 ₁ ^{int} 925.0 ₁ 926.72 ₁₅ 733.39 ₅	in equil./abs. ² 0.030 ₂ /18.9? 0.022 ₃ /14.0 ₉ 0.010 ₆ /6.4? 0.016 ₂ /10 ₆ 0.014 ₂ /8.6 ₉ 0.013 ₂ /8.2 ₅ 0.012 ₂ /7.6 ₁₀ 0.012 ₁ /7.2 ₄
int= ²²⁸ Th(131.61, .131%), 569: ²⁰⁷ Bi, ¹³⁷ Cs					

² ENSDF: normalization factor for absolute intensity 1.08g; branch for equilibrium 0.0016₄; relative photon intensity normalized to I(131.30keV)=17.5%; Example: 17.5%*1.08=18.9% absolute and 17.5%*1.08*0.0016=0.030% equilibrium