**Half-life / Decay Rate**

Radioactive decay is a random process:

- probability of a decay per gram per second
- decays/second = decay rate × mass
- specific time for half of nuclei to decay

= HALF LIFE

**Example:** 

\[ ^{14}\text{C} \text{ beta decay} \quad T_{1/2} = 5730 \text{ years} \]

\[ 0 \rightarrow 0 \quad 1 \text{ gram (1/2)^0} \]

\[ 2 \text{ Ti} = 5730 \text{ y} \quad 2 \text{ gram (1/2)^1} \]

\[ 4 \text{ Ti} = 5730 \text{ y} \quad 4 \text{ gram (1/2)^2} \]

\[ 8 \text{ Ti} = 5730 \text{ y} \quad 8 \text{ gram (1/2)^3} \]

\[ 16 \text{ Ti} = 5730 \text{ y} \quad 16 \text{ gram (1/2)^4} \]

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**Carbon dating:**

- look at ratio \( ^{14}\text{C} / ^{12}\text{C} \)
- slow decay

- to determine age of wood, bone, etc.

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*Half life varies enormously, very sensitive nuclear physics determines probability*

\[ ^{241}\text{Am} \quad T_{1/2} = 432 \text{ years} \]

Artificial (nuclear reactor) used in smoke detectors, long-lasting

\[ T = \text{tritium, } \beta \text{-decay, } T_{1/2} = 12 \text{ years} \]

\[ ^{238}\text{U}, \alpha \text{-decay, } T_{1/2} = 4.5 \text{ billion years (Sequend)} \]

\[ ^{226}\text{Ra}, \alpha \text{-decay, } T_{1/2} = 1600 \text{ years (Curie)} \]

\[ ^{227}\text{Ra}, \beta \text{-decay, } T_{1/2} = 42 \text{ minutes} \]

\[ ^{231}\text{Ra}, \beta \text{-decay, } T_{1/2} = 103 \text{ seconds} \]
Radiation Units

main unit for radio nuclides = Curie (huge)

1 Curie = 1 Ci = decay rate of 1 g of 226Ra
= $3.7 \times 10^{10}$ decays per second

Common to use $\mu$Ci = $10^{-6}$ Ci = $3.7 \times 10^{4}$ decays/sec

Radium (226Ra) series one of only four natural radiation series!

238 U: 4.5 billion years, natural mineral (Saskatchewan, South Dakota)
234 Th: 24 days
234 Pa: 6.7 hours
234 U: 245,500 years
230 Th: 75,380 years
226 Ra: 1,600 years
222 Rn: 3.8 days GAS! Short half-life! But long enough!
218 Po: 3.1 minutes
214 Pb: 27 minutes
214 Bi: 20 min
214 Po: 0.16 ms
210 Pb: 22 years
210 Bi: 5 days
210 Po: 138 days
206 Pb: stable

Medical Tracing $^{14}$C, $^{3}$H = T, $^{32}$P

Make compounds with isotopes, then trace through biological processes

$^{14}$C doubled in atmosphere from nuclear tests until 1963
Ionizing Radiation

α, β, γ are all subject to electromagnetic interaction
- photoelectric effect by γ (absorbed by atom)
- Compton effect by γ (scattered off electrons)
- scattering of α, β off electrons
- Bremsstrahlung X-rays from α, β slowing down

α, β ionize along their path until they stop
γ ionizes in several discrete interactions

Result in tissue, bone: DAMAGE, CANCER

Unit: Sierrad (Sv) in use may many others as well
1 Sv of radiation produces 1 J of ionizing energy
in 1 kg of biological material

⇒ HUGE

- Annual dose ≤ 3 mSv all sources
- chest x-ray = 0.06 mSv
- abdomen CT scan = 5 mSv ⇒ limit 1 per year or less