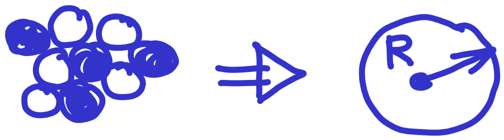
Nuclear radius



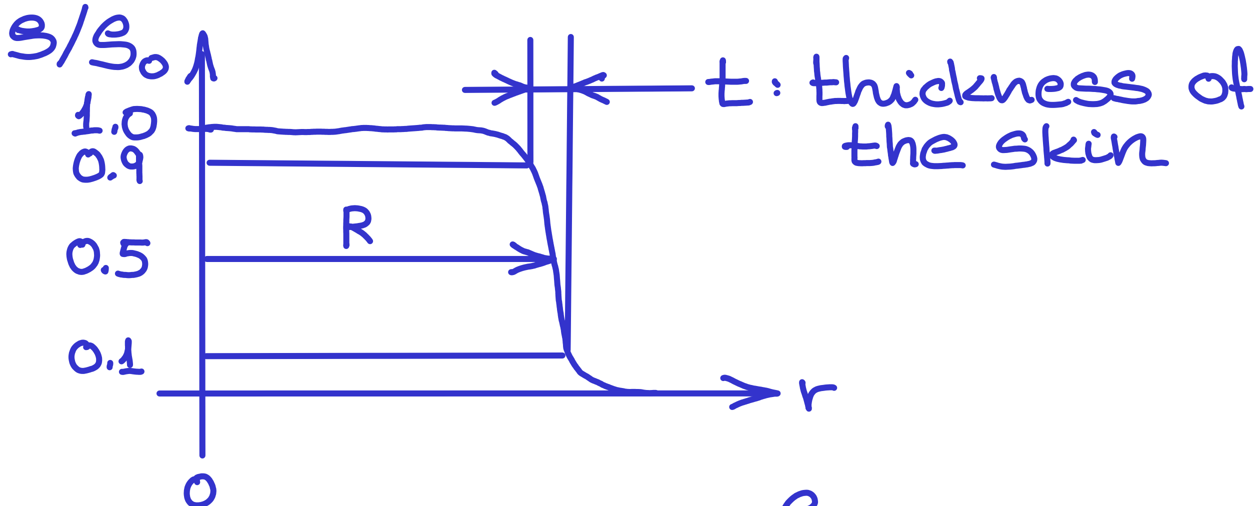
R: what kind of radius?

nuclear force radius
mass radius
electric charge radius

} ≈

$$R = r_0 \cdot A^{1/3} \; ; \; r_0 = 1{,}2 \text{ fm}$$

Enrico Fermi



$$\rho(r) = \frac{\rho_0}{1 + e^{\frac{r-R}{a}}} \; ; \quad t = 4{,}4a$$

Robert Hofstadter (1961, Nobel):
first nuclear radius measurements
using 100-500 MeV electrons.

Nuclear density

$$\rho = \frac{m}{V} = \frac{m}{\frac{4\pi}{3}R^3} = \frac{A\,(AMU)}{\frac{4\pi}{3}r_0^3\,A(1)} =$$

$$= \frac{1\,AMU}{\frac{4\pi}{3}\cdot(1.2\,fm)^3} = \frac{1.66\cdot 10^{-27}}{\frac{4\pi}{3}\cdot\left(1.2\cdot 10^{-15}\right)^3} =$$

$$= 2.29\cdot 10^{17}\,\frac{kg}{m^3} = 2.29\cdot 10^{14}\cdot\rho_{water}$$

The mass density of nuclear matter is incredibly high.

Radioactivity

("... discovered by Madame Curie."
Kraftwerk)

- Becquerel, Pierre and Marie Curie (1903 Nobel)
- Marie Curie (1911 C.Nobel)
- Irène and Frédéric Joliot-Curie (1935 C.Nobel)

α : alpha : ${}^4_2He$ nucleus

β : beta : e^- or e^+ from the nucleus

γ : gamma : photon from the nucleus in the MeV range

X-ray : photon from the electron shell or from accelerating electrons in the keV range

Cathode-ray : electron from the negative electrode accelerated by electric voltage, range: keV

Radioactive decay 1.

$\Delta N \propto N \cdot \Delta t$

ΔN : number of decays within Δt

N : total number of nuclei

Δt : small time interval

$\Delta N = -\lambda \cdot N \cdot \Delta t \Rightarrow dN = -\lambda \cdot N \cdot dt$

$\frac{dN}{dt} = -\lambda \cdot N$ Question: $N = N(t)$?

$$\boxed{N(t) = N_0 \cdot e^{-\lambda t} = N_0 \cdot e^{-t/\tau} = N_0 \cdot 2^{-\frac{t}{T_{1/2}}}}$$

N_0 : initial number of nuclei

$\lambda = \frac{-\frac{\Delta N}{N}}{\Delta t} = \frac{P}{\Delta t}$: probability per unit time that a decay will happen.

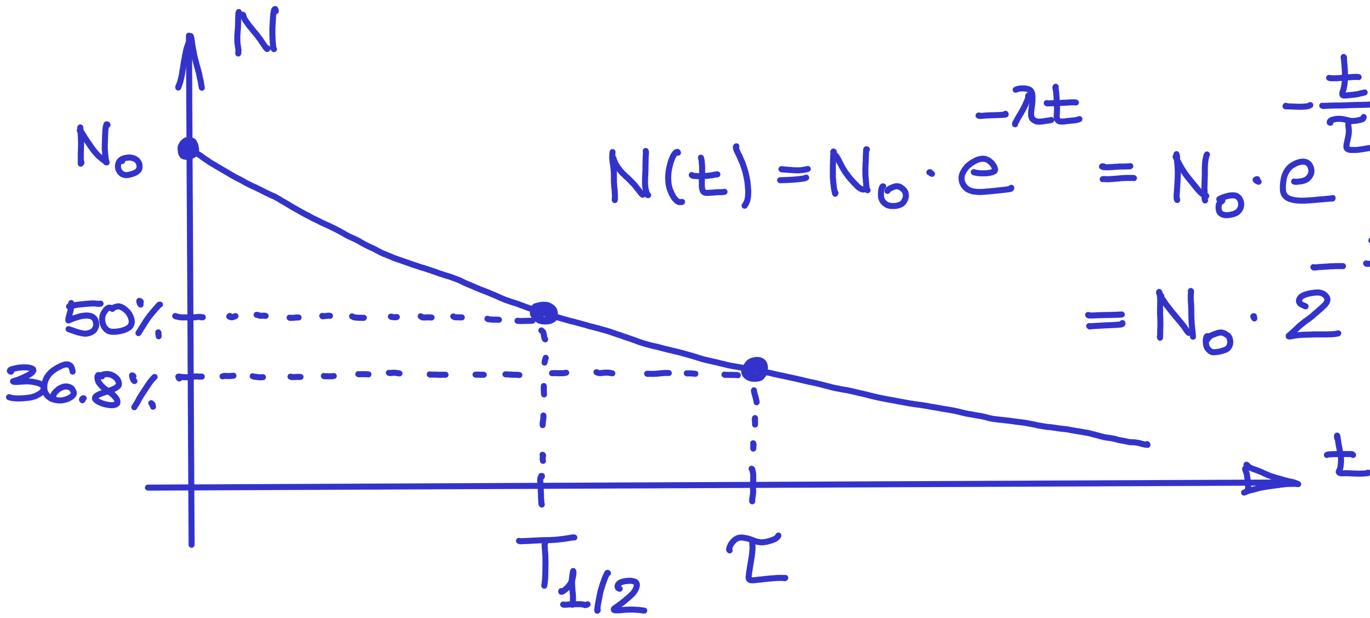
λ : decay constant, $[\lambda] = \frac{1}{s}$

$-\frac{\Delta N}{\Delta t} = \lambda N = R$: activity

$[R] = 1/s$ = decay/s

Curie: $1\,Ci = 3.7 \cdot 10^{10}$ decays/s

Radioactive decay 2.



$$N(t) = N_0 \cdot e^{-\lambda t} = N_0 \cdot e^{-\frac{t}{\tau}} =$$

$$= N_0 \cdot 2^{-\frac{t}{T_{1/2}}}$$

λ = decay constant, $[\lambda] = \frac{1}{s}$

τ = life time, $[\tau] = s$ (min, h, yrs)

$T_{1/2}$ = half life, $[T_{1/2}] = s$ (min, h, yrs)

$$\lambda = \frac{1}{\tau} \qquad T_{1/2} = \ln 2 \cdot \tau$$

$$\ln 2 = 0.693$$

$$\frac{1}{e} = \frac{1}{2.718} = 0.368$$