... od zadnjič

$$A(t) = A_{ca}(t) + A_{sc}(t)$$

$$A_{ca}(t) \to \frac{N_{ca}(t)}{\tau_1} \qquad A_{sc}(t) \to \frac{N_{sc}}{\tau_2}$$

Za Ca: $N_{ca}(t) = N_0 e^{-\frac{t}{\tau_1}}$

Sc: $$\frac{dN_{sc}}{dt} = \frac{N_{ca}}{\tau_1} - \frac{N_{sc}}{\tau_2}$$

Rešimo z nastavkom:

- homogena rešitev $N_{sc}^{h}(t) = B e^{-\frac{t}{\tau_2}}$
- partikularna rešitev $N_{sc}^{p}(t) = C e^{-\frac{t}{\tau_1}}$

Določimo C

$$\frac{dN_{sc}^{p}}{dt} = \left(-\frac{1}{\tau_1}\right) C e^{-\frac{t}{\tau_1}}$$

$$\Rightarrow \left(-\frac{1}{\tau_1}\right) C e^{-\frac{t}{\tau_1}} = \frac{1}{\tau_1} N_0 e^{-\frac{t}{\tau_1}} - \frac{1}{\tau_2} C e^{-\frac{t}{\tau_1}}$$

$$C = \frac{\frac{N_0}{\tau_1}}{\frac{1}{\tau_2} - \frac{1}{\tau_1}} = \frac{N_0 \tau_2}{\tau_1 - \tau_2}$$

IC: $N_{sc}(t=0) = 0$

$$\left[B e^{-\frac{t}{\tau_2}} + C e^{-\frac{t}{\tau_1}}\right]\Big|_{t=0} = 0 \Rightarrow B = -C = -\frac{N_0 \tau_2}{\tau_1 - \tau_2}$$

Celotna aktivnost

$$A(t)=\underbrace{\frac{N_0}{\tau_1}e^{-\frac{t}{\tau_1}}}_{Ca}+\underbrace{\frac{N_0\tau_2}{(\tau_1-\tau_2)\tau_2}\left[e^{-\frac{t}{\tau_1}}-e^{-\frac{t}{\tau_2}}\right]}_{Sc}$$

Iščemo ekstrem (maksimum)

$$\frac{dA(t)}{dt}=\left(-\frac{1}{\tau_1}\right)\frac{N_0}{\tau_1}e^{-\frac{t}{\tau_1}}+\frac{N_0}{\tau_1-\tau_2}\left[\left(-\frac{1}{\tau_1}\right)e^{-\frac{t}{\tau_1}}-\left(-\frac{1}{\tau_2}\right)e^{-\frac{t}{\tau_2}}\right] \Big/ \cdot e^{\frac{t}{\tau_1}}\tau_1\tau_2 \; (-1)$$

in $\left.\frac{dA}{dt}\right|_{t_{max}}=\emptyset$

$$\Rightarrow \frac{N_0\tau_2}{\tau_1}+\frac{N_0}{\tau_1-\tau_2}\left[\tau_2-\tau_1 e^{-t_{max}\left(\frac{1}{\tau_2}-\frac{1}{\tau_1}\right)}\right]=0$$

$$t_{max}=\ln\left(\frac{\dfrac{-\frac{N_0\tau_2}{\tau_1}}{\frac{N_0}{\tau_1-\tau_2}}-\tau_2}{-\tau_1}\right)\frac{(-1)}{\frac{1}{\tau_2}-\frac{1}{\tau_1}}$$

$$=-\frac{\tau_2\tau_1}{\tau_1-\tau_2}\ln\left(-\frac{\tau_2(2\tau_1-\tau_2)}{\tau_1^2}\right)=1'47 \text{ dneva}$$

$$A(t_{max})=1'11\cdot 10^{14}\,Bq$$

Zorko 5/16

Dva razpadna kanala

$$
\begin{tikzcd}
{}^{212}_{83}\mathrm{Bi} \arrow[r, "\alpha", "P_\alpha"'] \arrow[dr, "\beta^-", "P_\beta"'] & {}^{208}_{81}\mathrm{Tl} \arrow[r, "\beta^-", "\tau_{Tl}"'] & {}^{208}_{82}\mathrm{Pb} \\
 & {}^{212}_{84}\mathrm{Po} \arrow[ur, "\alpha", "\tau_{Po}"'] &
\end{tikzcd}
$$

$P_\alpha = 36\%$

$P_\beta = 64\%$

$\tau_{Bi} = 87'3$ min celoten razpadni čas bizmuta v svinec po obeh kanalih

$m_0 = 1\ \mu g$

$M_{Bi} = 208'9804$ g/mol

↳ ni ok, saj imamo mi le ${}^{212}_{83}\mathrm{Bi}$ → njegov M izračunamo s pomočjo SEMF

$A(t=1h) = ?$

$$\frac{A_\alpha(t=1h)}{A(t=1h)} = ?$$

$$N_{Bi} = N_0 e^{-\frac{t}{\tau_B}} \qquad N_0 = \frac{m_0}{M_{Bi}} N_A$$

$$A(t) = A_{Bi}(t) + \underbrace{A_{Tl}(t)}_{\frac{N_{Tl}(t)}{\tau_{Tl}}} + \underbrace{A_{Po}(t)}_{\frac{N_{Po}(t)}{\tau_{Po}}}$$

$$A_{Bi}(t) \to \frac{N_0}{\tau_B} e^{-\frac{t}{\tau_B}}$$

Talij:

$$\frac{dN_{Tl}}{dt} = \boxed{P^{\alpha}} \frac{N_B}{\tau_B} - \frac{N_{Tl}}{\tau_{Tl}}$$

verjetnost za razpad

Nastavek: • homogen $\quad B e^{-\frac{t}{\tau_{Tl}}}$

• partikularna $\quad C e^{-\frac{t}{\tau_B}}$

$$\Rightarrow C\left(-\frac{1}{\tau_B}\right) e^{-\frac{t}{\tau_B}} = P^{\alpha} \frac{1}{\tau_B} N_0 e^{-\frac{t}{\tau_B}} - \frac{1}{\tau_T} e^{-\frac{t}{\tau_B}}$$

$$C = \frac{P^{\alpha} N_0 \tau_{Tl}}{\tau_{Bi} - \tau_{Tl}}$$

IC: $N_{Tl}(t=\varnothing) = 0$

$$B = -C = -\frac{P^{\alpha} N_0 \tau_{Tl}}{\tau_{Bi} - \tau_{Tl}}$$

Enako velja za polonij

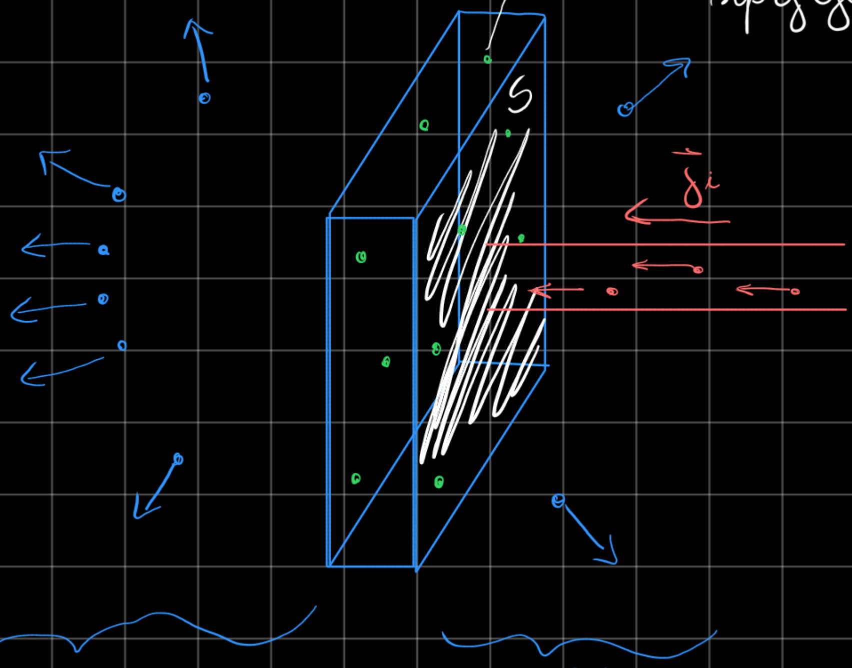
$$\text{skupaj: } A(t) = \underbrace{\frac{N_0}{\tau_B} e^{-\frac{t}{\tau_B}}}_{A_B} + \underbrace{\overbrace{\frac{P^{\alpha} N_0}{\tau_B - \tau_{Tl}} \left[e^{-\frac{t}{\tau_B}} - e^{-\frac{t}{\tau_T}} \right]}^{A_{Tl}} + \frac{P^{\beta} N_0}{\tau_B - \tau_{P_0}} \left[e^{-\frac{t}{\tau_B}} - e^{-\frac{t}{\tau_P}} \right]}_{A_{Po}}$$

$$A(t = 60\,\text{min}) = 5{,}43 \cdot 10^{11}\ \text{Bq}$$

$$A_{\alpha}(t) = \frac{P_{\alpha} N_0}{\tau_B} e^{-\frac{t}{\tau_B}} + A_{P_0}$$

$$A_{\alpha}(t = 1\text{h}) = 2{,}68 \cdot 10^{11}\ \text{Bq} \Rightarrow \left.\frac{A_{\alpha}(t)}{A(t)}\right|_{t=1\text{h}} = 49\%$$

Sipalni procesi



$$j^i = \frac{N_i}{S t}$$

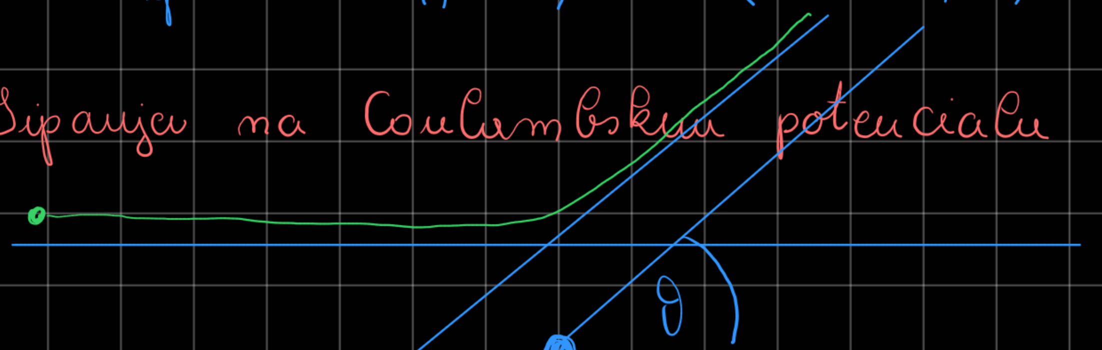
$$\underbrace{N_{int}}_{\#\text{ interakcij}} = \underbrace{N_i}_{\#\text{ vpadnih delcev}} \underbrace{\frac{N_j}{S}}_{\#\text{ (gostota) delcev v tarči}} \underbrace{\sigma}_{\text{sipalni presek}}$$

σ ... kakšna je verjetnost za sipanje v nekem prostorskem kotu?

Če me zanima, koliko delcev se sipa v določen prostorski kot:

$$N_{sip}\left(\vartheta \in (\vartheta_1, \vartheta_2)\right) \propto \sigma\left(\vartheta \in (\vartheta_1, \vartheta_2)\right)$$

Sipanje na Coulombskem potencialu



$$\frac{d\sigma}{d\cos\vartheta} = 2\pi \left(\frac{Z_1 Z_2 e_0^2}{16\pi\varepsilon_0 T}\right)^2 \frac{1}{\sin^2\frac{\vartheta}{2}}$$

$$\frac{e_0^2}{4\pi\varepsilon_0} = \alpha\hbar c \quad , \quad \alpha = \frac{1}{137} \quad , \quad \hbar c = 197\ \mathrm{MeV\ fm}$$

Elastično sipanje. Pri neelastičnem sipanju je možnost notranje zgradbe sipalcev ali tarče (tvorba novih delcev)

Zorko 5/22

$T = 3\,\mathrm{MeV}$

$^{197}_{79}Am$

$P_{Pr} = 99{,}97\% \Rightarrow P_{OD} = 0{,}03\%$

$\rho_{Am} = 19{,}3\,\mathrm{g/cm^3}$

$M_{Am} = 196{,}967\,\mathrm{g/mol}$

$$P_{OD} = \frac{N_{OD}}{N_i} = \frac{N_{Am}}{S} \cdot \sigma_{OD} \ ; \ N_{Am} = \frac{m_{Am}}{M_{Am}} \cdot N_A = \frac{\rho_{Am} \overset{S\cdot d}{\overset{\parallel}{V}}}{M_{Am}} N_A$$

$$P_{OD} = \frac{\rho d \sigma_{OD} N_{Am}}{M_{Am}} \Rightarrow d = \frac{P_{OD} M_{Am}}{\rho_{Am}\sigma_{OD} N_A} \ , \ \sigma_{OD} = ?$$

$$\sigma_{OD} = \int_{-1}^{0} \frac{d\sigma}{d\cos\vartheta}\, d\cos\vartheta$$

pri odboju velja $\vartheta \in \left(\frac{\pi}{2}, \pi\right)$

$\Rightarrow \cos\vartheta \in (-1, 0)$

$$\sigma_{OD} = \int_{-1}^{0} 2\pi \left(\frac{Z_1 Z_2 e_0^2}{16\pi\varepsilon_0 T}\right)^2 \frac{1}{\sin^4\left(\frac{\vartheta}{2}\right)}\, d\cos\vartheta$$

Upoštevamo $Z_\alpha = 2$, $Z_{Am} = 79$

$$\sigma_{OD} = 2\pi \left(\frac{79\,\hbar c\alpha}{2T}\right)^2 \int_{-1}^{0} \frac{d\cos\vartheta}{\sin^4\left(\frac{\vartheta}{2}\right)}$$

$$\sin\left(\frac{\vartheta}{2}\right) = \pm\sqrt{\frac{1-\cos\vartheta}{2}} \qquad \sin^4\left(\frac{\vartheta}{2}\right) = \frac{(1-\cos\vartheta)^2}{4}$$

$$\int_{-1}^{0} \frac{d\cos\vartheta}{(1-\cos\vartheta)^2} = \int_{-1}^{0} \frac{dx}{(1-x)^2} = -\int_{2}^{1} \frac{dt}{t^2} = \frac{1}{t}\Big|_{2}^{1} = \frac{1}{2}$$

$$t = 1-x$$
$$dt = dx$$

$$\sigma_{OD} = \pi \left(\frac{79\,\alpha\,\hbar c}{T}\right)^2 = 4'52 \cdot 10^3\ \mathrm{fm}^2$$

Zorko 6/13

$p_n = 350\ \mathrm{MeV}/c$

$R = 1'5\ \mathrm{fm}$ //parameter potenciala jokave

$m_{int} = ?$ //masa nosilca interakcije

$$\frac{P(\vartheta = 80^\circ \pm 5^\circ)}{P(\vartheta = 30^\circ \pm 3^\circ)} = 2$$

$V(r) = \frac{g^2}{r} e^{-\frac{r}{R}}$ //doseg moči interakcije

V tej teoriji imamo virtualni prenašalec interakcije, ki skrbijo za propagacijo te interakcije.

- interakcija ∞ dosega, nosilci so brezmasni (npr. pri EM interakciji, virtualni fotoni)

- interakcije so končne, nosilci imajo maso (npr. pri močni jedrski interakciji, virtualni pioni)

Zapletenejši formalizem je potreben, saj se delci gibajo s tako velikimi hitrostmi, da se potencial v okolici delca ne spreminja več dovolj hitro, da bi lahko obravnavali hitre spremembe.

Močna interakcija deluje med kvarki → nosilci gluoni
in tudi med gluoni → nosilci pioni

$$R = \frac{\hbar c}{m c^2} \longrightarrow m_{int} = \frac{\hbar c}{R c^2} \qquad m_{int} c^2 = \frac{\hbar c}{R} = 130\ \mathrm{MeV}$$

$$\frac{d\sigma}{d\Omega} \propto |M|^2$$