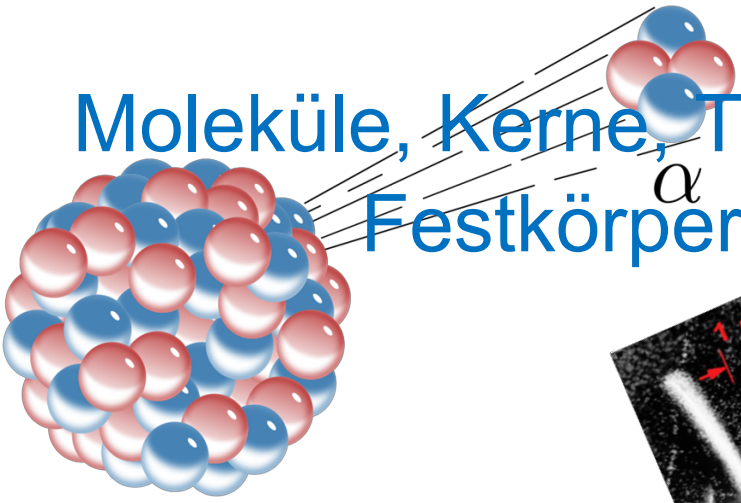
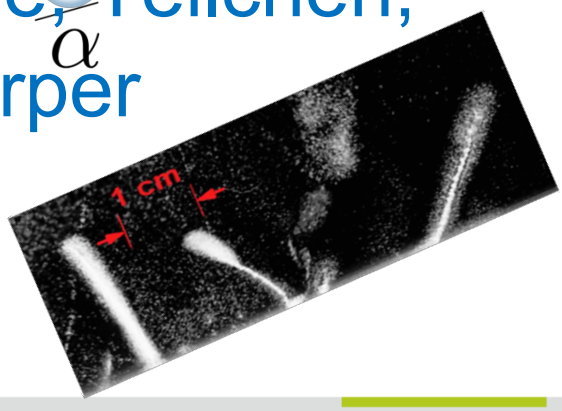
Leibniz Universität Hannover

IRS- Institut für Radioökologie und Strahlenschutz

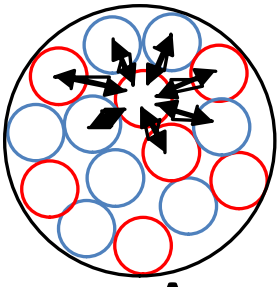
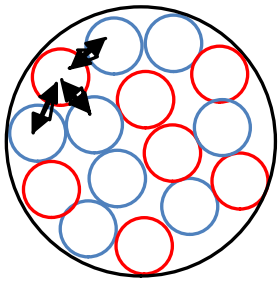
Experimentalphysik IV

Moleküle, Kerne, Teilchen, Festkörper



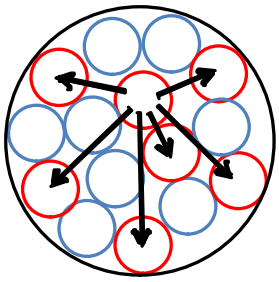
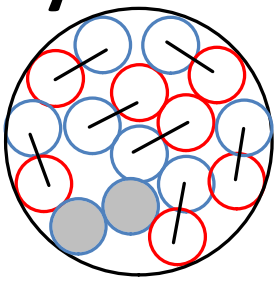
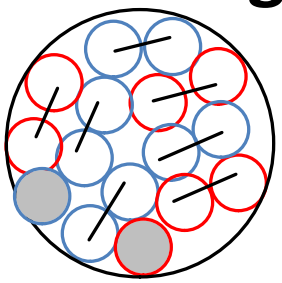


Volumen **Oberfläche**

$E_{bind} =$  +  +

αA $\alpha A^{2/3}$

Coulomb **Asymmetrie** **Paarung**

 +  + 

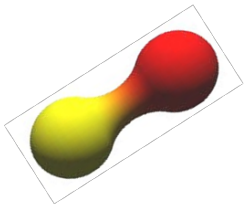
$\alpha Z(Z-1)/A^{1/3}$ $\alpha(A-2Z)^2/A$ $\pm\delta$

Weizsäckers Massen Formel

(Tröpfchen Modell)

$$m(Z,A) = Z \cdot m_{\mathrm{H}} + (A-Z)\cdot m_{\mathrm{n}} - BE_{Kern} - BE_{\mathrm{Elektronen}}$$

$$BE_{Kern} = a_{\mathrm{v}} \cdot A - a_{\mathrm{s}} \cdot A^{2/3} - a_{\mathrm{C}} \cdot \frac{Z(Z-1)}{A^{1/3}} - a_{\mathrm{a}} \cdot \frac{(A-2\cdot Z)^2}{A} + \delta$$

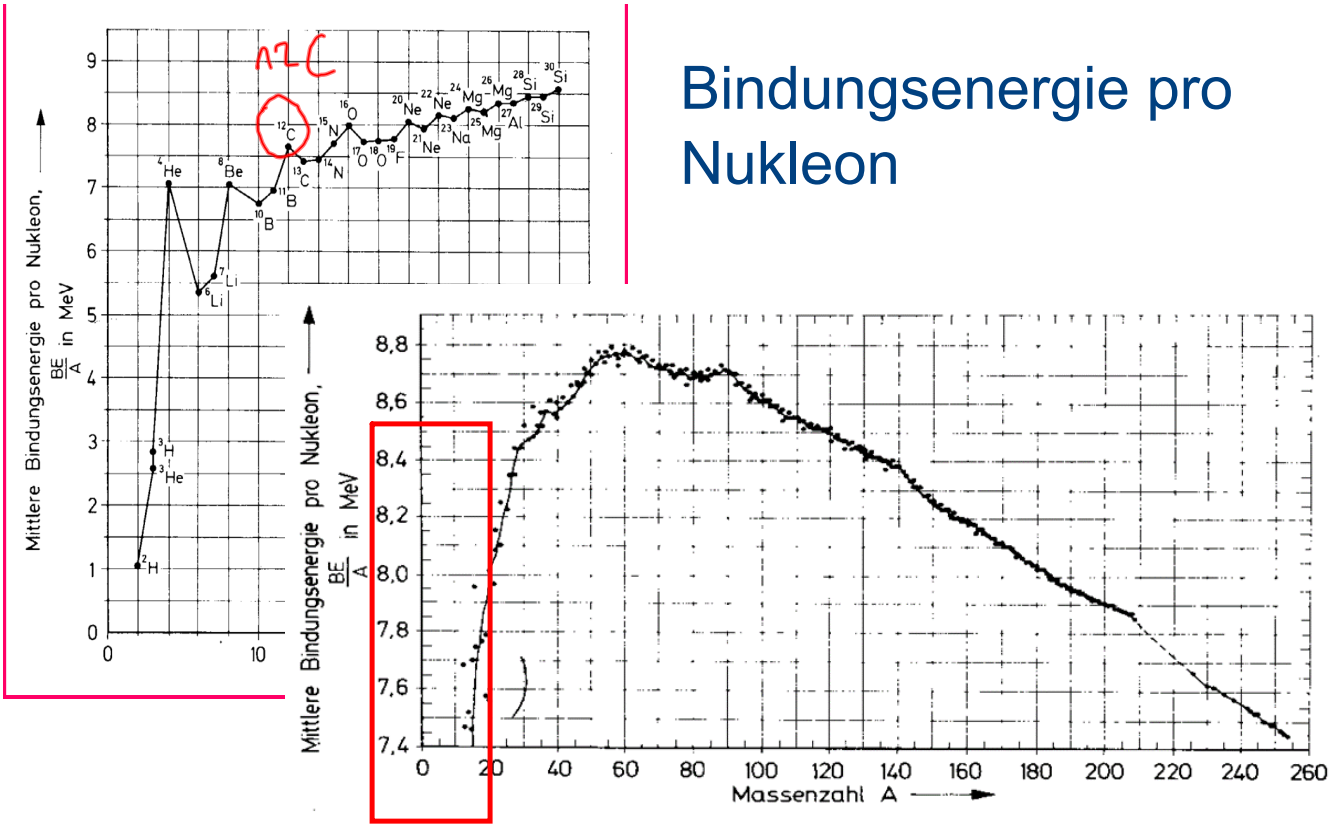


Volumen Energie	$a_{\mathrm{v}} A$	mit	$a_v = 15.56\mathrm{MeV}$
Oberflächen Energie	$a_s A^{2/3}$	mit	$a_s = 17.23\mathrm{MeV}$
Coulomb Energie	$a_C \frac{Z(Z-1)}{A^{1/3}}$	mit	$a_C = 0.7\mathrm{MeV}$
Asymmetrie Energie	$a_a \frac{(A-2Z)^2}{A}$	mit	$a_a = 23.285\mathrm{MeV}$

Paarungs Energie

$$\delta = \begin{cases} +11/A^{1/2}\mathrm{MeV} & \text{für gerade - gerade} \quad (gg / ee) \text{ Kerne} \\ 0 & \text{für ungerade - gerade, gerade - ungerade} \quad (ug/oe),\ (gu/eo) \text{ Kerne} \\ -11/A^{1/2}\mathrm{MeV} & \text{für ungerade - ungerade} \quad (uu / oo) \text{ Kerne} \end{cases}$$

Bindungsenergie pro Nukleon

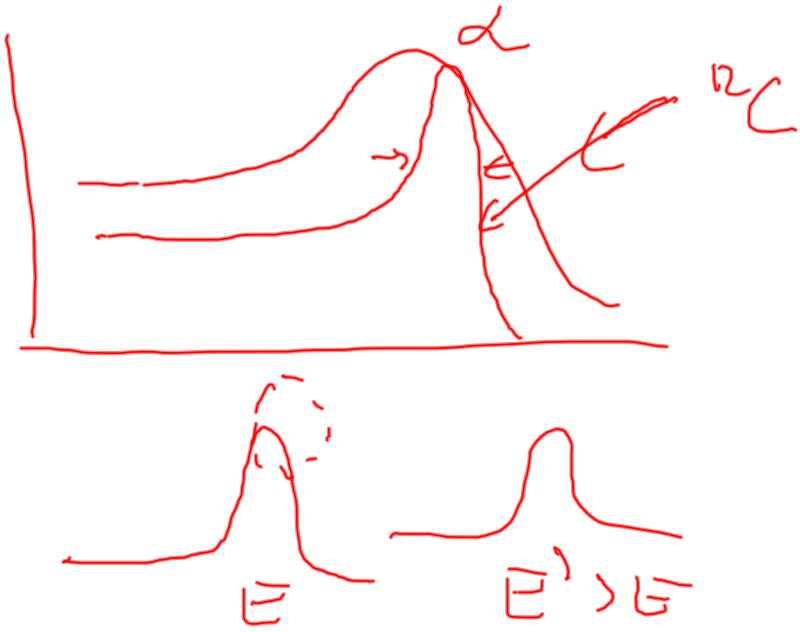


Bethe Bloch Gleichung

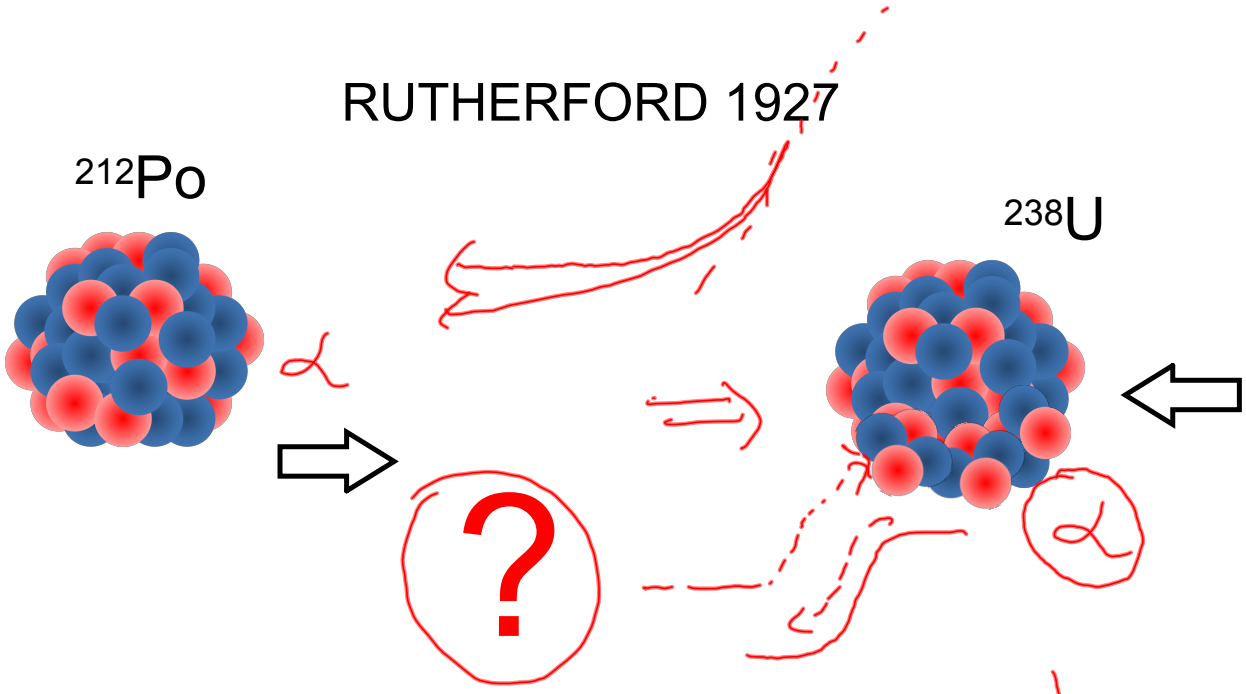
$$-\frac{dE}{ds} = \frac{4\pi \cdot N^V z^2}{m_e v^2}\left(\frac{e^2}{4\pi\epsilon_o}\right)^2 \cdot B \qquad B = Z \cdot \left[\ln\frac{2m_e v^2}{I(1-\beta^2)} - \frac{c_k}{Z}\right]$$

$$\beta = \frac{v}{c} \qquad I = 11{,}5 \cdot Z\,(\mathrm{eV})$$

$-\frac{dE}{ds}$	Bremsvermögen (stopping power)
z	Kernladungszahl des schweren geladenen Teilchens
m_e	Ruhemasse des Elektrons
v	Geschwindigkeit des schweren Teilchens
N^V	Anzahl der Kerne im Absorber pro cm^3
B	Bremszahl (atomic stopping number)
Z	Kernladungszahl des Absorbers
I	mittleres Ionisationspotential des Absorbers
c_k	Korrektionsfaktor für E < 4 MeV, $0 < c_k < 1$, Umladung

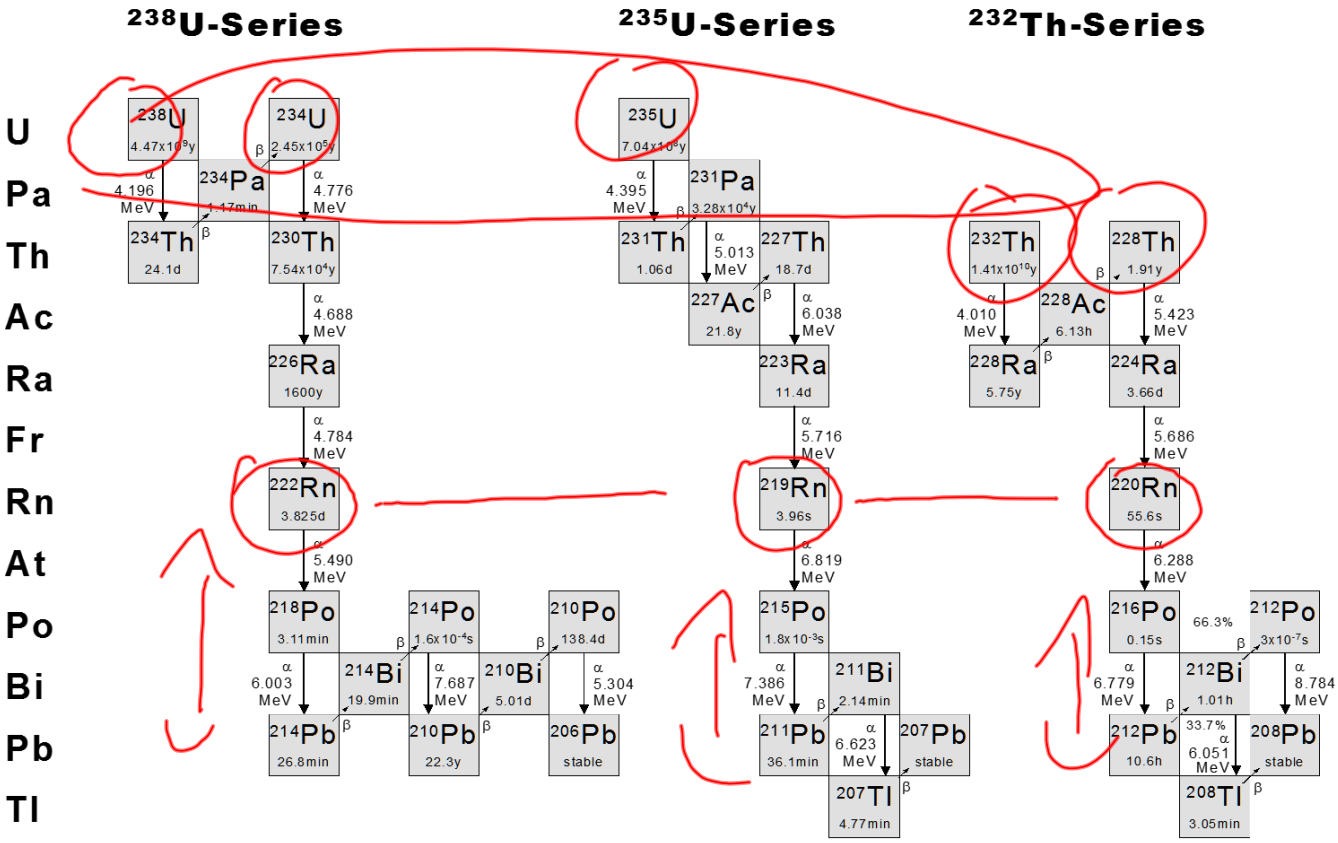

α
12C
E
E' > E

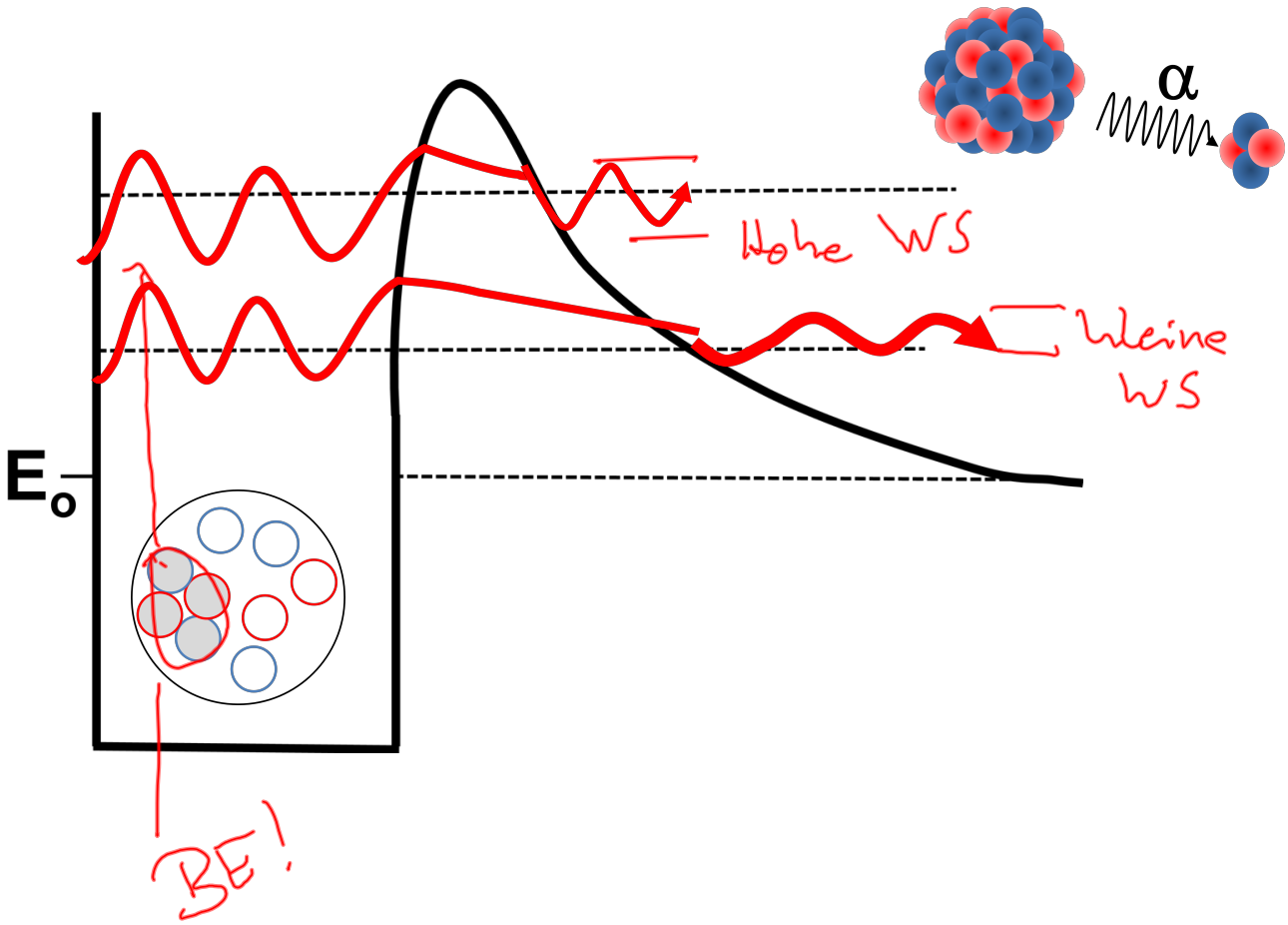
Alpha Strahlung



Po 212		
45.1 s	17.1 ns	0.3 µs
α	IT 120	
11.65...	γ 727	
γ 2615	405	
583	223	
IT	α 10.22	α 8.785

U 238	
99.2742	
280 ns	$4.468 \cdot 10^9$ a
IT	α 4.198...
2513...	γ (50...), e^-
γ 1879...	sf, $2\beta^-$, σ 2.7
sf	σ_f 3E-6


238U-Series
235U-Series
232Th-Series
U
Pa
Th
Ac
Ra
Fr
Rn
At
Po
Bi
Pb
Tl
238U 4.47x10^9y
234U 2.45x10^5y
234Pa 1.17min
234Th 24.1d
230Th 7.54x10^4y
226Ra 1600y
222Rn 3.825d
218Po 3.11min
214Pb 26.8min
214Bi 19.9min
214Po 1.6x10^-4s
210Pb 22.3y
210Bi 5.01d
210Po 138.4d
206Pb stable
α 4.196 MeV
α 4.776 MeV
α 4.688 MeV
α 4.784 MeV
α 5.490 MeV
α 6.003 MeV
α 7.687 MeV
α 5.304 MeV
β
235U 7.04x10^8y
231Pa 3.28x10^4y
231Th 1.06d
227Ac 21.8y
227Th 18.7d
223Ra 11.4d
219Rn 3.96s
215Po 1.8x10^-3s
211Pb 36.1min
211Bi 2.14min
207Tl 4.77min
207Pb stable
α 4.395 MeV
α 5.013 MeV
α 6.038 MeV
α 5.716 MeV
α 6.819 MeV
α 7.386 MeV
α 6.623 MeV
232Th 1.41x10^10y
228Ra 5.75y
228Ac 6.13h
228Th 1.91y
224Ra 3.66d
220Rn 55.6s
216Po 0.15s
212Pb 10.6h
212Bi 1.01h
212Po 3x10^-7s
208Tl 3.05min
208Pb stable
α 4.010 MeV
α 5.423 MeV
α 5.686 MeV
α 6.288 MeV
α 6.779 MeV
α 8.784 MeV
66.3%
33.7%
α 6.051 MeV


α
Hohe WS
kleine WS
E_o
BE!

Gamow Theorie 1

$$\lambda \equiv \frac{1}{\tau} = \lambda_0 \cdot T_\alpha \propto T_\alpha$$

Theoretische Bestimmung schwierig

Hängt von Kernstruktur ab

Transmission durch Potentialbarriere

$$T_\alpha \approx e^{-G}$$

G: Gamov Faktor

Gamow Theorie 2

$$\frac{1}{\lambda} \propto \frac{1}{T_\alpha}\tau \propto t_{1/2} \propto e^{G} \qquad G \propto \frac{1}{\sqrt{E_\alpha}}$$

$$\ln(t_{1/2}) \propto \frac{1}{\sqrt{E_\alpha}}$$

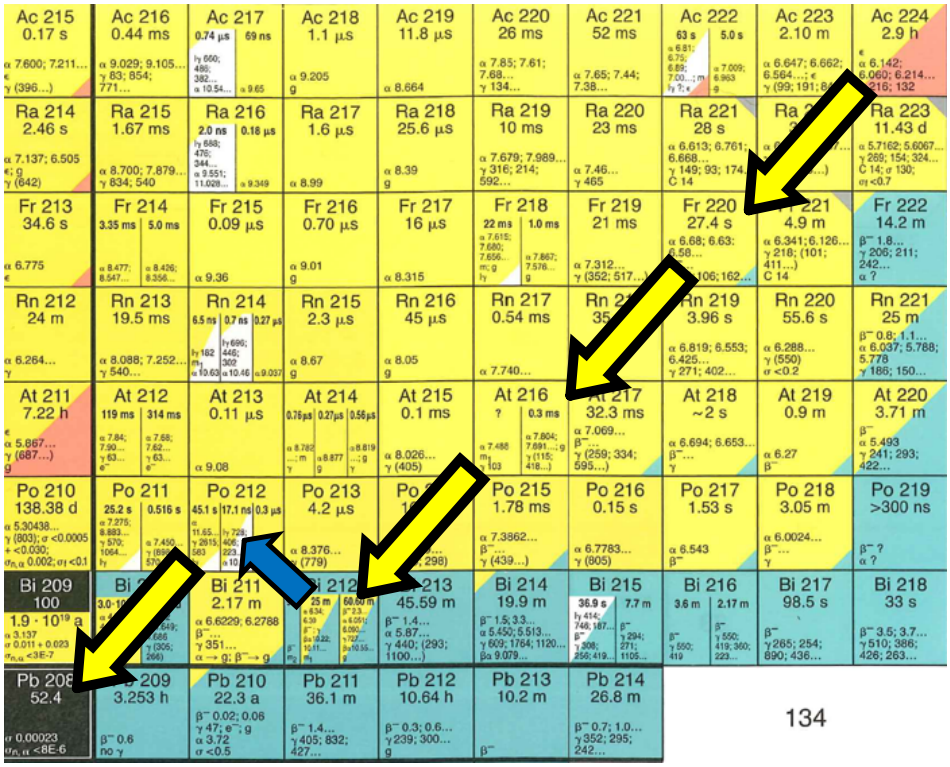
Gamow Theorie 3

$$\frac{1}{\lambda} \propto \frac{1}{T_\alpha}\tau \propto t_{1/2} \propto e^{G} \qquad G \propto \frac{1}{\sqrt{E_\alpha}}$$

$$\ln(t_{1/2}) \propto \frac{1}{\sqrt{E_\alpha}}$$

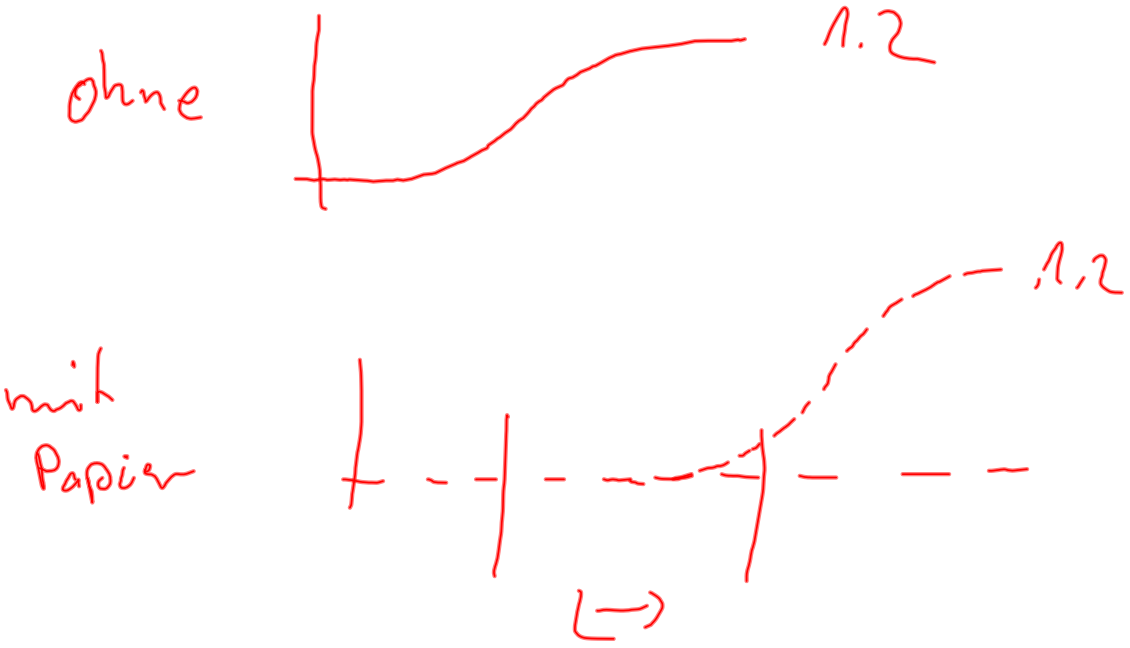
Nuklid	$T_{1/2}$	E_α	T_α
^{212}Po	0,3 ms	8,78 MeV	$1{,}32 \cdot 10^{-13}$
^{224}Ra	3,6 d	5,7 MeV	$5{,}9 \cdot 10^{-26}$
^{144}Nd	$2 \cdot 10^{15}$ a	1,83 MeV	$2{,}18 \cdot 10^{-42}$

Long range alphas



Long range alphas

Po 210 138.38 d α 5.30438... γ (803); σ <0.0005 + <0.030; $\sigma_{n,\alpha}$ 0.002; σ_f <0.1	**Po 211** 25.2 s: α 7.275; 8.883... γ 570; 1064... Iγ 0.516 s: α 7.450... γ (898; 570...)	**Po 212** 45.1 s: α 11.65... γ 2615; 583 Iγ 17.1 ns: Iγ 728; 406; 223... α 10.22 0.3 µs: α 8.785	**Po 213** 4.2 µs α 8.376... γ (779)
Bi 209 100 $1.9 \cdot 10^{19}$ a α 3.137 σ 0.011 + 0.023 $\sigma_{n,\alpha}$ <3E-7	**Bi 210** $3.0 \cdot 10^6$ a: α 4.946; 4.908... γ 266; 304... σ 0.054 5.013 d: β⁻ 1.2 α 4.649; 4.686 γ (305; 266)	**Bi 211** 2.17 m α 6.6229; 6.2788 β⁻... γ 351... α → g; β⁻ → g	**Bi 212** 9 m: β⁻ m_2 25 m: α 6.34; 6.30 β⁻; γ βα 10.22; 10.11... m_1 60.60 m: β⁻ 2.3... α 6.051; 6.090... γ 727... βα 10.55... g
Pb 208 52.4 σ 0.00023 $\sigma_{n,\alpha}$ <8E-6	**Pb 209** 3.253 h β⁻ 0.6 no γ	**Pb 210** 22.3 a β⁻ 0.02; 0.06 γ 47; e⁻; g α 3.72 σ <0.5	**Pb 211** 36.1 m β⁻ 1.4... γ 405; 832; 427...


ohne
1.2
mit
Papier
1,2


sehr klein
$T_{1/2}$

U-235 Decay Chain: Actinium-Chain