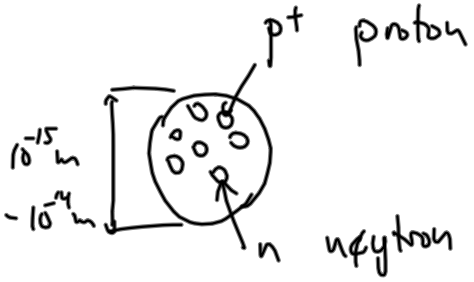
Kapittel 19:
Kjernefysikk

Kjernens oppbygning

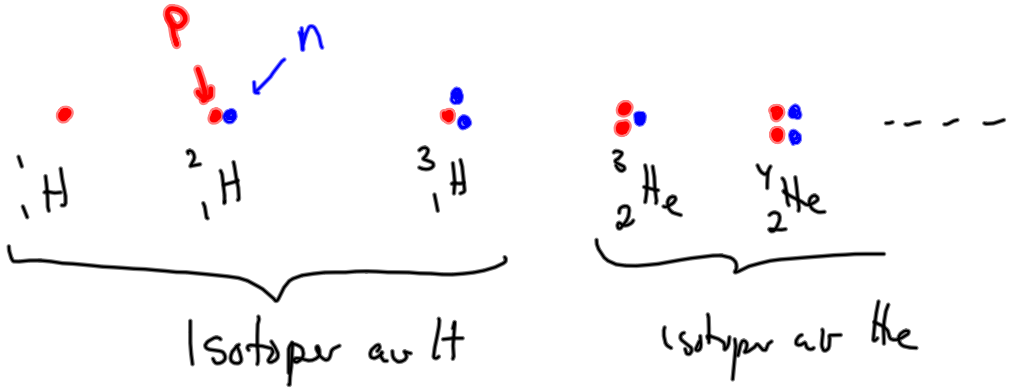


Antall p : Z

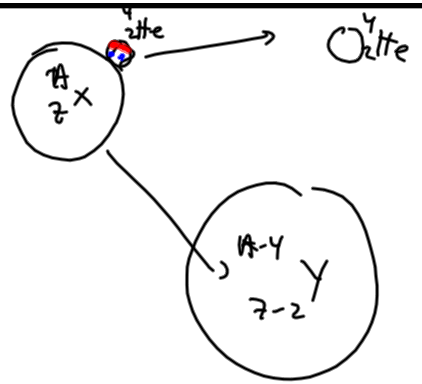
Antall n : N

Antall nukleoner : $A = Z + N$

$^{A}_{Z}X$



Kjernereaksjoner



α:

$$^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^4_2He \quad (\alpha)$$

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^4_2He$$

β^-:

$$^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + e^- + \bar{\nu}_e \quad (\beta^-)$$

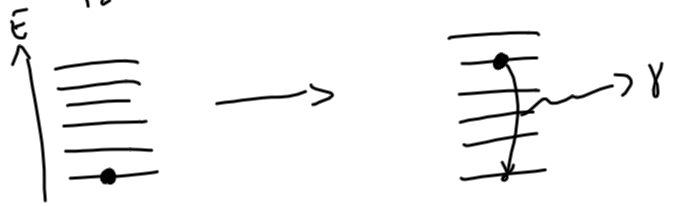
$$n \longrightarrow p^+ + e^- + \bar{\nu}_e$$

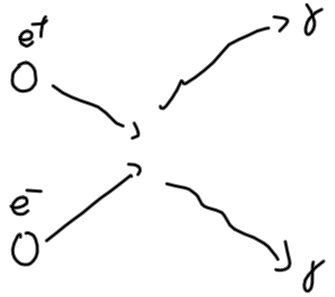
β^+:

$$^{11}_{6}C \longrightarrow {}^{11}_{5}B + e^+ + \nu_e \quad (e^+ \text{ positron})$$

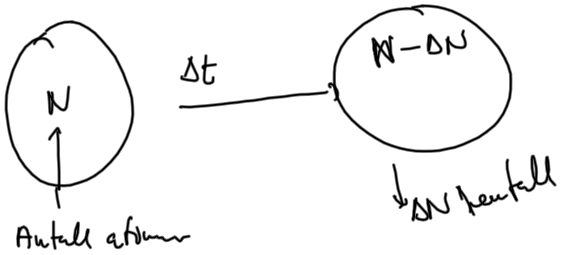
$$p^+ \longrightarrow n + e^+ + \nu_e$$

γ: $^{238}_{92}U$ $^{234}_{90}Th$





Aktivitet og halveringstid



$$A = \frac{\Delta N}{\Delta t} \qquad [A] = \frac{1}{s} = Bq$$

Becquerel

Naturlig antagelse: $A = \lambda N$

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

$$N'(t) = -\lambda N(t)$$

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

$$N(0) = N_0$$

$$A = A_0 e^{-\lambda t}$$

$f(x) = e^x$
$f'(x) = e^x$
$f(x) = e^{-\lambda x}$
$f'(x) = -\lambda e^{-\lambda x}$

Halveringstid: $\frac{1}{2} = e^{\ln \frac{1}{2}} = e^{-\ln 2}$ $\quad \ln\frac{1}{x} = -\ln x$

$$N(t) = N_0 e^{-\lambda t} = N_0 e^{-\ln 2 \frac{\lambda t}{\ln 2}} = N_0 \underbrace{\left(e^{-\ln 2}\right)}_{\frac{1}{2}}^{\frac{\lambda t}{\ln 2}} = N_0 \left(\frac{1}{2}\right)^{t/t_{\frac{1}{2}}}$$

$(e^x)^y = e^{xy}$

$$= N_0 \left(\frac{1}{2}\right)^{\frac{t}{(\ln 2/\lambda)}} \to t_{1/2}$$

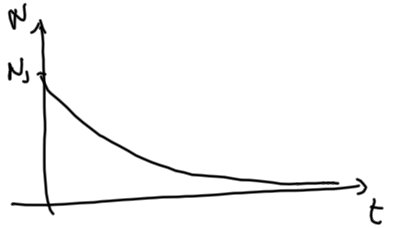
$$t_{1/2} = \frac{\ln 2}{\lambda}$$

$t = 0$ $\quad N_0$

$t = t_{1/2}$: $\quad N = N_0 \left(\frac{1}{2}\right)^1$

$t = 2t_{1/2}$: $\quad N = N_0 \left(\frac{1}{2}\right)^2 = N_0 \cdot \frac{1}{4}$

$t = 3t_{1/2}$: $\quad N = N_0 \left(\frac{1}{2}\right)^3$



En radioaktiv prøve har aktiviteten $3{,}5 \cdot 10^3$ Bq.

Halveringstida er 23 dager, hvor mange atomer inneholder prøven?

$A = \lambda N$ $\quad A = 3{,}5 \cdot 10^3$ Bq $\quad t_{1/2} = \frac{\ln 2}{\lambda}$ $\quad \lambda = \frac{\ln 2}{t_{1/2}} = 3{,}49 \cdot 10^{-7} \frac{1}{s}$

$N = \frac{A}{\lambda} = 1{,}0 \cdot 10^{10}$

Halveringstiden til ^{235}U er $7{,}0 \cdot 10^8$ år. Jordas alder er $4{,}5 \cdot 10^9$ år. Hvor stor andel av det opprinnelige ^{235}U er fortsatt her? Idag utgjør ^{235}U 0,7% av alt uran, resten er ^{238}U (99,3%). Hvordan var det da jorda ble dannet?

^{235}U: $N = N_0 \left(\frac{1}{2}\right)^{t/t_{1/2}^{235}}$ $\qquad \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{4{,}5 \cdot 10^9 \text{ år}}{7{,}0 \cdot 10^8 \text{ år}}} = 0{,}012 = 1{,}2\%$

^{238}U: $t_{1/2}^{238} = 4{,}5 \cdot 10^9$ år $\qquad \frac{N}{N_0} = 0{,}50 \simeq 50\%$

$r = \frac{N_{235}}{N_{238}} \simeq 0{,}007$ $\qquad N_T = N_{235} + N_{238}$

$\%\,235$: $\frac{N_{235}}{N_T} = \frac{N_{235}}{N_{235} + N_{238}} = \frac{r}{r+1}$

$\%\,238$: $\frac{N_{238}}{N_T}$

$r_0 = \frac{N_{235,0}}{N_{238,0}}$

$r = \frac{N_{235,0} \left(\frac{1}{2}\right)^{t/t_{1/2}^{235}}}{N_{238,0} \left(\frac{1}{2}\right)^{t/t_{1/2}^{238}}}$ $\qquad r_0 = r \cdot \frac{\left(\frac{1}{2}\right)^{t/t_{1/2}^{238}}}{\left(\frac{1}{2}\right)^{t/t_{1/2}^{235}}} = 0{,}607$ $\qquad \%\,235,0: \frac{r_0}{r_0+1} = 46\%$

^{14}C-datering:

Halveringstida er 5730 år. I atmosfæren (og levende planter) er $N_{14}/N_{12} = 1{,}2 \cdot 10^{-12}$. Du har en prøve der $N_{14}/N_{12} = 1{,}0 \cdot 10^{-13}$, hvor gammel er den?

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + e^- + \bar{\nu}$$

$$\frac{N_{14}}{N_{12}} = \frac{N_{14,0}}{N_{12,0}} \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\frac{N_{14,0}}{N_{12,0}} = 1{,}2 \cdot 10^{-12}$$

$$N_{14} = N_{14,0} \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$N_{12} = N_{12,0}$$

$$\left(\frac{1}{2}\right)^{t/t_{1/2}} = \frac{1{,}0 \cdot 10^{-13}}{1{,}2 \cdot 10^{-12}} = 0{,}0833\ldots$$

$$\ln(x^y) = y \ln x$$

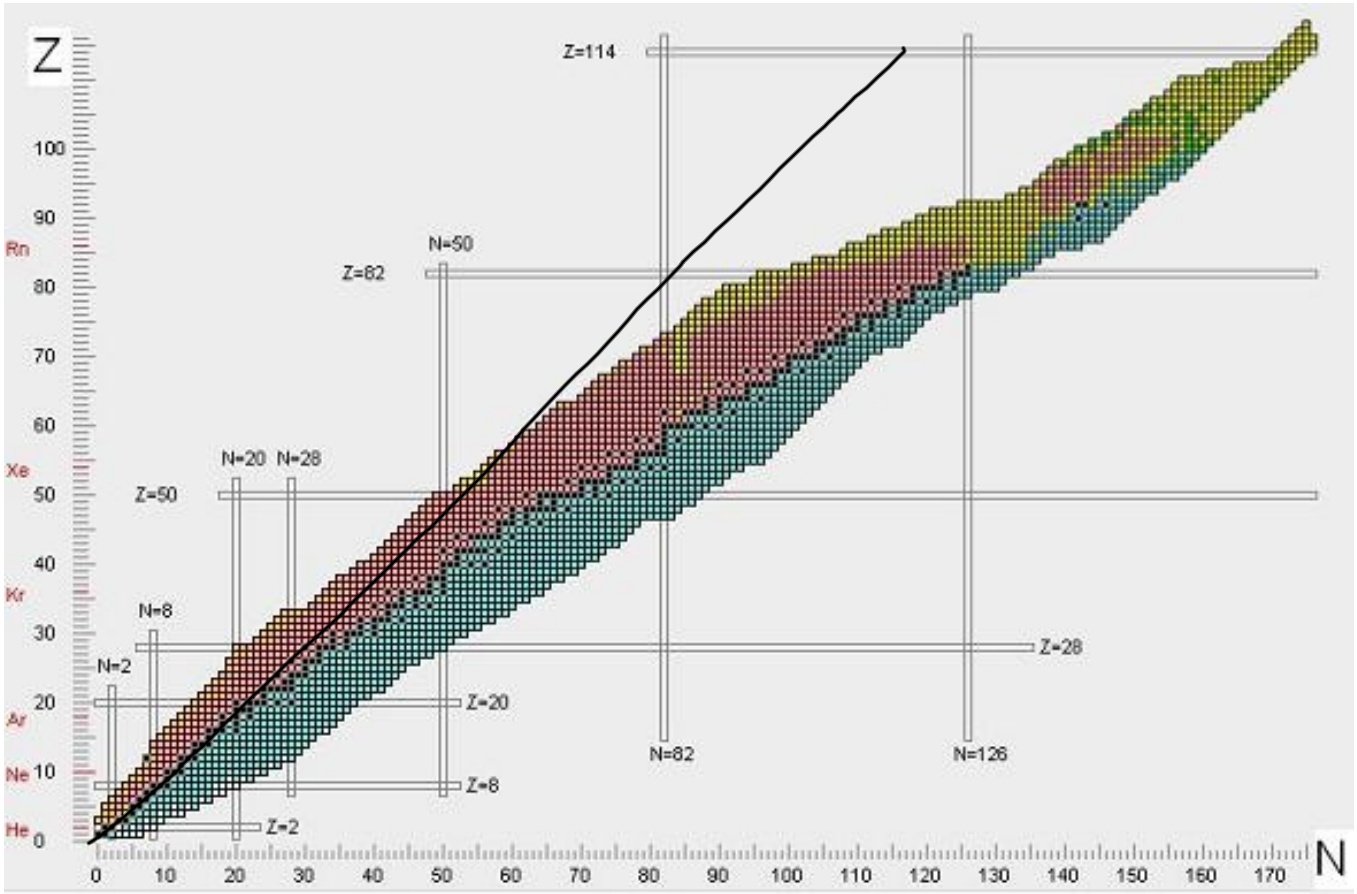
$$\frac{t}{t_{1/2}} \ln\frac{1}{2} = \ln 0{,}0833\ldots$$

$$t = t_{1/2} \cdot \frac{\ln 0{,}0833}{\ln 1/2} = 21 \cdot 10^3 \text{ år}$$

Hvor kommer ^{14}C fra?

$$^{14}_{7}N + n \rightarrow {}^{14}_{6}C + p$$

Nuklidekart:



http://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html