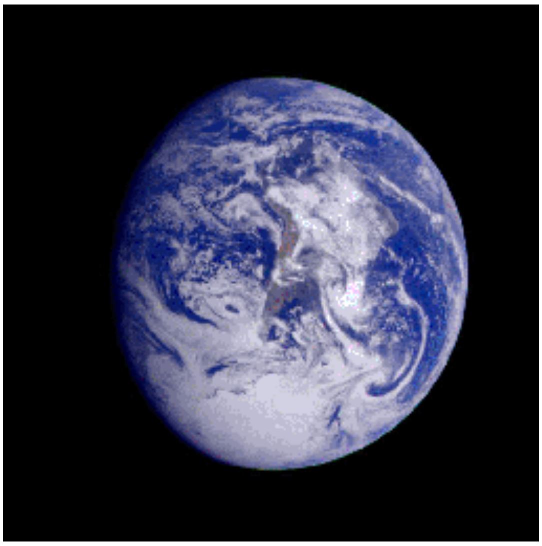
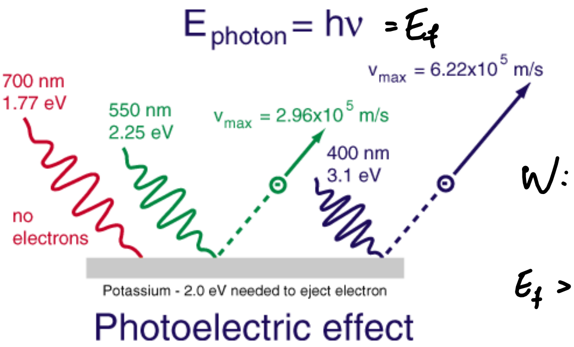
Hvordan kan vi måle jordas alder?



https://photojournal.jpl.nasa.gov/animation/PIA00114

Fotoelektrisk effekt



$= E_f$

W: løsrivningsarbeid →

$[W] = J$

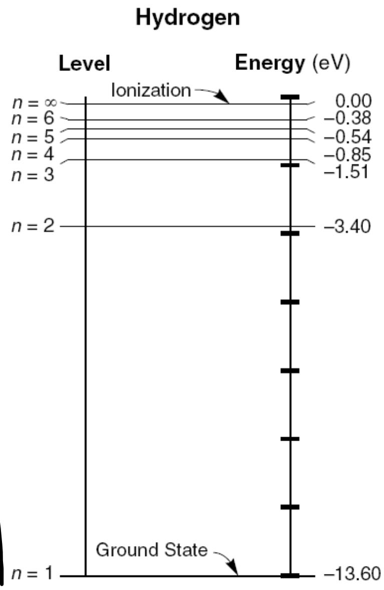
$E_f > W \Rightarrow$ rive løs elektron.

$$\boxed{\underset{\text{fotonet}}{E_f} = W + \underset{\text{kinetisk energi til } e^-}{E_k}}$$

Einsteins likning

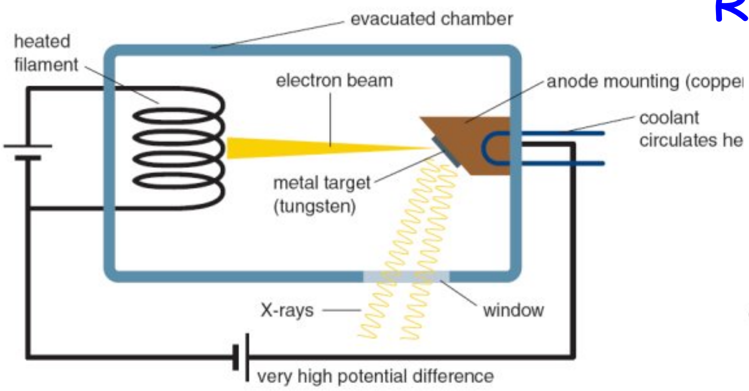
Eksperimentelle fakta:

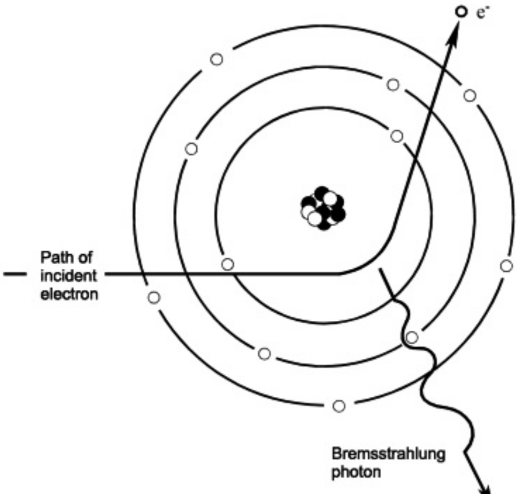
- $f<f_g$: Ingen elektroner uansett hvor stor intesitet
- $f>f_g$: Elektroner uansett hvor liten intesitet.



Energy Levels for the Hydrogen Atom

Røntgenstråling



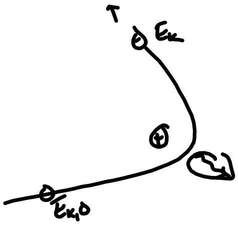


Bremsestråling

arbeid → $W_{KA} = qU_{KA}$ ← spenning

$E_{k,0} = qU_{KA}$

↳ kinetisk energi



$E_f = E_{k0} - E_k$

$E_{f,maks} = E_{k0} = qU_{KA}$

Energien i røntgenstråling

Eksempel: $U_{KA} = 20\,kV$

$$E_{k0} = q\,U_{KA} = (-1{,}60 \cdot 10^{-19}\,C) \cdot (-20 \cdot 10^{3}\,V)$$

$$= 3{,}20 \cdot 10^{-15}\,J$$

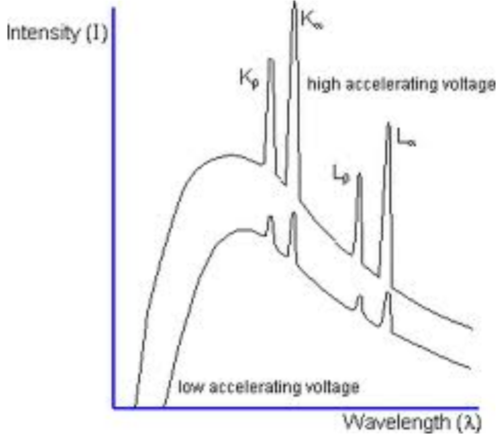
$\lambda = ?$

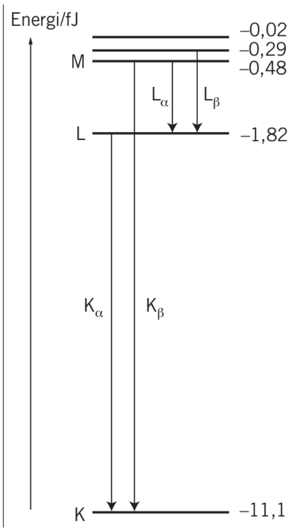
$$E_{f,maks} = E_{k0} = hf = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E_f} = 6{,}2 \cdot 10^{-11}\,m$$

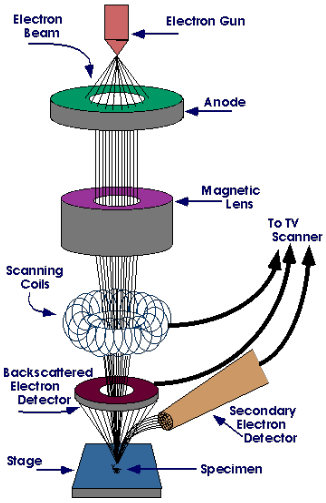
synlig lys: $\lambda = 500\,nm = 5 \cdot 10^{-7}\,m$

Røntgenspekteret

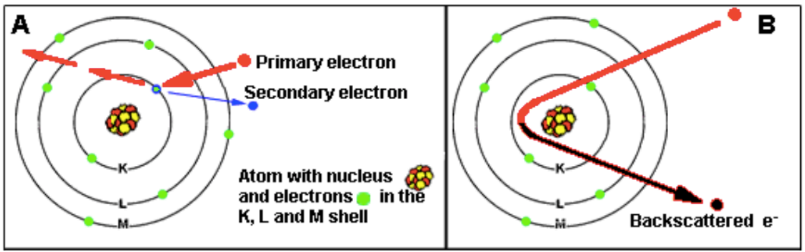




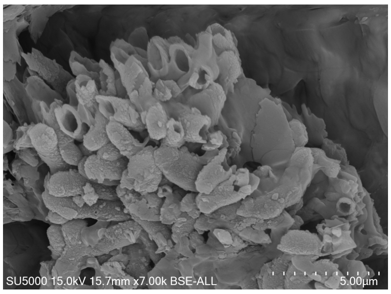
Elektronmikroskopet



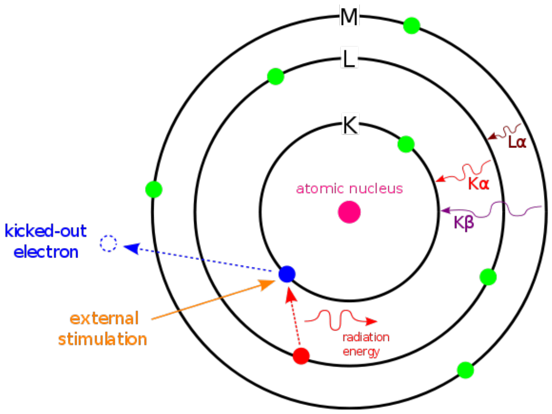
https://www.mse.iastate.edu/research/laboratories/sem/microscopy/how-does-the-sem-work/high-school/how-the-sem-works/



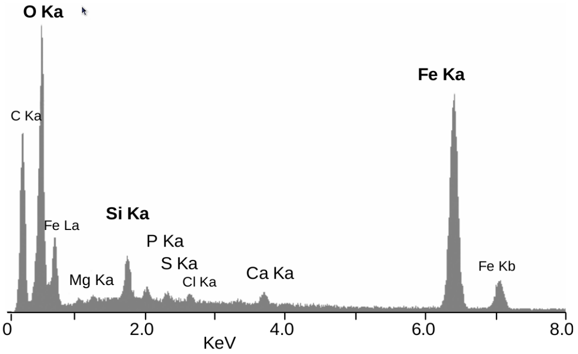
http://www.vcbio.science.ru.nl/en/fesem/eds/



Energy Dispersive Spectroscopy (EDS)



https://en.wikipedia.org/wiki/Energy-dispersive_X-ray_spectroscopy#/media/File:EDX-scheme.svg

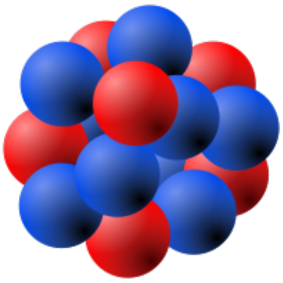


EDS spectrum of the mineral crust of the vent shrimp Rimicaris exoculata[1] Most of these peaks are X-rays given off as electrons return to the K electron shell.(K-alpha and K-beta lines) One peak is from the L shell of iron.

https://en.wikipedia.org/wiki/Energy-dispersive_X-ray_spectroscopy#/media/File:EDS_-_Rimicaris_exoculata.png

Atomkjernen

https://youtu.be/0fKBhvDjuy0?t=4m35s



Består av $\underbrace{\text{protoner og nøytroner}}_{\text{nukleoner}}$

Grunnstoff $\quad {}^{A}_{Z}X$ (A ← nukleontall, Z ← protontall)

Nuklider:

$^{1}_{1}H \quad ^{2}_{1}H \quad \underbrace{^{12}_{6}C \quad ^{14}_{6}C}_{\text{isotoper av grunnstoffet karbon}}$

Atommasse

$$u = \frac{m_{^{12}_{6}C}}{12} = 1,66 \cdot 10^{-27}\ \text{kg}$$

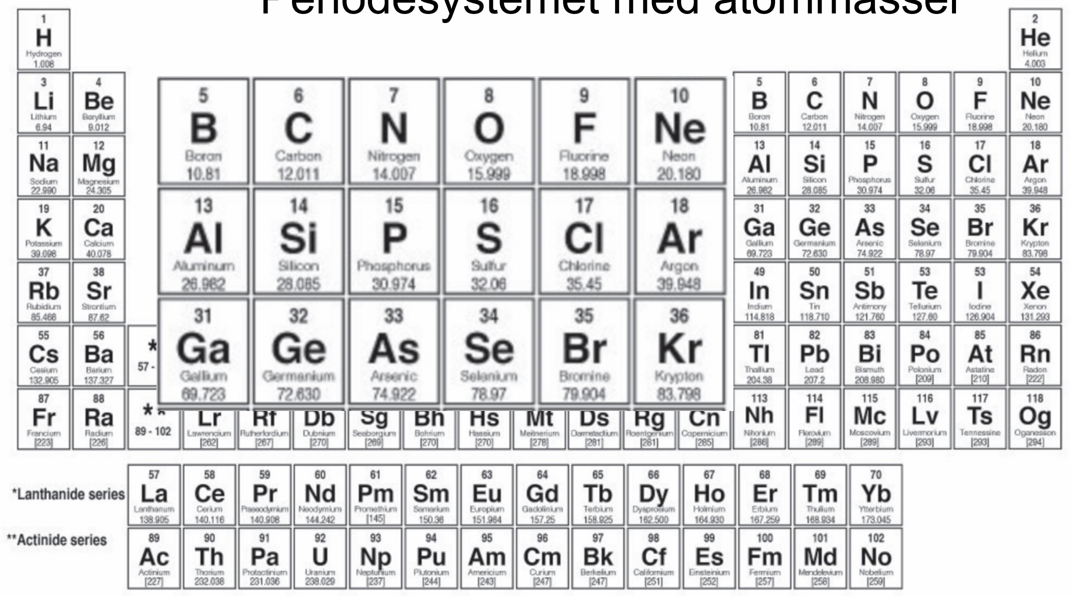
ett atom

Fri masse: $m_{\text{nøytron}} = 1,0086\ u$

$m_{\text{proton}} = 1,0072\ u$

$m_{\text{elektron}} = 5,49 \cdot 10^{-9}\ u$

Periodesystemet med atommasser



5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
13 Al Aluminum 26.982	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948
31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.97	35 Br Bromine 79.904	36 Kr Krypton 83.798

1 H Hydrogen 1.008																		2 He Helium 4.003
3 Li Lithium 6.94	4 Be Beryllium 9.012												5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305												13 Al Aluminum 26.982	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078												31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.97	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62												49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	53 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.293
55 Cs Cesium 132.905	56 Ba Barium 137.327	* 57 -											81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	** 89 - 102	Lr Lawrencium [262]	Rf Rutherfordium [267]	Db Dubnium [270]	Sg Seaborgium [269]	Bh Bohrium [270]	Hs Hassium [270]	Mt Meitnerium [278]	Ds Darmstadtium [281]	Rg Roentgenium [281]	Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [293]	118 Og Oganesson [294]

*Lanthanide series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.045
**Actinide series	89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [257]	101 Md Mendelevium [258]	102 No Nobelium [259]

https://youtu.be/0fKBhvDjuy0?t=4m35s

De fire fundamentale vekselvirkningene

Gravitasjon
Elektromagnetisme
Sterk kjernekraft
Svak kjernekraft

i kjernen

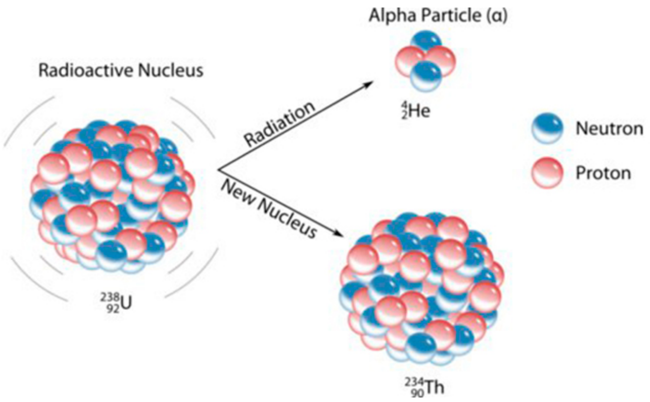
Stråling fra radioaktive stoffer

3 typer

	Rekkevidde	Består av
α	papirark	${}^{4}_{2}He$ -kjerner
β	noen cm luft	e^- , e^+
γ	flere cm bly	foton

alpha-stråling

α



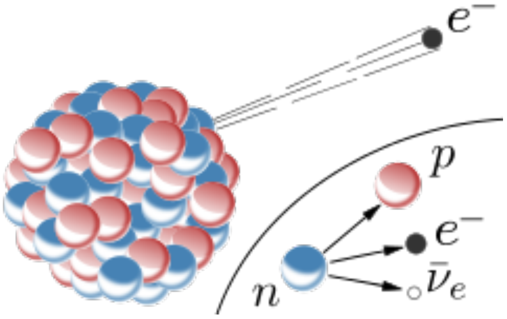
https://socratic.org/questions/how-do-you-determine-alpha-decay

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

↑ datterkjerne

beta-stråling

β



elektron

$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e + \bar{\nu}_e$

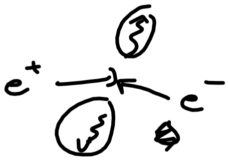
antinøytrino

$^{23}_{12}Mg \rightarrow ^{23}_{11}Na + ^{0}_{+}e + \nu_e$

nøytrino

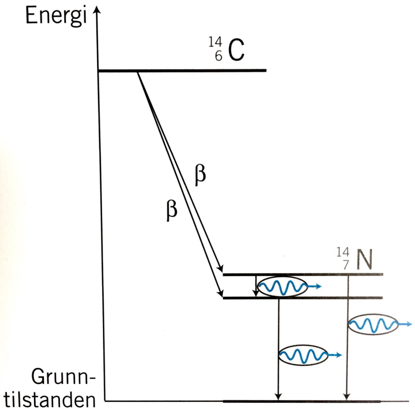
positron

= antielektron



gamma-stråling

γ



Ved en α- eller β-utsending kan datterkjernen være eksitert. Ved overgang til lavere energinivåer blir det sendt ut et γ-foton.

Bevaringslover ved kjernereaksjoner

bevares

$${}^{A}_{Z}X$$

bevares

$$23 = 23 + 0 \checkmark$$

$${}^{23}_{12}Mg \rightarrow {}^{23}_{11}Na + {}^{0}_{1}e + \nu_e$$

$$12 = 11 + 1 \checkmark$$

Aktivitet

Foto: Audun Kristiansen / NRK

Becquerel-sau i 30 år til

23 år etter Tsjernobyl må mange sauebesetninger på spesialdiett før de kan slaktes. Slik vil det fortsatt være i mange tiår.

Illustrasjonsfoto

FOTO: LIEN, KYRRE / SCANPIX

Helle Therese Kongsrud
@helletherese

Publisert 6. okt. 2009 kl. 14:28

Artikkelen er flere år gammel.

$$A = \frac{\Delta N}{\Delta t}$$

$$[A] = \frac{1}{s} = Bq$$

1 kg radium

$$A = 3,7 \cdot 10^{13} \ Bq$$

Halveringstid

$A \propto N$ ← antell kjener

ved tiden $t_0 = 0$

$A_0 = C N_0$

↳ en konstant

$A_1 = C N_1$

Hva er A etter en tid t?

n = antell halveringstider $n = t/t_{1/2}$

$$\boxed{A = A_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}}$$

velger $t = t_{1/2}$

$N_1 = \frac{1}{2} N_0$

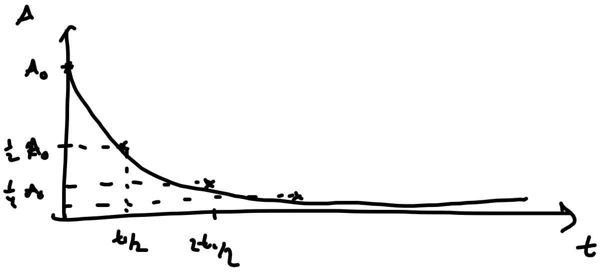
$A_1 = \frac{1}{2} A_0$

$2t_{1/2}$

$N_2 = \frac{1}{2} N_1 = \left(\frac{1}{2}\right)^2 N_0$

$A_2 = \frac{1}{2} A_1 = \left(\frac{1}{2}\right)^2 A_0$

$A_n = \left(\frac{1}{2}\right)^n A_0$



Datering med C-14

I luft: $\frac{^{14}_{6}C}{^{12}_{6}C} = \frac{1{,}5}{10^{12}}$

$$\overset{\overset{\frac{^{14}C}{^{12}C}\text{, nå}}{\swarrow}}{N} = \overset{\overset{\frac{^{14}C}{^{12}C}\text{ : i luft}}{\swarrow}}{N_0}\left(\frac{1}{2}\right)^{t/t_{1/2}} \qquad t = ?$$

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

$t_{1/2} = 5730$ år

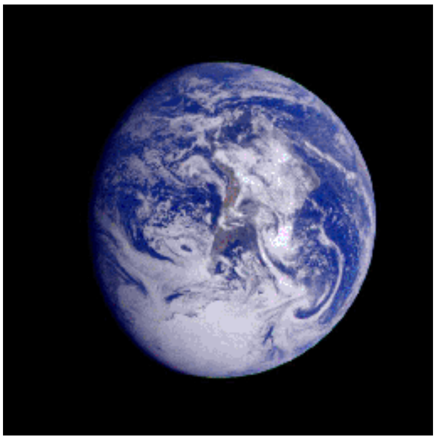
$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

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

$$t = t_{1/2}\frac{\log(N/N_0)}{\log(1/2)}$$

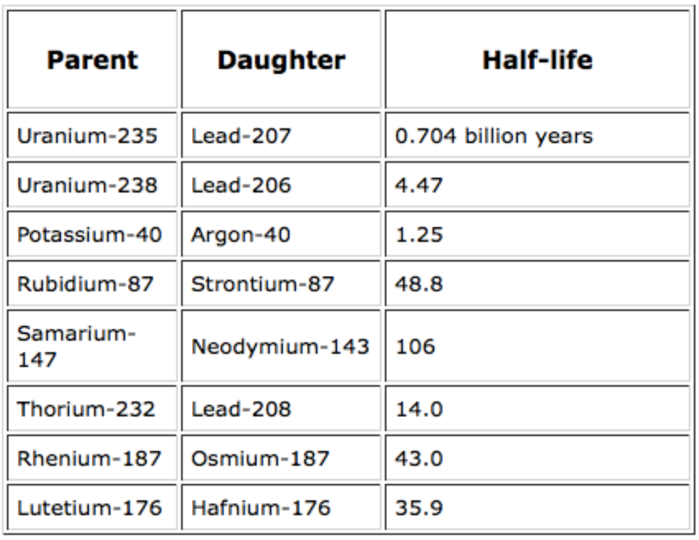
eksempel: $\frac{N}{N_0} = 0{,}35$

$$t = 5730 \text{ år } \frac{\log(0{,}35)}{\log(1/2)} = 8680 \text{ år}$$



https://photojournal.jpl.nasa.gov/animation/PIA00114

Datering med større halveringstid - jordas alder



Parent	**Daughter**	**Half-life**
Uranium-235	Lead-207	0.704 billion years
Uranium-238	Lead-206	4.47
Potassium-40	Argon-40	1.25
Rubidium-87	Strontium-87	48.8
Samarium-147	Neodymium-143	106
Thorium-232	Lead-208	14.0
Rhenium-187	Osmium-187	43.0
Lutetium-176	Hafnium-176	35.9

Hva skjer når en atombombe sprenges?

https://en.wikipedia.org/wiki/Operation_Crossroads#/media/File:Operation_Crossroads_Baker_Edit.jpg

Energi og masse

$$\boxed{\begin{array}{c}\text{Hvileenergien}\\ E = mc^2\end{array}}$$

Totalenergien i et isolert system, inkludert hvileenergien, er bevart (massen er ikke nødvendigvis bevart)

- Massesvinn

$$\Delta E = \Delta m c^2$$

$$\underbrace{\underset{m=238{,}0508u}{^{238}_{92}U}}_{m_{før}} \rightarrow \underbrace{\underset{m=234{,}0436u}{^{234}_{90}Th} + \underset{m=4{,}0026u}{^{4}_{2}He}}_{m_{etter}}$$

$$\Delta m = m_{etter} - m_{før} = -0{,}00460\ u$$

massesvinn $m_s = -\Delta m$

Reaksjonsenergi $E_r = m_s c^2$

$$= 0{,}00460\ u \cdot 1{,}66 \cdot 10^{-27}\ kg/u \cdot (3{,}00 \cdot 10^{8}\ m/s)^2$$

$$= 6{,}87 \cdot 10^{-13}\ J$$

$$\swarrow \quad \downarrow \quad \searrow$$

$$\underbrace{E_{k,\alpha} \qquad E_{k,Th} \qquad \gamma\text{-stråling}}_{\Rightarrow\ \text{varme}}$$

Fisjon

$$\underbrace{{}^{1}_{0}n + {}^{235}_{92}U}\rightarrow {}^{236}_{92}U \longrightarrow \underbrace{{}^{89}_{36}Kr + {}^{144}_{56}Ba + \boxed{3\,{}^{1}_{0}n}}$$

$m_s = 0{,}21u$

$E_r = 3{,}2 \cdot 10^{-11}\ J$

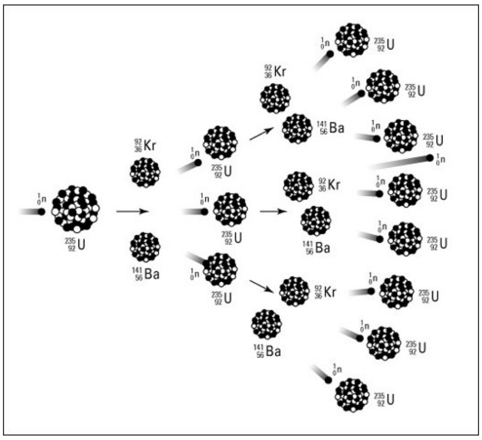
Energi i 2kg uran?

$$N = \frac{1\ kg}{235u} = 2{,}563 \cdot 10^{24} \text{ urankjerner}$$

$$E = E_r N = 8{,}20 \cdot 10^{13}\ J = 82{,}0\ TJ = 878\ \overset{?}{M}Wh$$

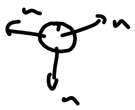
Norge, 1 år: $225\ \overset{?}{T}Wh \Rightarrow 256$ kg uran

Kjedereaksjon

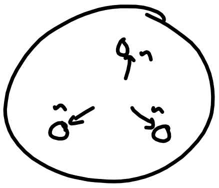


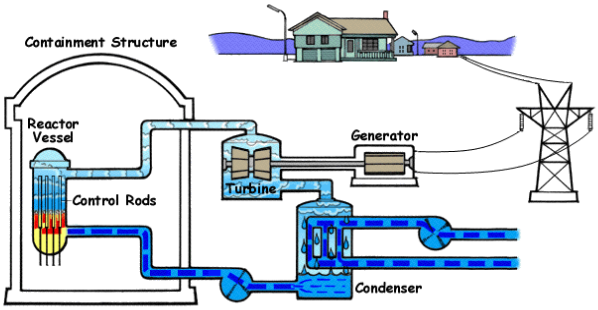
Nuclide	Half Life (y)	Critical Mass (kg)	Diameter (cm)
uranium-233	159,200	15	11
uranium-235	704,000,000	52	17
neptunium-236	154,000	7	8.7
neptunium-237	2,144,000	60	18
plutonium-238	87.7	9.04-10.07	9.5-9.9
plutonium-239	24,110	10	9.9
plutonium-240	6561	40	15
plutonium-241	14.3	12	10.5
plutonium-242	375,000	75-100	19-21

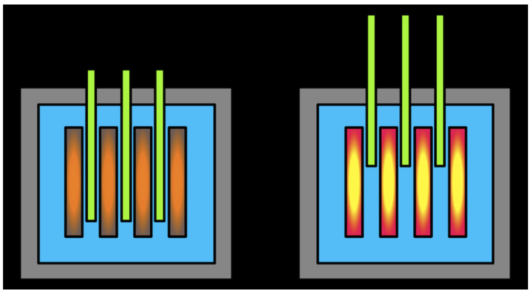
Liten klump

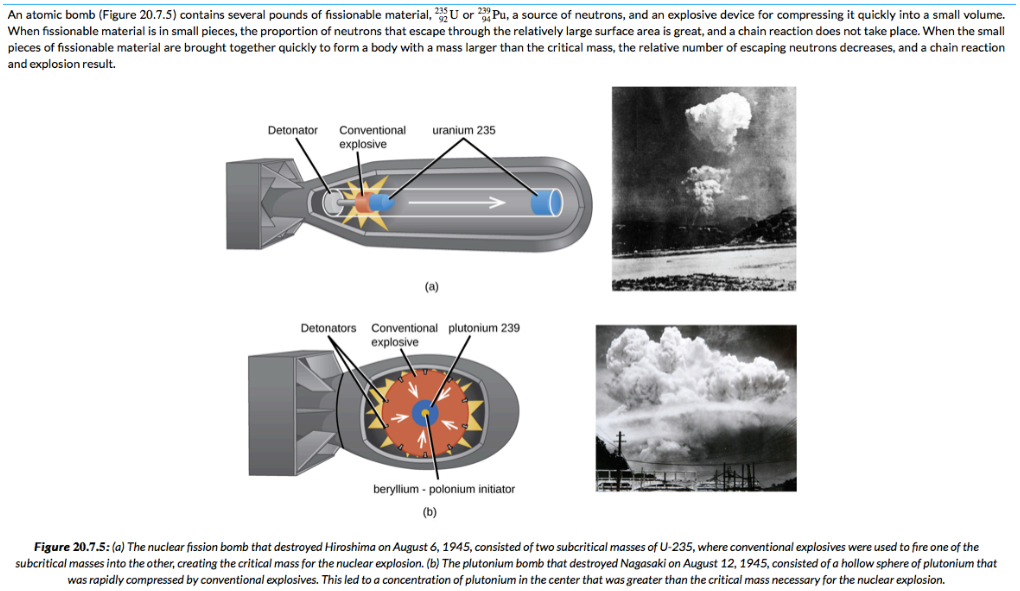


stor klump




Containment Structure
Reactor Vessel
Control Rods
Turbine
Generator
Condenser



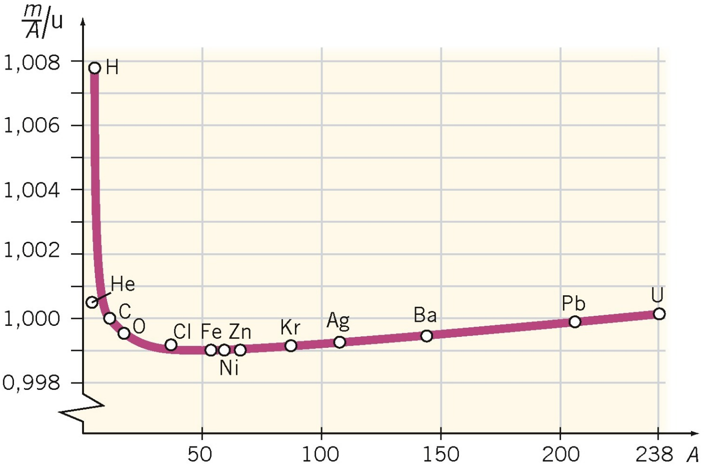


An atomic bomb (Figure 20.7.5) contains several pounds of fissionable material, $^{235}_{92}\text{U}$ or $^{239}_{94}\text{Pu}$, a source of neutrons, and an explosive device for compressing it quickly into a small volume. When fissionable material is in small pieces, the proportion of neutrons that escape through the relatively large surface area is great, and a chain reaction does not take place. When the small pieces of fissionable material are brought together quickly to form a body with a mass larger than the critical mass, the relative number of escaping neutrons decreases, and a chain reaction and explosion result.

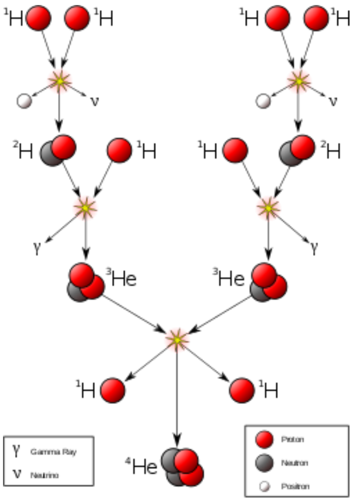
Figure 20.7.5: *(a) The nuclear fission bomb that destroyed Hiroshima on August 6, 1945, consisted of two subcritical masses of U-235, where conventional explosives were used to fire one of the subcritical masses into the other, creating the critical mass for the nuclear explosion. (b) The plutonium bomb that destroyed Nagasaki on August 12, 1945, consisted of a hollow sphere of plutonium that was rapidly compressed by conventional explosives. This led to a concentration of plutonium in the center that was greater than the critical mass necessary for the nuclear explosion.*

https://chem.libretexts.org/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3A_A_Molecular_Approach_(Tro)/20%3A_Radioactivity_and_Nuclear_Chemistry/20.07%3A_The_Discovery_of_Fission%3A_The_Atomic_Bomb_and_Nuclear_Power

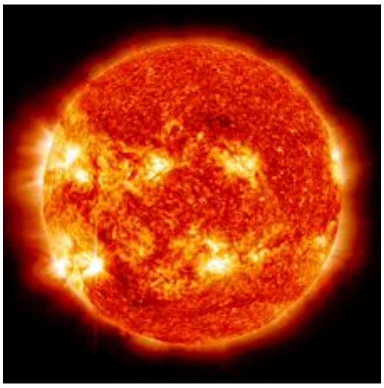
Fusjon og fisjon

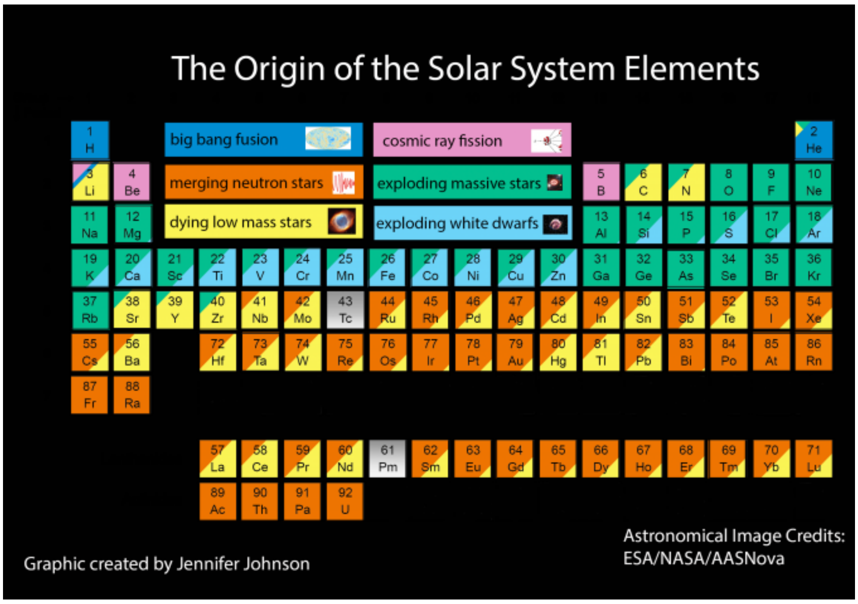


Fusjon



https://en.wikipedia.org/wiki/Nuclear_fusion





The Origin of the Solar System Elements

big bang fusion

cosmic ray fission

merging neutron stars

exploding massive stars

dying low mass stars

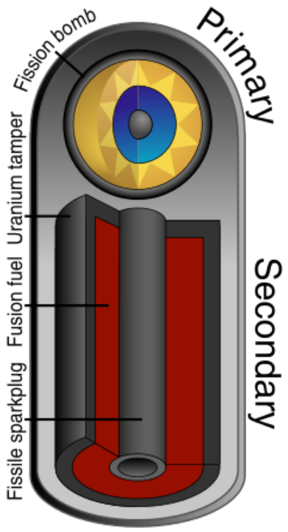
exploding white dwarfs

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra																
			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
			89 Ac	90 Th	91 Pa	92 U											

Graphic created by Jennifer Johnson

Astronomical Image Credits:
ESA/NASA/AASNova

http://blog.sdss.org/2017/01/09/origin-of-the-elements-in-the-solar-system/



https://en.wikipedia.org/wiki/Thermonuclear_weapon

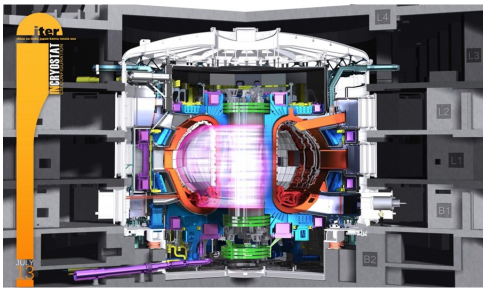
Så farlig er hydrogenbomben

I januar 2016 hevdet også Nord-Korea at de hadde testet en hydrogenbombe. Her vises spreningen på nasjonalt TV i Nord-Korea. Foto: Jung Yeon-je

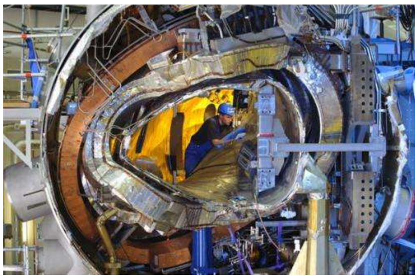
En hydrogenbombe kan ha tusen ganger så mye kraft som en atombombe.

Synnøve Gjerstad og **Kaja Kirkerud** 03.09.2017 (Oppdatert: 03.09.2017)

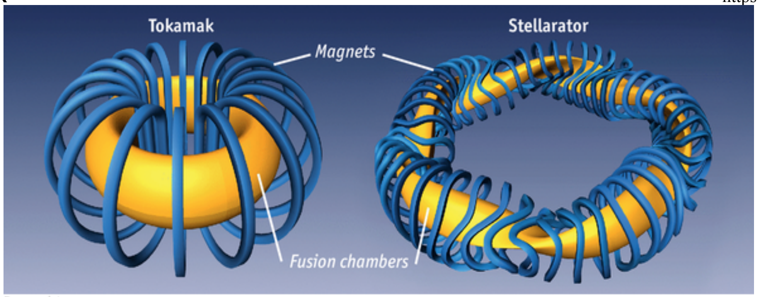
Drømmen om fusjonsenergi



ITER Tokamak https://www.iter.org/mach/tokamak



Wendelstein 7-X Stellerator https://phys.org/news/2014-05-wendelstein-x.html



Economist.com

http://fusion4freedom.com/stellar-work/

Ioniserende stråling

Stråling med nok energi til å slå ut elektroner i atomer og molekyler

Aktivitet $A = \frac{\Delta N}{\Delta t}$ $[A] = Bq$

Stråledose $D = \frac{E}{m}$ $\leftarrow$ absorbert energi

$[D] = \frac{J}{kg} = Gy$ gray

Ekvivalent dose

$$H = W_R \overset{\swarrow \text{ stråledose}}{D}$$

$$[H] = \frac{J}{kg} = Sv$$

sievert

Røntgen, gamma, elektroner	1
Nøytroner	2-20 (avhengig av energi)
Protoner, ladde pioner	2
a-Partikler, fisjonsprodukter, tunge kjerner	20

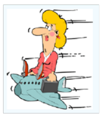
Typiske stråledoser

Kosmisk stråling gir opphav til nordlys

Naturlig bakgrunnsstråling:	***ca 3 mSv pr år***	*(globalt snitt)*
- stor variasjon	**1 - 250 mSv pr år**	

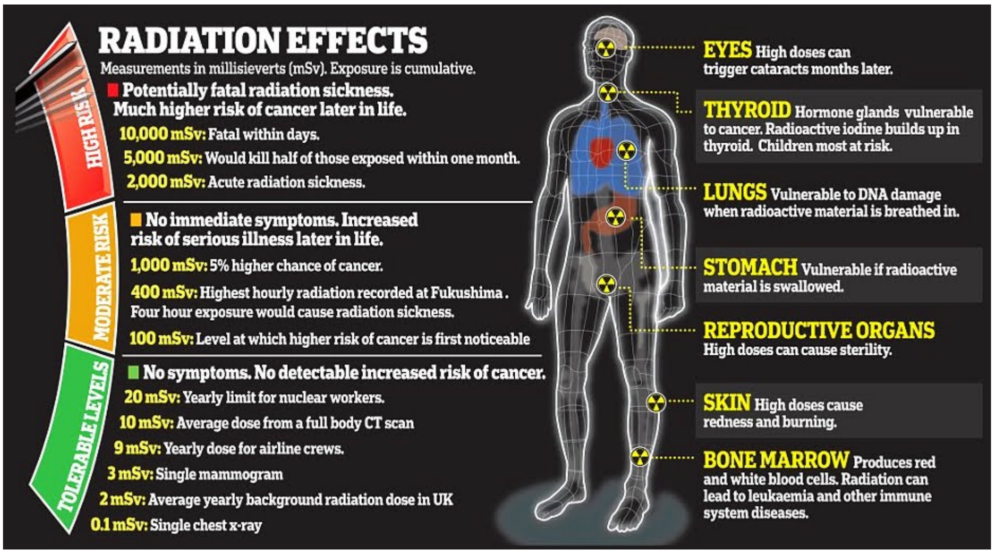
radon (globalt snitt) *utendørs 10 Bq/m^3* *innendørs 46 Bq/m^3* *(maxverdier over 80 000)*

Tsjernobylnedfall		**0,040 mSv pr år**
Flyreiser (Oslo-New York t/r)	ca	**0,1 mSv**
Flytte fra trehus til murhus	**+**	0,4 mSv pr år



0,007 mSv pr time

Tannlegerøntgen	**0,030 mSv pr bilde**
CT -røntgen	**1-20 mSv pr bilde**
Strålebehandling (kreft)	**2000 – 80 000 mSv pr behandling**



RADIATION EFFECTS

Measurements in millisieverts (mSv). Exposure is cumulative.

HIGH RISK

🟥 **Potentially fatal radiation sickness. Much higher risk of cancer later in life.**

10,000 mSv: Fatal within days.
5,000 mSv: Would kill half of those exposed within one month.
2,000 mSv: Acute radiation sickness.

MODERATE RISK

🟧 **No immediate symptoms. Increased risk of serious illness later in life.**

1,000 mSv: 5% higher chance of cancer.
400 mSv: Highest hourly radiation recorded at Fukushima . Four hour exposure would cause radiation sickness.
100 mSv: Level at which higher risk of cancer is first noticeable

TOLERABLE LEVELS

🟩 **No symptoms. No detectable increased risk of cancer.**

20 mSv: Yearly limit for nuclear workers.
10 mSv: Average dose from a full body CT scan
9 mSv: Yearly dose for airline crews.
3 mSv: Single mammogram
2 mSv: Average yearly background radiation dose in UK
0.1 mSv: Single chest x-ray

EYES High doses can trigger cataracts months later.

THYROID Hormone glands vulnerable to cancer. Radioactive iodine builds up in thyroid. Children most at risk.

LUNGS Vulnerable to DNA damage when radioactive material is breathed in.

STOMACH Vulnerable if radioactive material is swallowed.

REPRODUCTIVE ORGANS High doses can cause sterility.

SKIN High doses cause redness and burning.

BONE MARROW Produces red and white blood cells. Radiation can lead to leukaemia and other immune system diseases.

Hva skjer når en atombombe sprenges?

https://en.wikipedia.org/wiki/Operation_Crossroads#/media/File:Operation_Crossroads_Baker_Edit.jpg