

Periodic Table of the Elements

1 1A 1A 1 H Hydrogen 1.008 -299.3	2 IIA 2A 4 Be Beryllium 9.012 1287	3 IIIB 3B 11 Na Sodium 22.990 97.8	4 IVB 4B 12 Mg Magnesium 24.305 650	5 VB 5B 19 K Potassium 39.098 63.5	6 VIB 6B 20 Ca Calcium 40.078 842	7 VIIB 7B 21 Sc Scandium 44.956 1541	8 VIII 8 22 Ti Titanium 47.88 1668	9 VIII 8 23 V Vanadium 50.942 1910	10 VIII 8 24 Cr Chromium 51.996 1907	11 IB 1B 25 Mn Manganese 54.938 1246	12 IIB 2B 26 Fe Iron 55.933 1538	13 IIIA 3A 27 Co Cobalt 58.933 1495	14 IIIA 3A 28 Ni Nickel 58.693 1455	15 IVA 4A 29 Cu Copper 63.546 1084.62	16 IVA 4A 30 Zn Zinc 65.39 419.53	17 VA 5A 31 Ga Gallium 69.732 2075	18 VA 5A 32 Ge Germanium 72.61 4489 TP (10.3 MPa)	19 VIA 6A 33 As Arsenic 74.922 -210	20 VIA 6A 34 Se Selenium 78.972 -218.79	21 VIIA 7A 35 Br Bromine 79.904 -101.5	22 VIIA 7A 36 Kr Krypton 84.80 -248.609 TP (51 kPa)	23 VIIA 7A 37 Rb Rubidium 84.468 -272.20 (2.5 MPa)	24 VIIA 7A 38 Sr Strontium 87.62 -219.67 TP	25 VIIA 7A 39 Y Yttrium 88.906 -219.67 TP	26 VIIA 7A 40 Zr Zirconium 91.224 -219.67 TP	27 VIIA 7A 41 Nb Niobium 92.906 -219.67 TP	28 VIIA 7A 42 Mo Molybdenum 95.95 -219.67 TP	29 VIIA 7A 43 Tc Technetium 98.907 -219.67 TP	30 VIIA 7A 44 Ru Ruthenium 101.07 -219.67 TP	31 VIIA 7A 45 Rh Rhodium 102.906 -219.67 TP	32 VIIA 7A 46 Pd Palladium 106.42 -219.67 TP	33 VIIA 7A 47 Ag Silver 107.868 -219.67 TP	34 VIIA 7A 48 Cd Cadmium 112.411 -219.67 TP	35 VIIA 7A 49 In Indium 114.818 -219.67 TP	36 VIIA 7A 50 Sn Tin 118.71 -219.67 TP	37 VIIA 7A 51 Sb Antimony 121.760 -219.67 TP	38 VIIA 7A 52 Te Tellurium 127.6 -219.67 TP	39 VIIA 7A 53 I Iodine 126.904 -219.67 TP	40 VIIA 7A 54 Xe Xenon 131.29 -219.67 TP	41 VIIA 7A 55 Cs Cesium 132.905 -219.67 TP	42 VIIA 7A 56 Ba Barium 137.327 -219.67 TP	43 VIIA 7A 57-71 Lanthanide Series	44 VIIA 7A 72 Hf Hafnium 178.49 -219.67 TP	45 VIIA 7A 73 Ta Tantalum 180.948 -219.67 TP	46 VIIA 7A 74 W Tungsten 183.85 -219.67 TP	47 VIIA 7A 75 Re Rhenium 186.207 -219.67 TP	48 VIIA 7A 76 Os Osmium 190.23 -219.67 TP	49 VIIA 7A 77 Ir Iridium 192.22 -219.67 TP	50 VIIA 7A 78 Pt Platinum 195.08 -219.67 TP	51 VIIA 7A 79 Au Gold 196.967 -219.67 TP	52 VIIA 7A 80 Hg Mercury 200.59 -219.67 TP	53 VIIA 7A 81 Tl Thallium 204.383 -219.67 TP	54 VIIA 7A 82 Pb Lead 207.2 -219.67 TP	55 VIIA 7A 83 Bi Bismuth 208.980 -219.67 TP	56 VIIA 7A 84 Po Polonium [208.982] -219.67 TP	57 VIIA 7A 85 At Astatine 208.987 -219.67 TP	58 VIIA 7A 86 Rn Radon 222.018 -219.67 TP	59 VIIA 7A 87 Fr Francium 223.020 -219.67 TP	60 VIIA 7A 88 Ra Radium 226.025 -219.67 TP	61 VIIA 7A 89-103 Actinide Series	62 VIIA 7A 104 Rf Rutherfordium [261] -219.67 TP	63 VIIA 7A 105 Db Dubnium [262] -219.67 TP	64 VIIA 7A 106 Sg Seaborgium [266] -219.67 TP	65 VIIA 7A 107 Bh Bohrium [264] -219.67 TP	66 VIIA 7A 108 Hs Hassium [269] -219.67 TP	67 VIIA 7A 109 Mt Meitnerium [268] -219.67 TP	68 VIIA 7A 110 Ds Darmstadtium [269] -219.67 TP	69 VIIA 7A 111 Rg Roentgenium [272] -219.67 TP	70 VIIA 7A 112 Cn Copernicium [277] -219.67 TP	71 VIIA 7A 113 Uut Ununtrium unknown -219.67 TP	72 VIIA 7A 114 Fl Flerovium [289] -219.67 TP	73 VIIA 7A 115 Uup Ununpentium unknown -219.67 TP	74 VIIA 7A 116 Lv Livermorium [298] -219.67 TP	75 VIIA 7A 117 Uus Ununseptium unknown -219.67 TP	76 VIIA 7A 118 Uuo Ununoctium unknown -219.67 TP
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Normal melting points are in °C.
TP = Triple Point
Pressure is listed if not 1 atm.
Allotrope is listed if more than one allotrope.

Atomic Number	Melting Point
Symbol	
Name	
Atomic Mass	

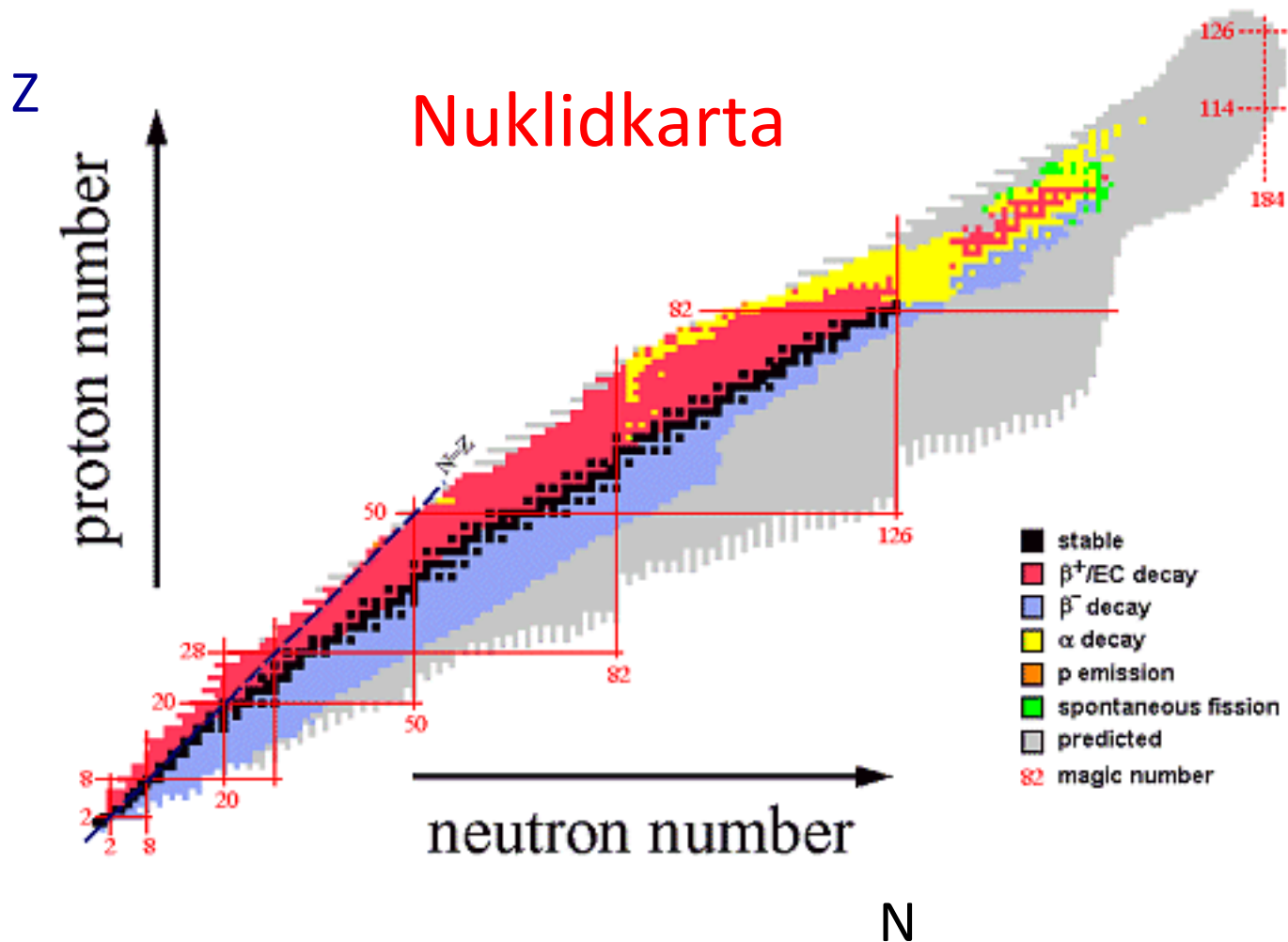
Lanthanide Series

Actinide Series

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Semimetal
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

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Antalet elektroner bestämmer kemiska egenskaper



300+ naturliga; <300 stabila, >3000 totalt – varje nuklid är unik!

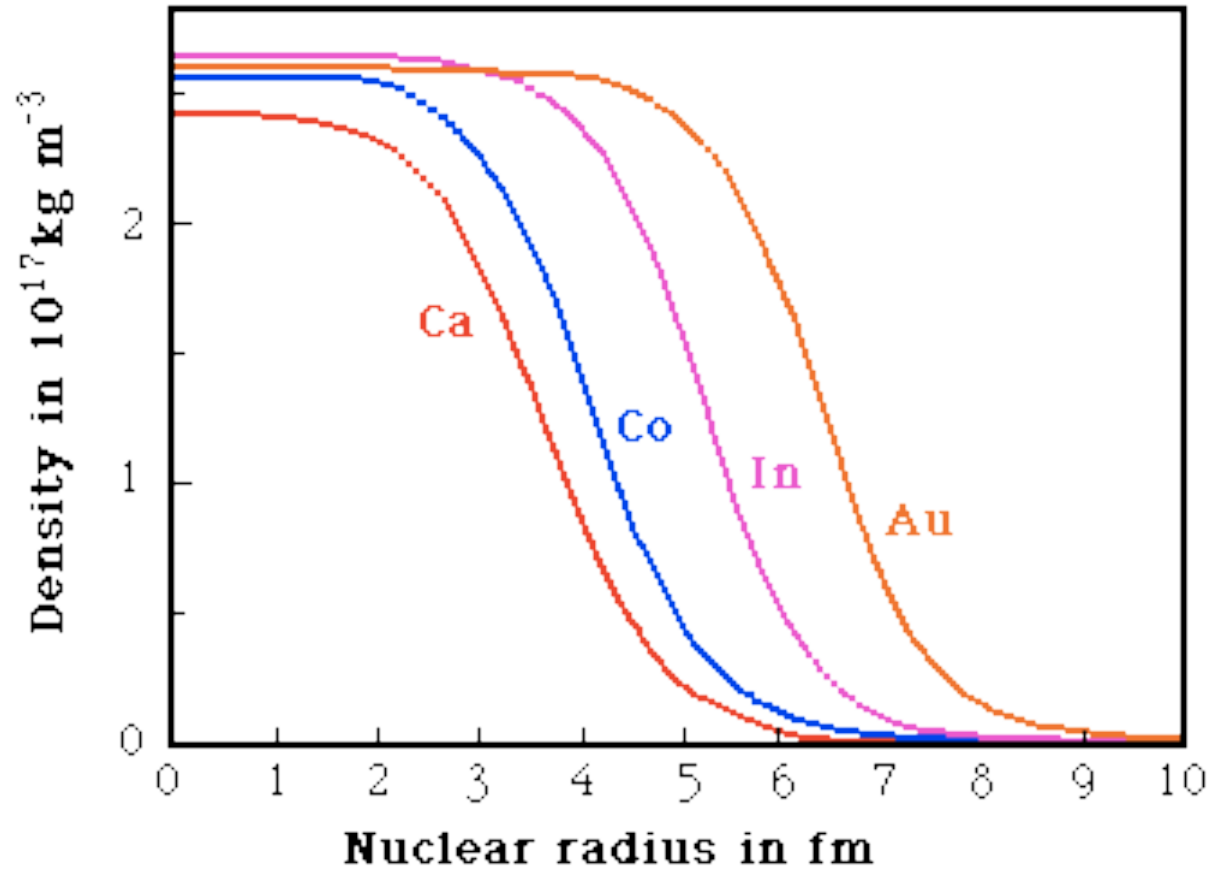
Lätta: stabila kring $Z=N$; Tyngre: $Z < N$, upp till ^{208}Pb

Table 43.2 Neutral Atomic Masses for Some Light Nuclides

Element and Isotope	Atomic Number, Z	Neutron Number, N	Atomic Mass (u)	Mass Number, A
Hydrogen (${}^1_1\text{H}$)	1	0	1.007825	1
Deuterium (${}^2_1\text{H}$)	1	1	2.014102	2
Tritium (${}^3_1\text{H}$)	1	2	3.016049	3
Helium (${}^3_2\text{He}$)	2	1	3.016029	3
Helium (${}^4_2\text{He}$)	2	2	4.002603	4
Lithium (${}^6_3\text{Li}$)	3	3	6.015122	6
Lithium (${}^7_3\text{Li}$)	3	4	7.016004	7
Beryllium (${}^9_4\text{Be}$)	4	5	9.012182	9
Boron (${}^{10}_5\text{B}$)	5	5	10.012937	10
Boron (${}^{11}_5\text{B}$)	5	6	11.009305	11
Carbon (${}^{12}_6\text{C}$)	6	6	12.000000	12
Carbon (${}^{13}_6\text{C}$)	6	7	13.003355	13
Nitrogen (${}^{14}_7\text{N}$)	7	7	14.003074	14
Nitrogen (${}^{15}_7\text{N}$)	7	8	15.000109	15
Oxygen (${}^{16}_8\text{O}$)	8	8	15.994915	16
Oxygen (${}^{17}_8\text{O}$)	8	9	16.999132	17
Oxygen (${}^{18}_8\text{O}$)	8	10	17.999160	18

Source: A. H. Wapstra and G. Audi, *Nuclear Physics* **A595**, 4 (1995).

Kärn-densitet/täthet



Det diagram som betyder mest för våra livsbetingelser...

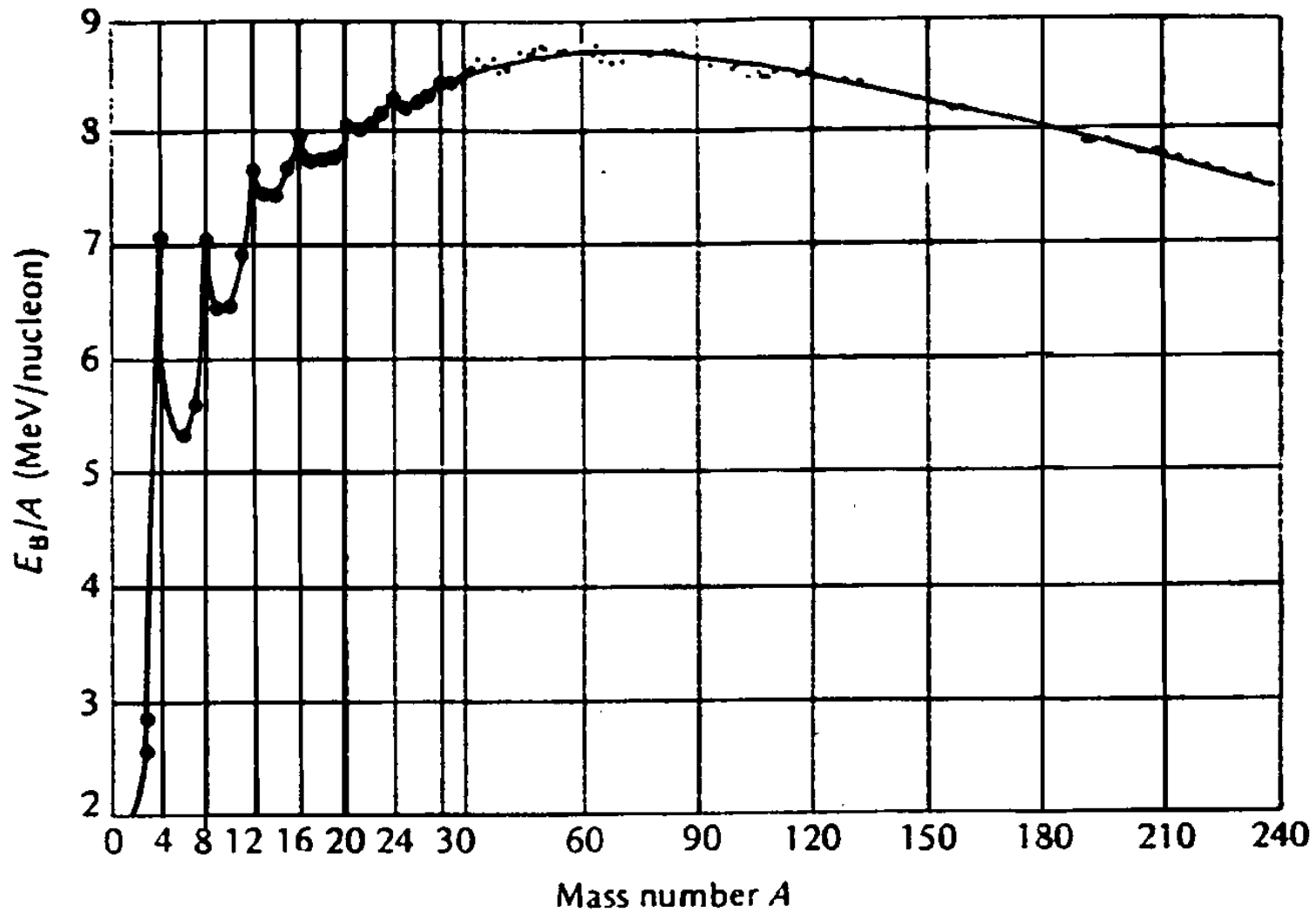
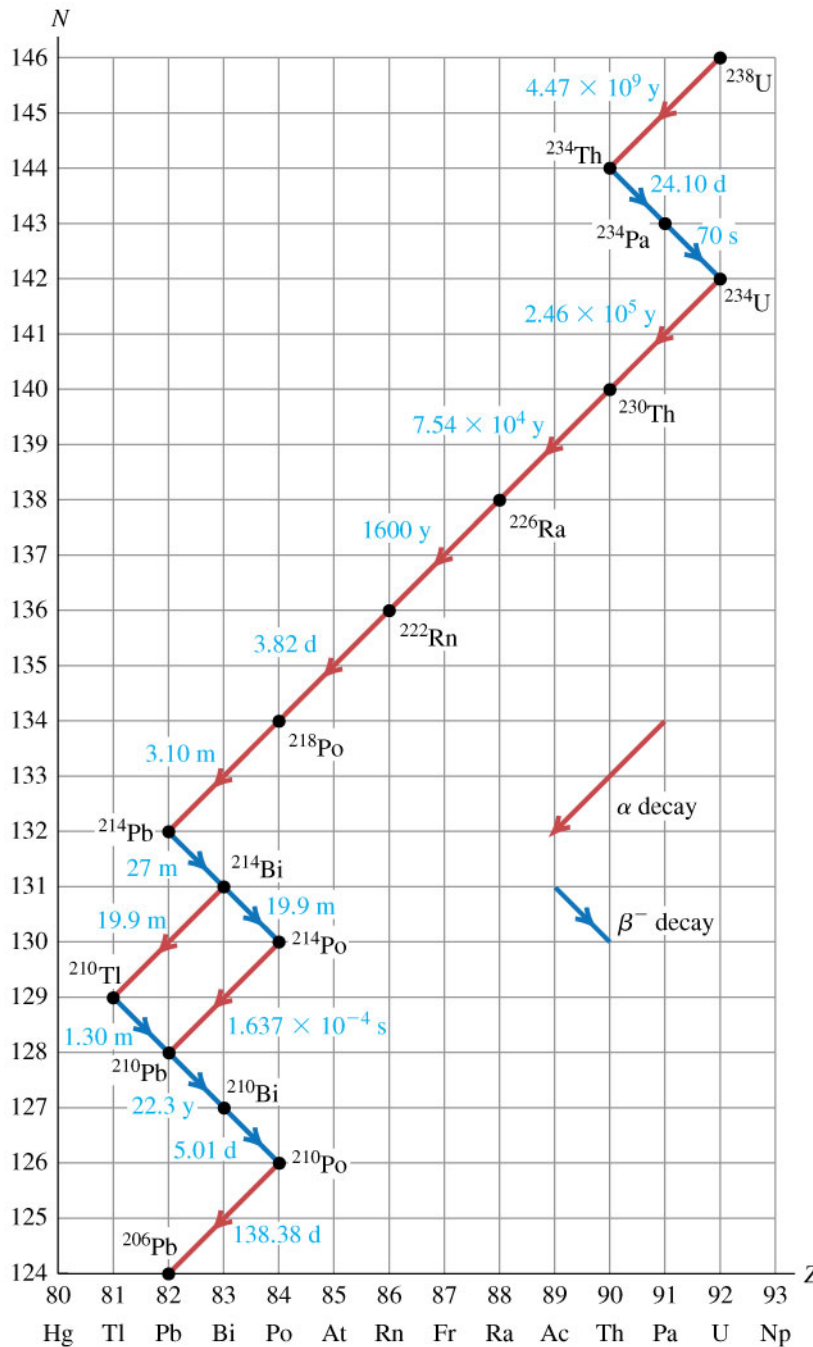


Figure 43.7

Uranium series



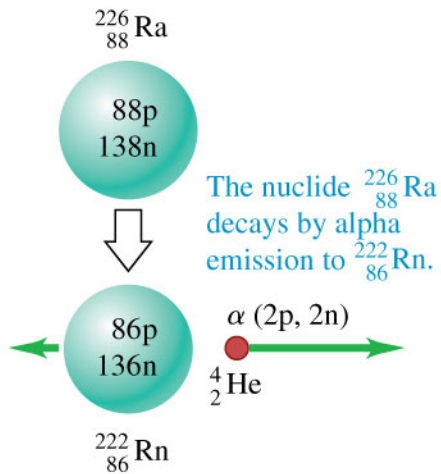
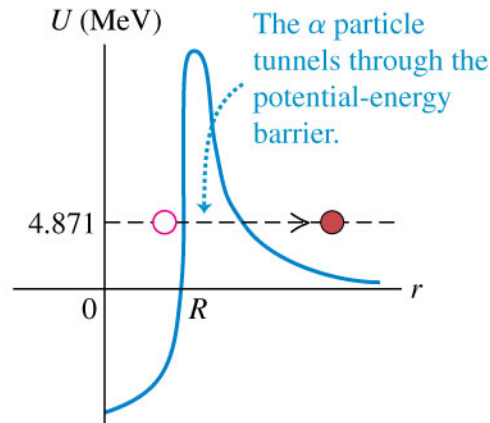
4 series in nature

Uranium
Actinium
Thorium
Neptunium

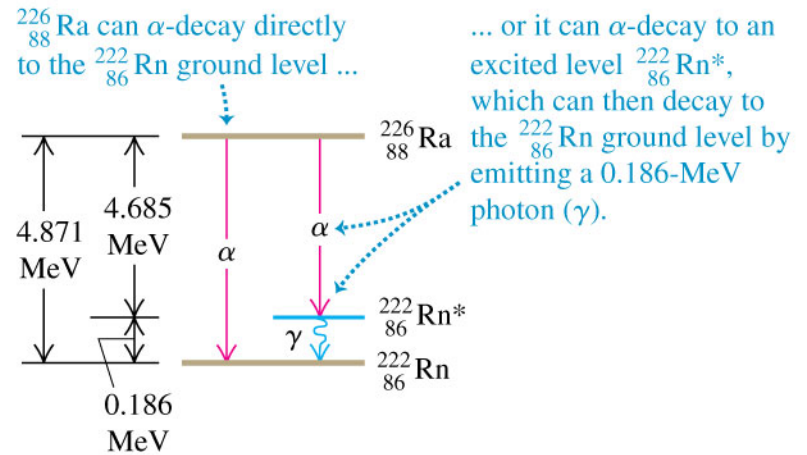
All end in Pb isotope

Potentialbarriär > Q => tunneleffekt behövs

(a)

(b) Potential-energy curve for an α particle and $^{222}_{86}\text{Rn}$ nucleus

(c) Energy-level diagram for the system

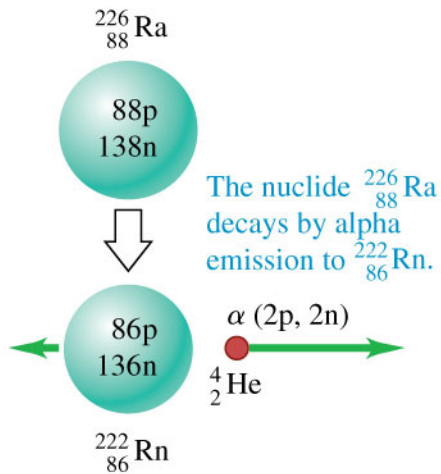
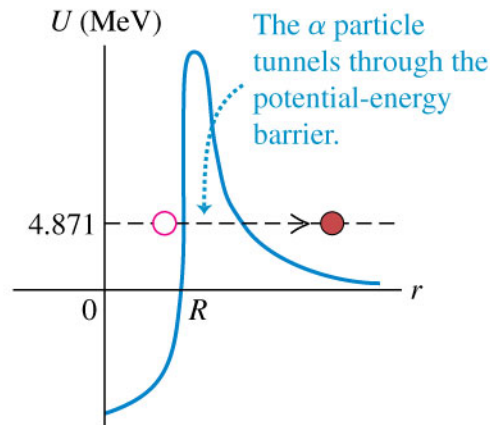


Shell model / Skal modell

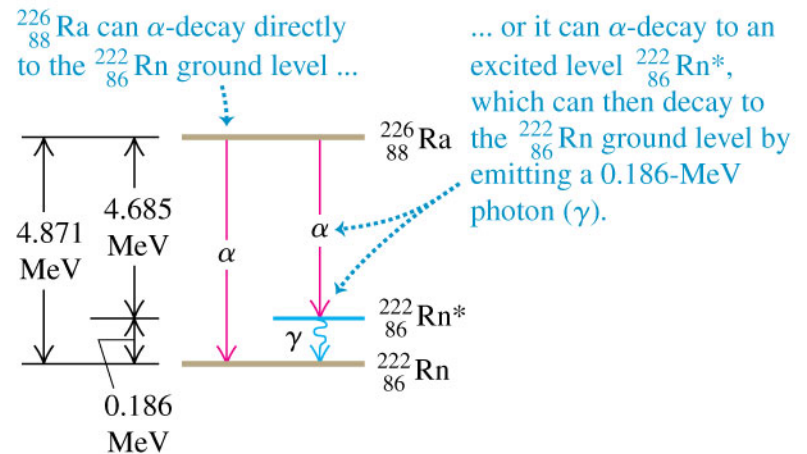
Många olika energitillstånd i kärnor

Mer komplicerat kvantmekaniskt än atomfysiks skalmodell:
kommer mer i senare kurser...

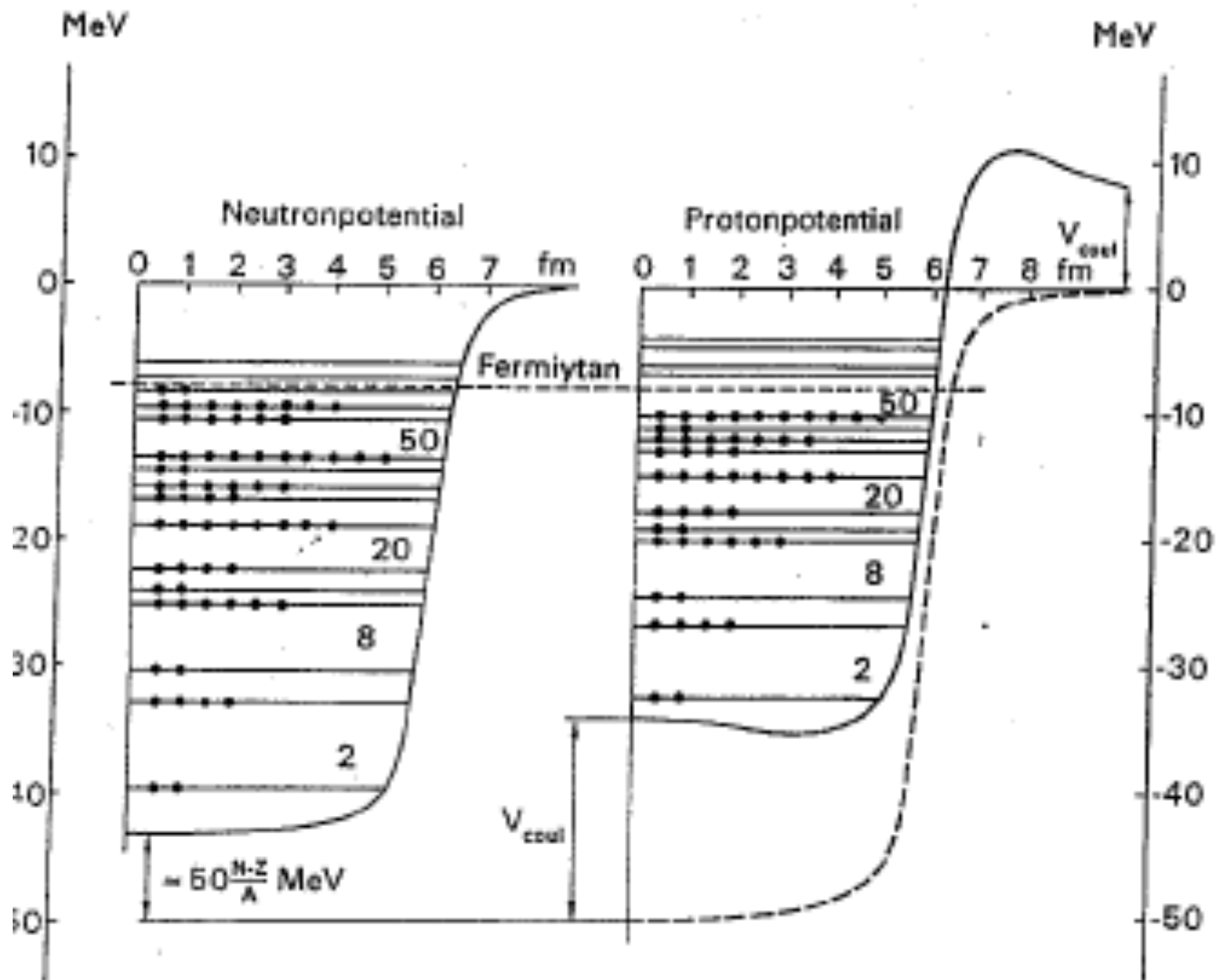
(a)

(b) Potential-energy curve for an α particle and $^{222}_{86}\text{Rn}$ nucleus

(c) Energy-level diagram for the system



Level scheme ^{116}Sn



Gamma energies from ^{61}Zn

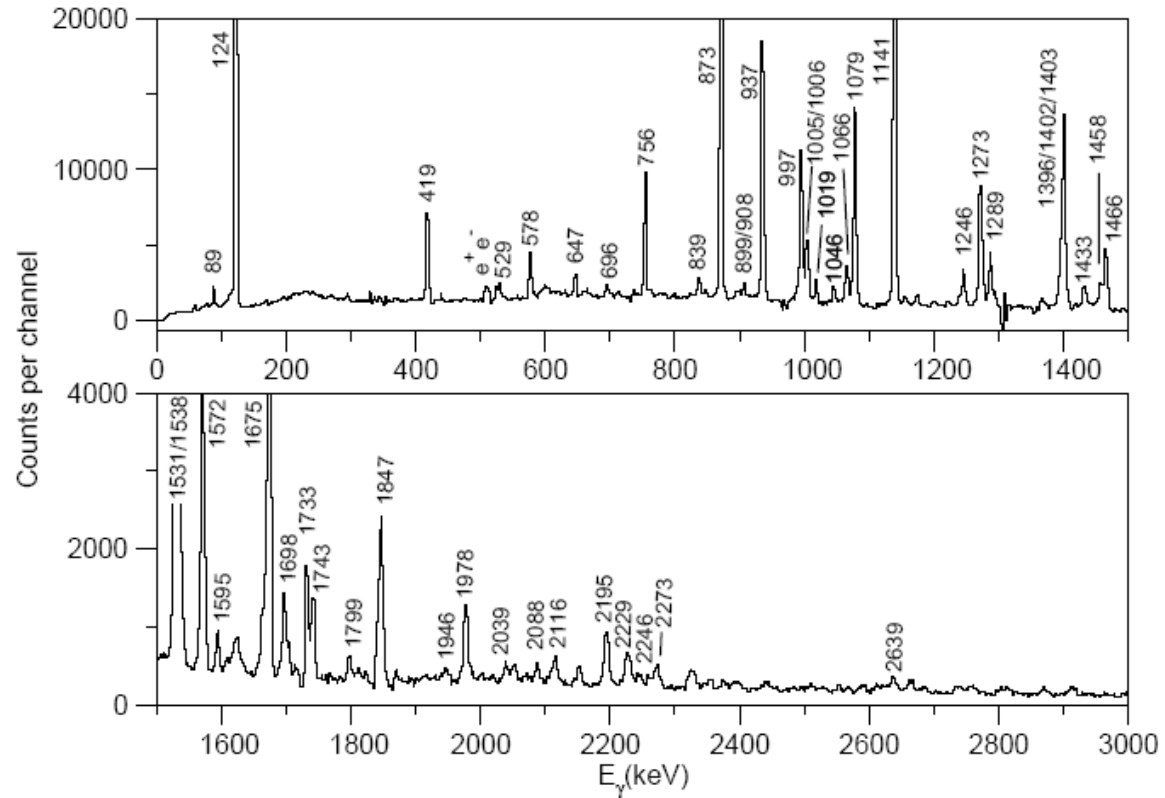
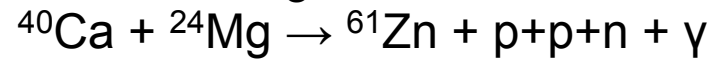
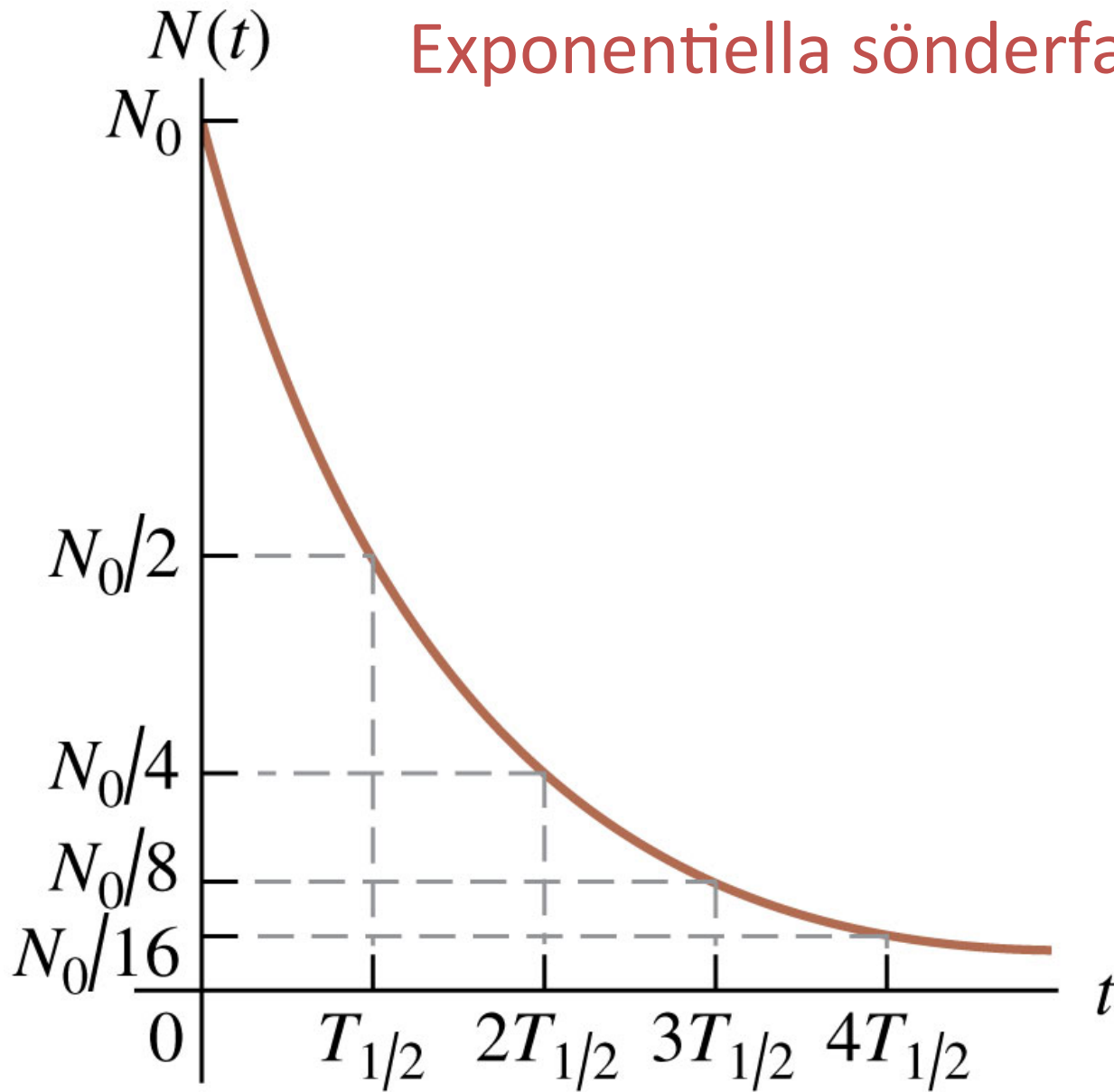
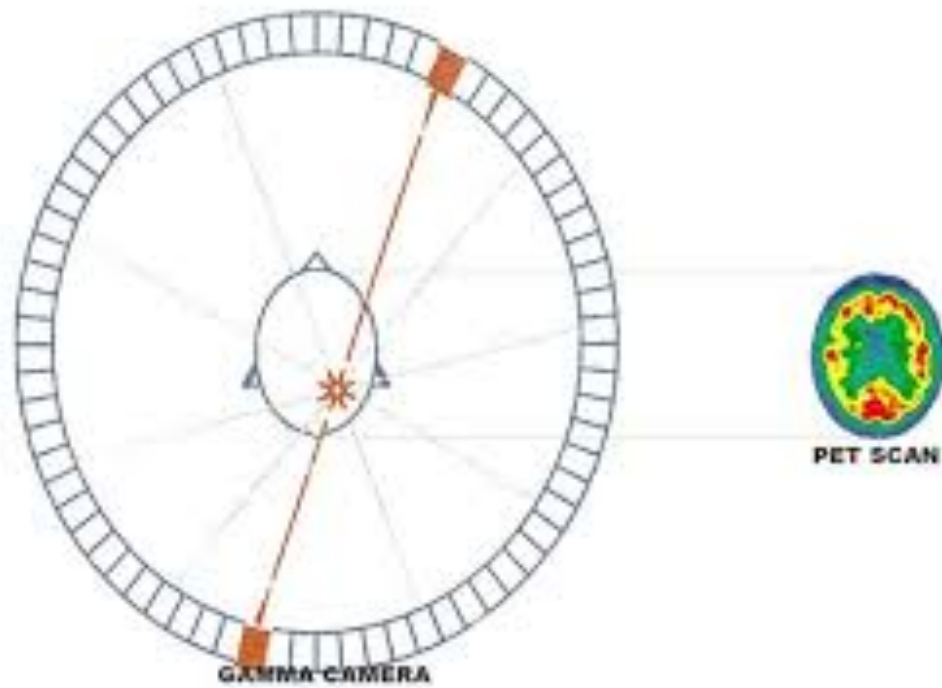


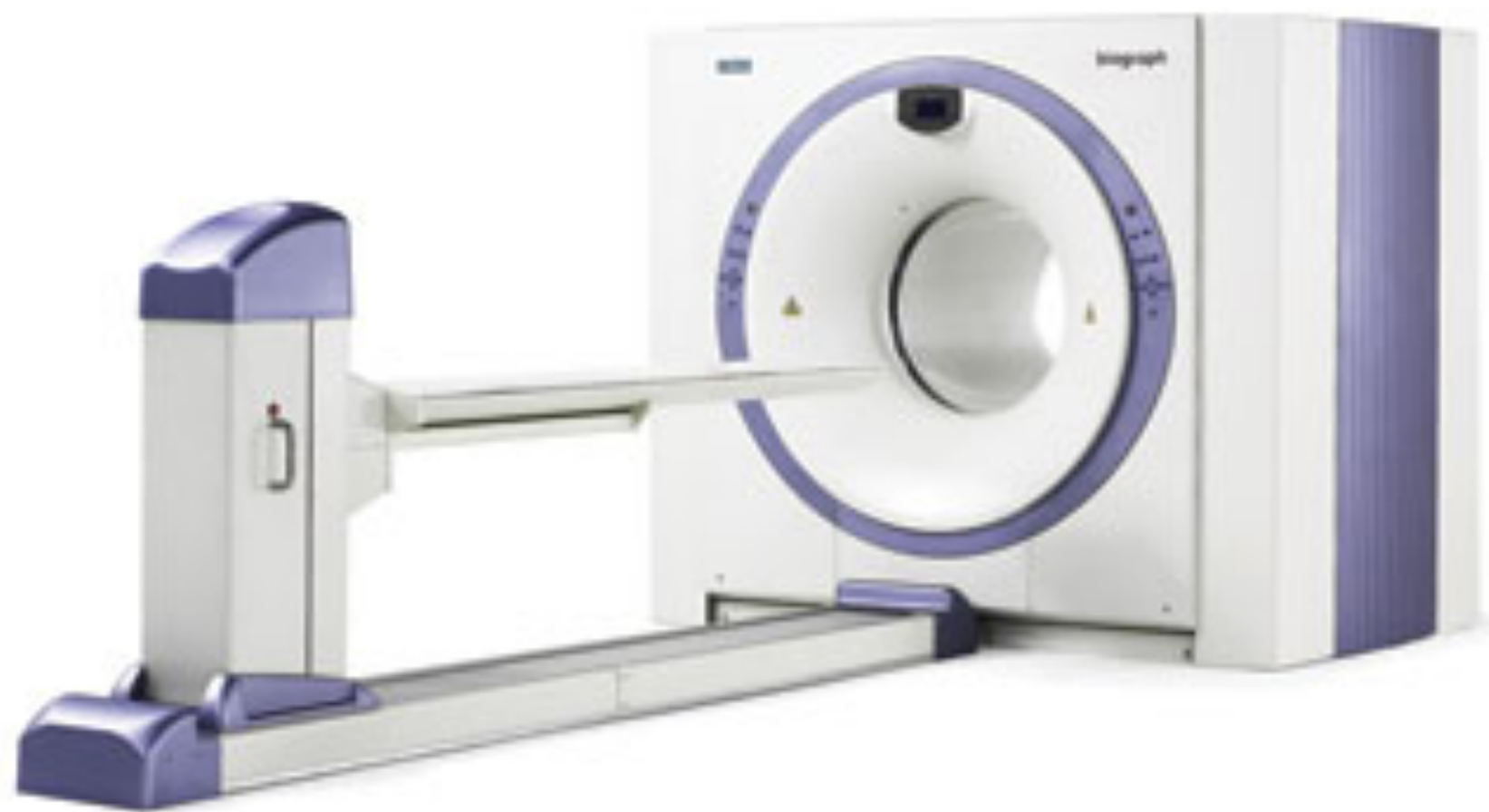
Figure 43.8

Exponentiella sönderfallslagen



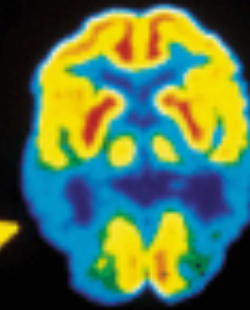
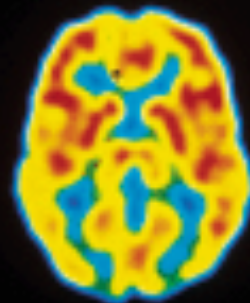
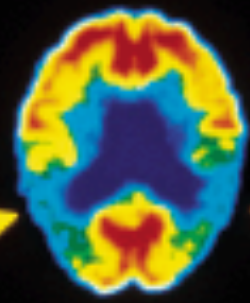
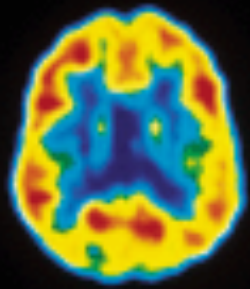
PET Imaging





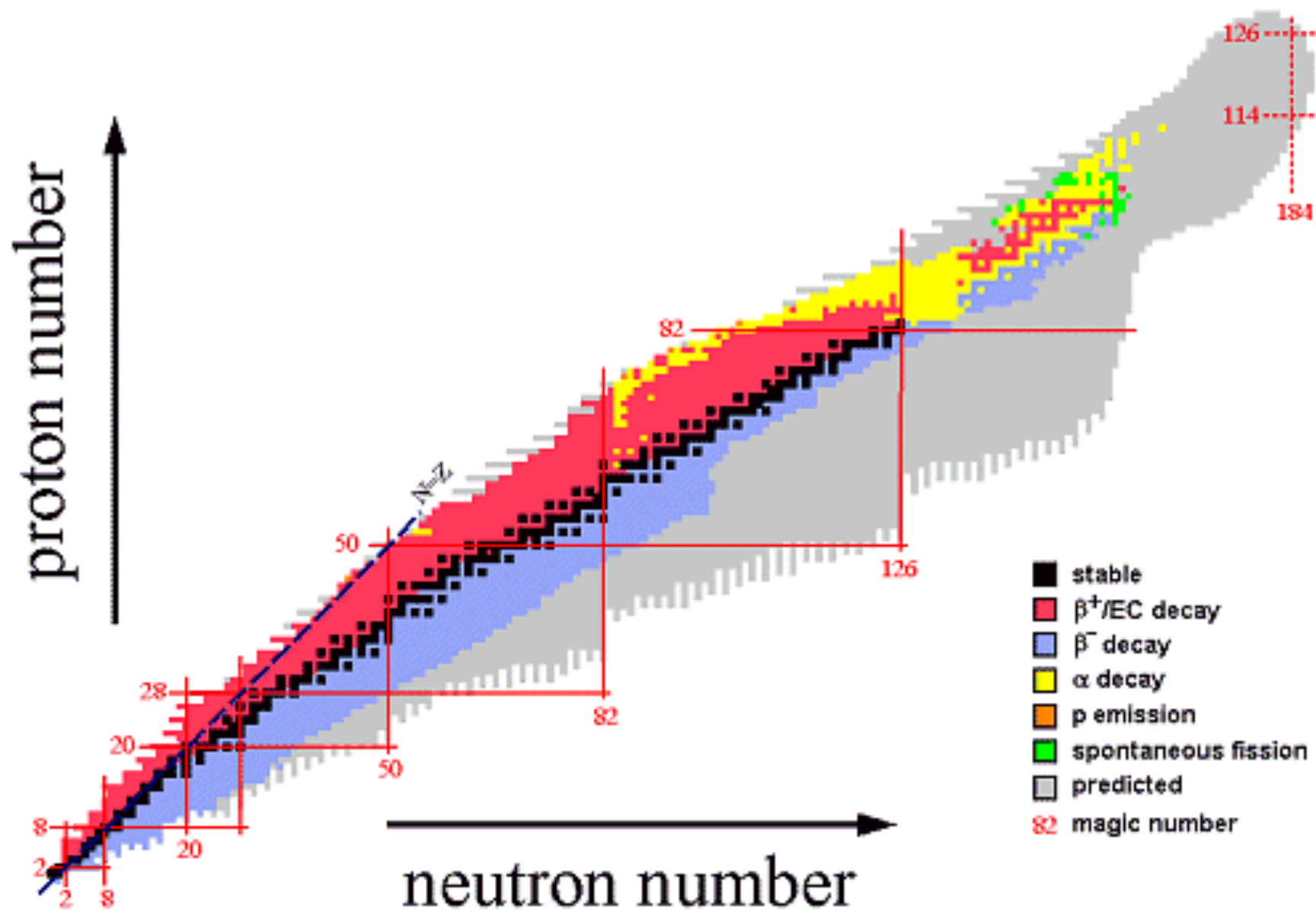
NORMAL

ALZHEIMER'S



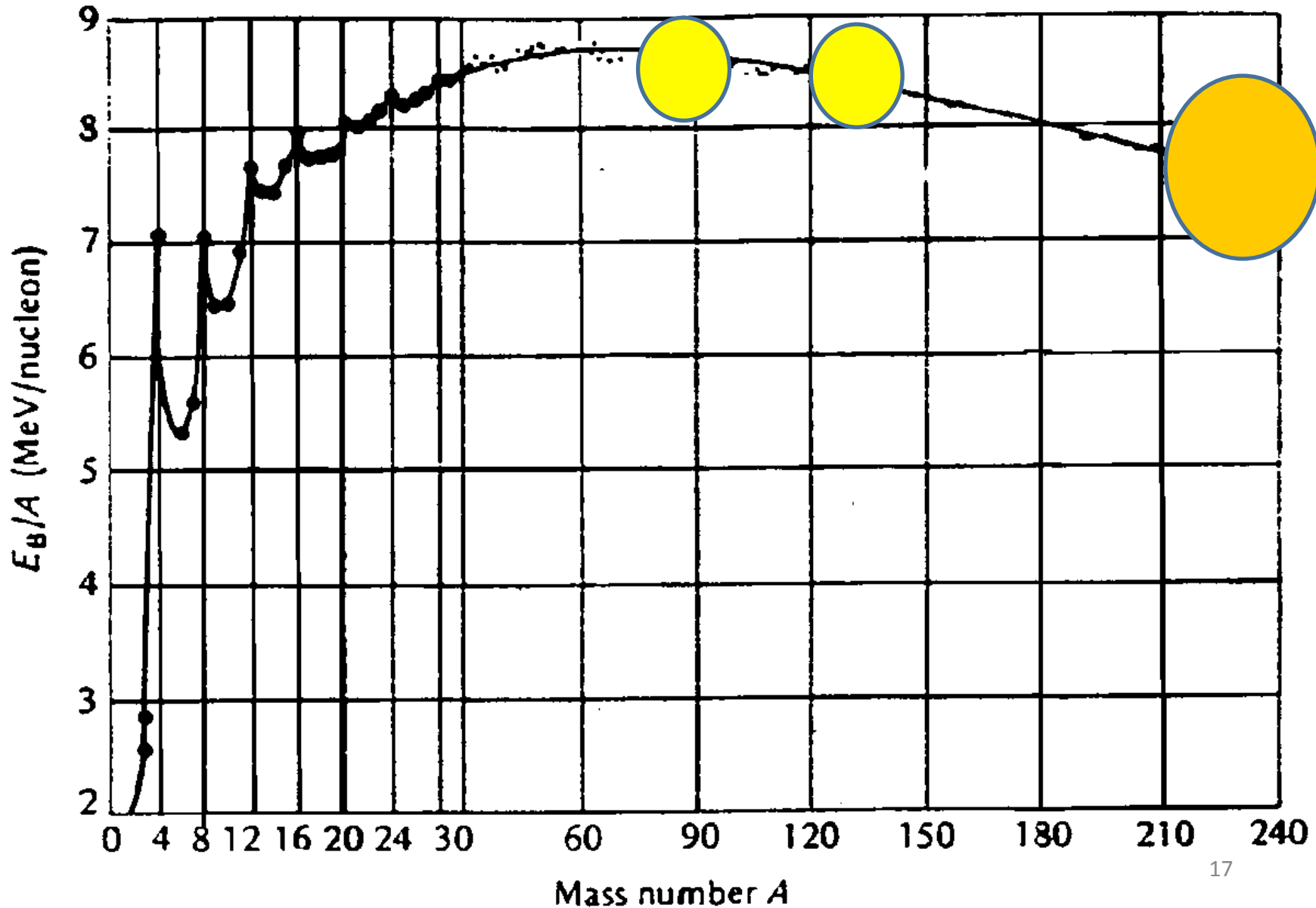
β^+ exempel for PET

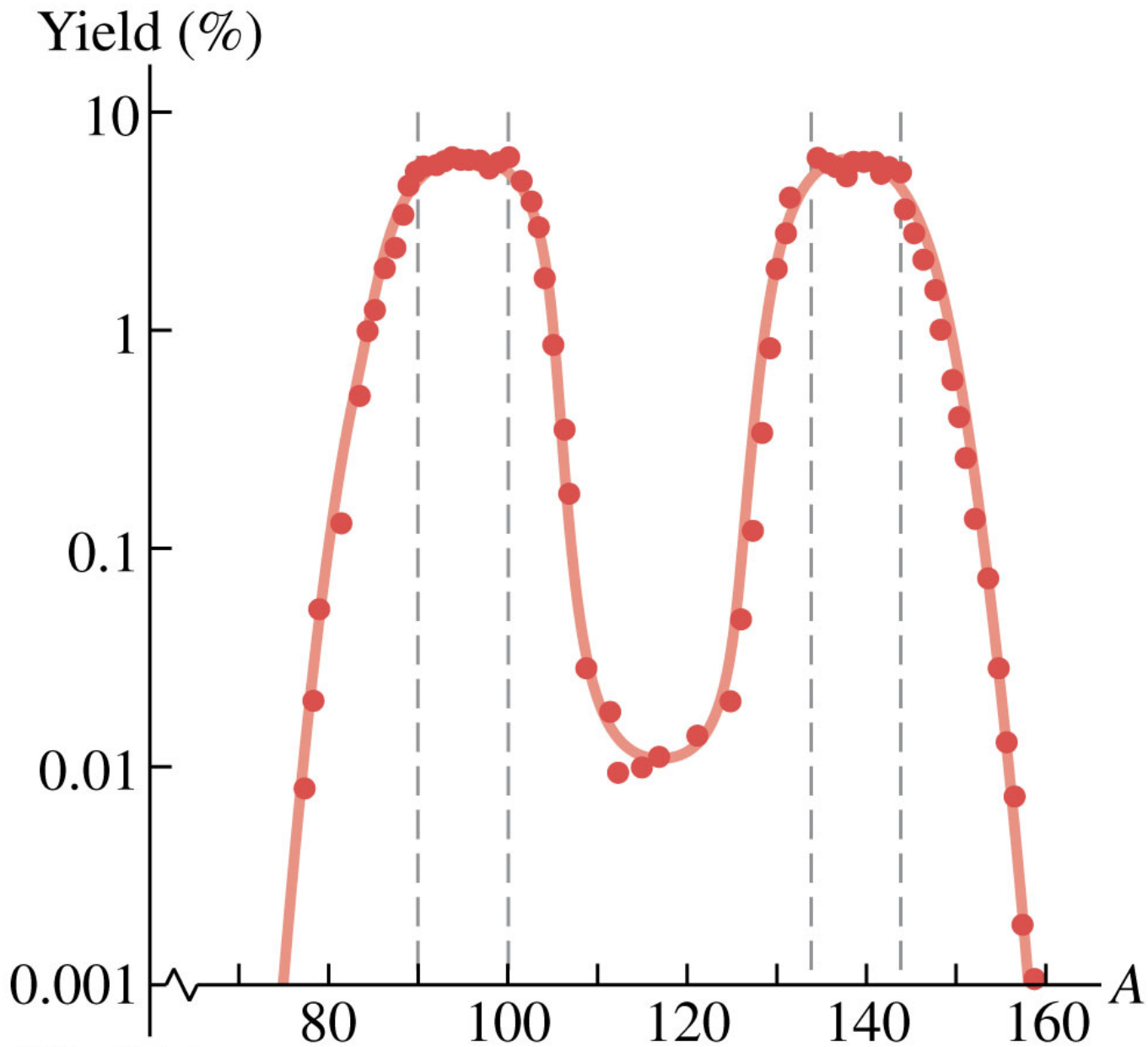
Isotope	reaction	Halflife (min)
^{18}F	$^{18}\text{O}(\text{p},\text{n})^{18}\text{F}$	110
^{11}C	$^{14}\text{N}(\text{p},\alpha)^{11}\text{C}$	20,4
^{15}O	$^{14}\text{N}(\text{d},\text{n})^{15}\text{O}$	2,1
^{13}N	$^{16}\text{O}(\text{p},\alpha)^{13}\text{N}$	10



$$Q = BE_{\text{efter}} - BE_{\text{före}}$$

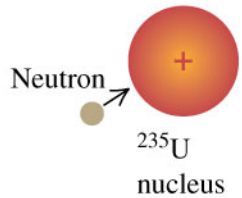
Fördelaktigt att gå mot max BE



Massfördelning av fissionsfragment från ^{235}U 

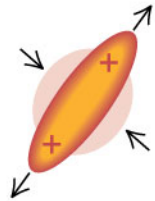
Fission

(a) A ^{235}U nucleus absorbs a neutron.

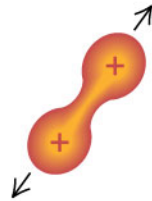


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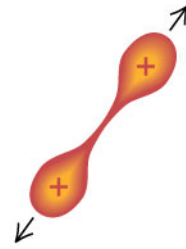
(b) The resulting $^{236}\text{U}^*$ nucleus is in a highly excited state and oscillates strongly.



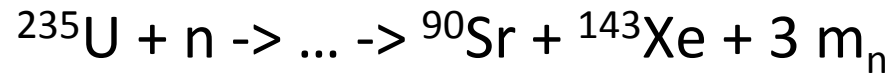
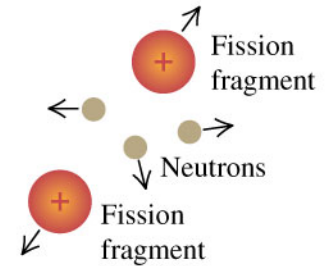
(c) A neck develops, and electric repulsion pushes the two lobes apart.



(d) The two lobes separate, forming fission fragments.



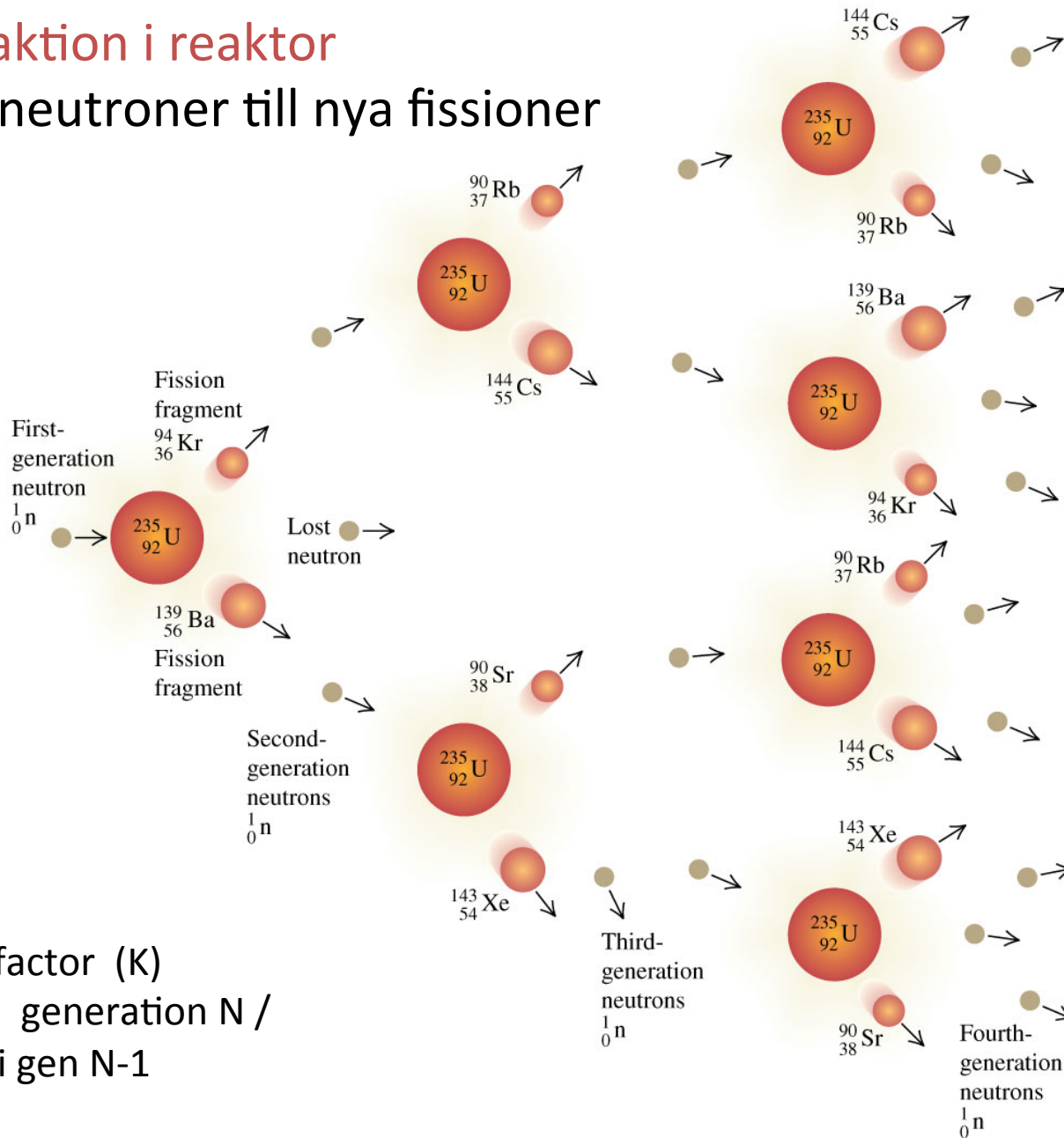
(e) The fragments emit neutrons at the time of fission (or occasionally a few seconds later).



$$Q = [m_n + m(^{235}\text{U}) - m(^{90}\text{Sr}) - m(^{143}\text{Xe}) - 3m_n]c^2$$

Kedjereaktion i reaktor

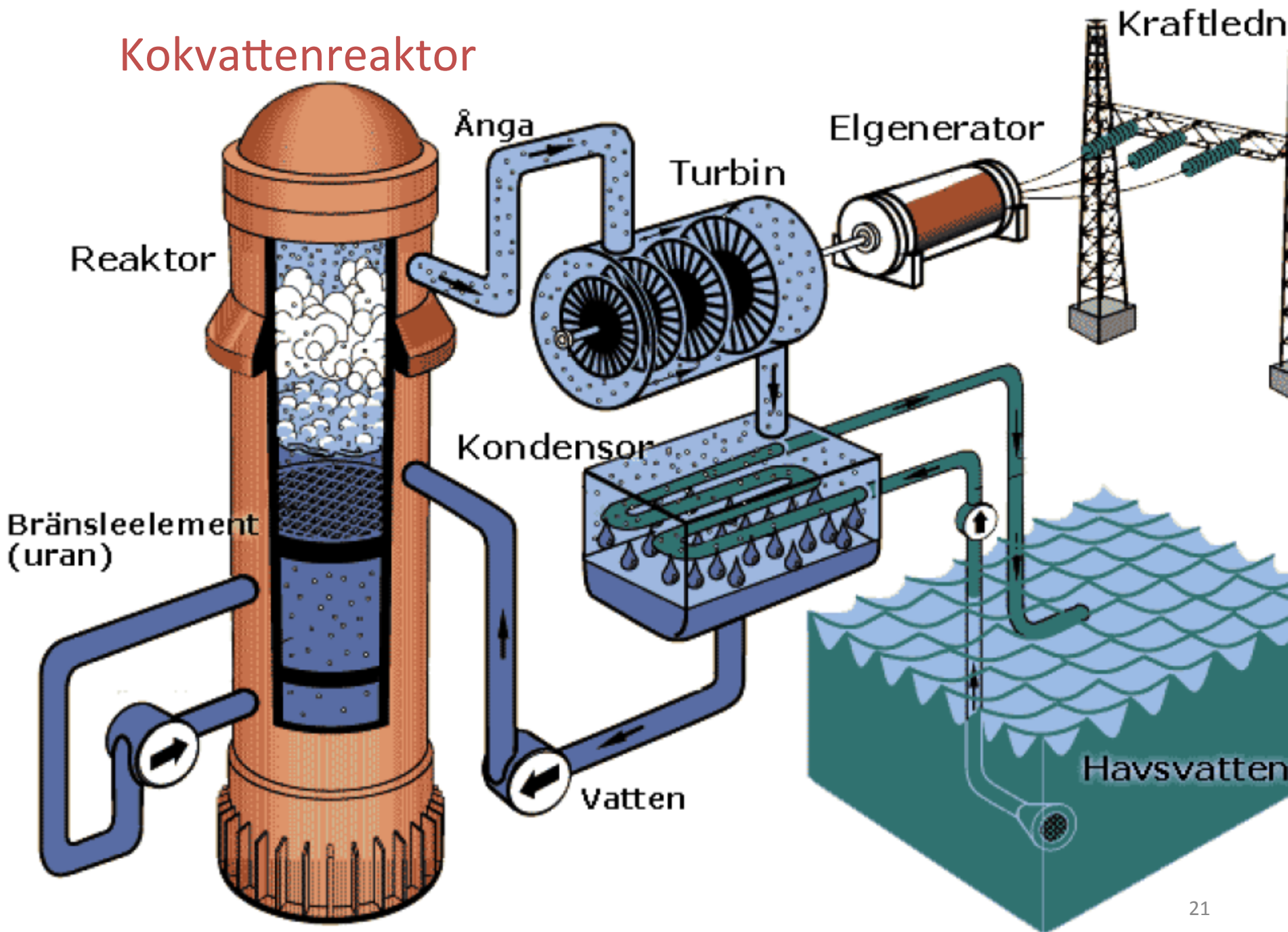
Använd neutroner till nya fissioner



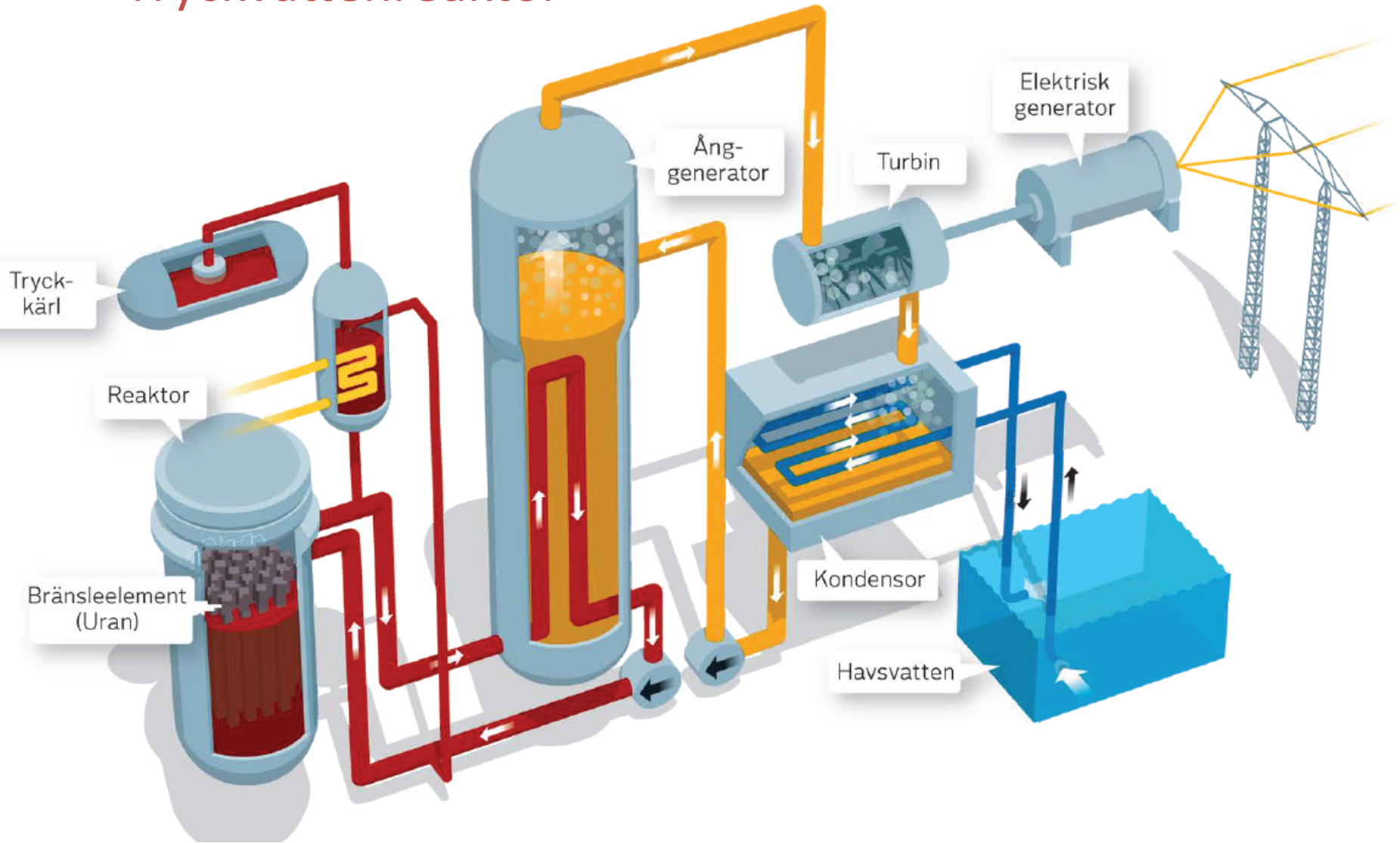
Multiplication factor (K)

$$K: \frac{\text{\#neutroner i generation N}}{\text{\# neutroner i gen N-1}}$$

Kokvattenreaktor



Tryckvattenreaktor



FAQ

KTH/SKC har allmän info ang. kärnkraft/bränsle etc

<https://www.kth.se/sci/centra/skc/omkarnkraft/>

Ska samla ytterligare länkar på

<http://www.hep.lu.se/staff/silvermyr/fysa01/>

Uran bryts mestadels i Australien och Kanada (även afrikanska länder och Ryssland), anrikas (centrifugering, tidigare diffusion) i bl.a.

Frankrike, Holland. Svenskt kärnbränsle, urankutsar, tillverkades i Västerås.

MOX fuel (med plutonium) används i bl.a. Frankrike. Bridreaktorer har varit testanläggningar i bl.a. Frankrike (drivs ej längre)

Andra möjligheter

- **Använd neutroner från accelerator typ ESS**
- Kan då använda ^{232}Th , som det finns gott om
- Mindre farligt kärnavfall.
- Utvecklingsstudier sedan 60-talet. Mer komplicerat än U cykeln

- **Transmutering**
- Använd kärnreaktioner för att utvinna energi ur existerande kärnavfall, och göra det mindre farligt.

- Inte så kostnadseffektivt som fission. På utvecklingsstadiet – behöver bättre accelerator teknologi

Neutroner från reaktorer används även för radioaktiva tracer-nuklider för medicinska ändamål

Det diagram som betyder mest för våra livsbetingelser...

Fusion av lätta kärnor

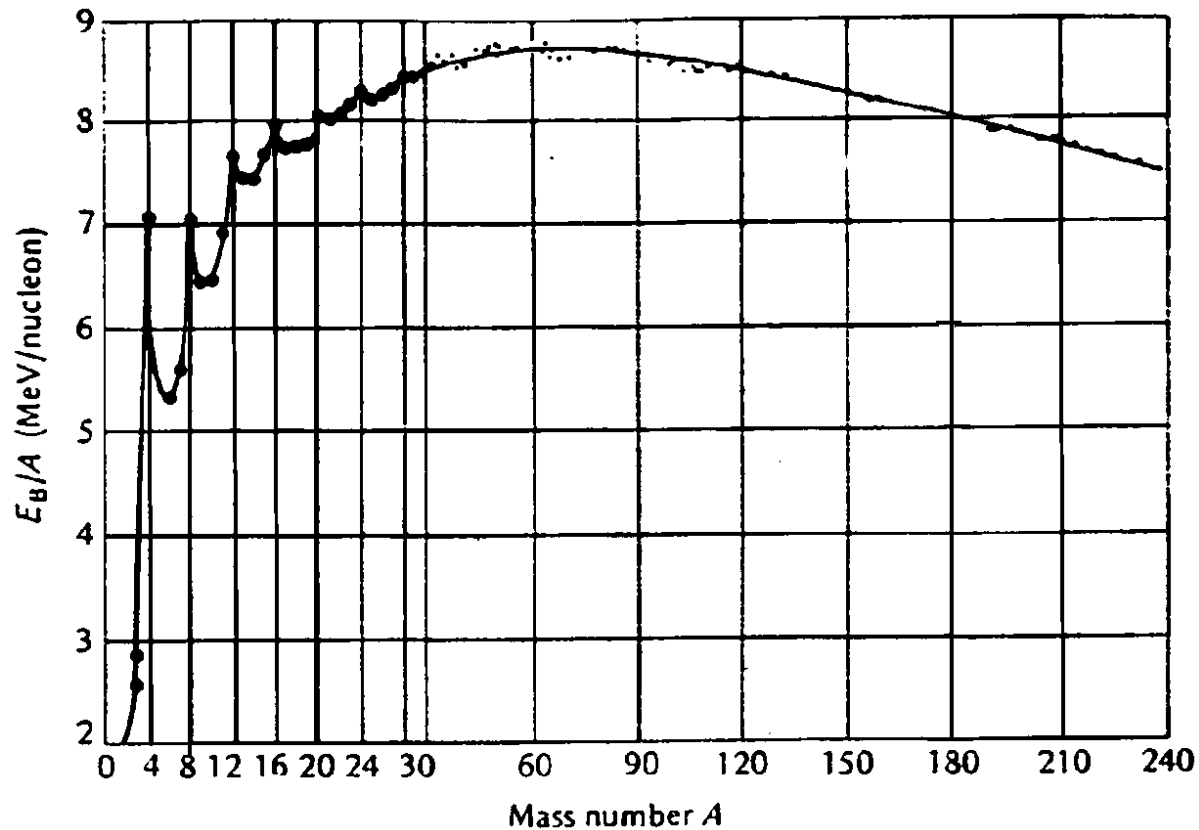
$Q > 0$

Exoterm reaktion

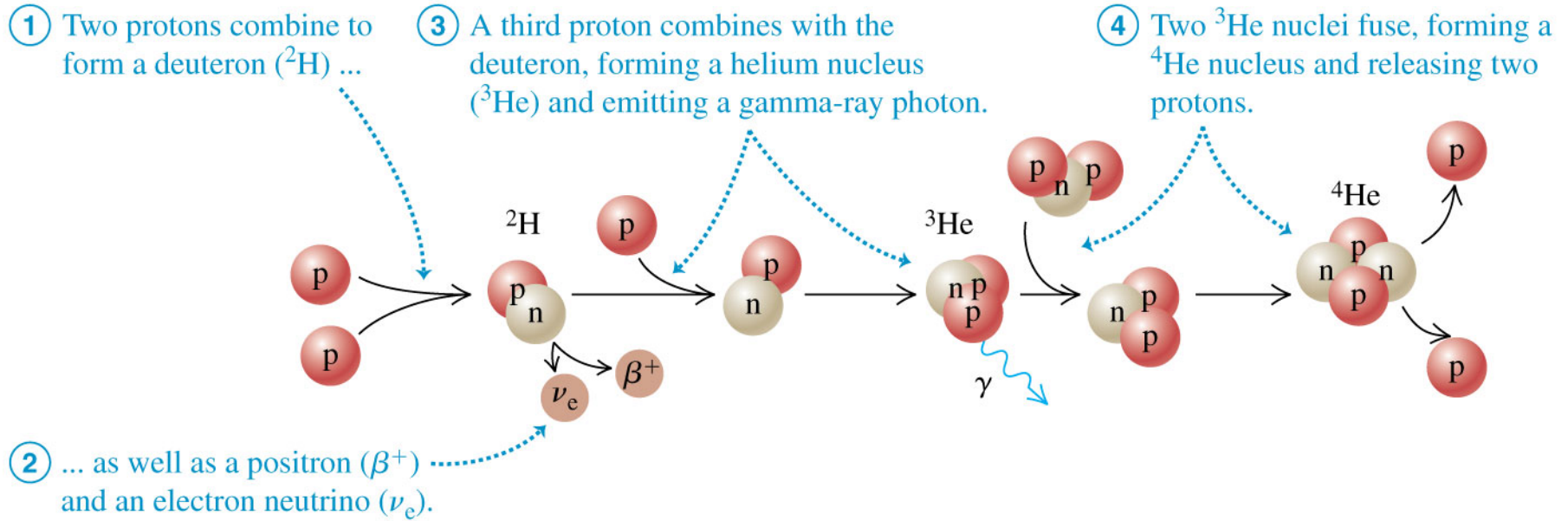
Fission av tunga kärnor

$Q > 0$

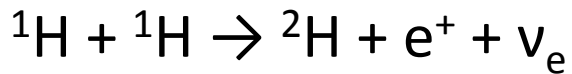
Exoterm reaktion



Fusion, pp cykeln i solen



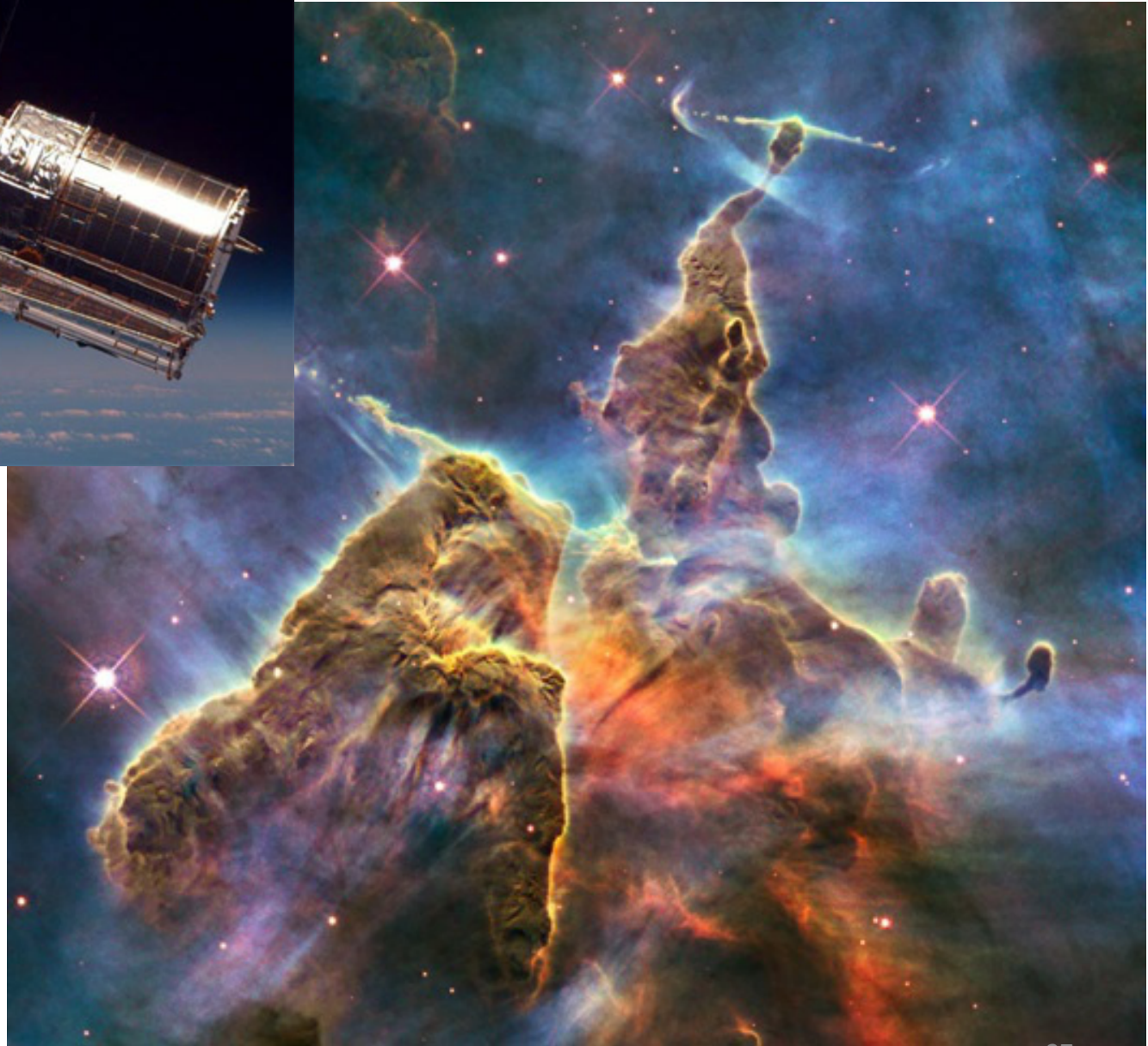
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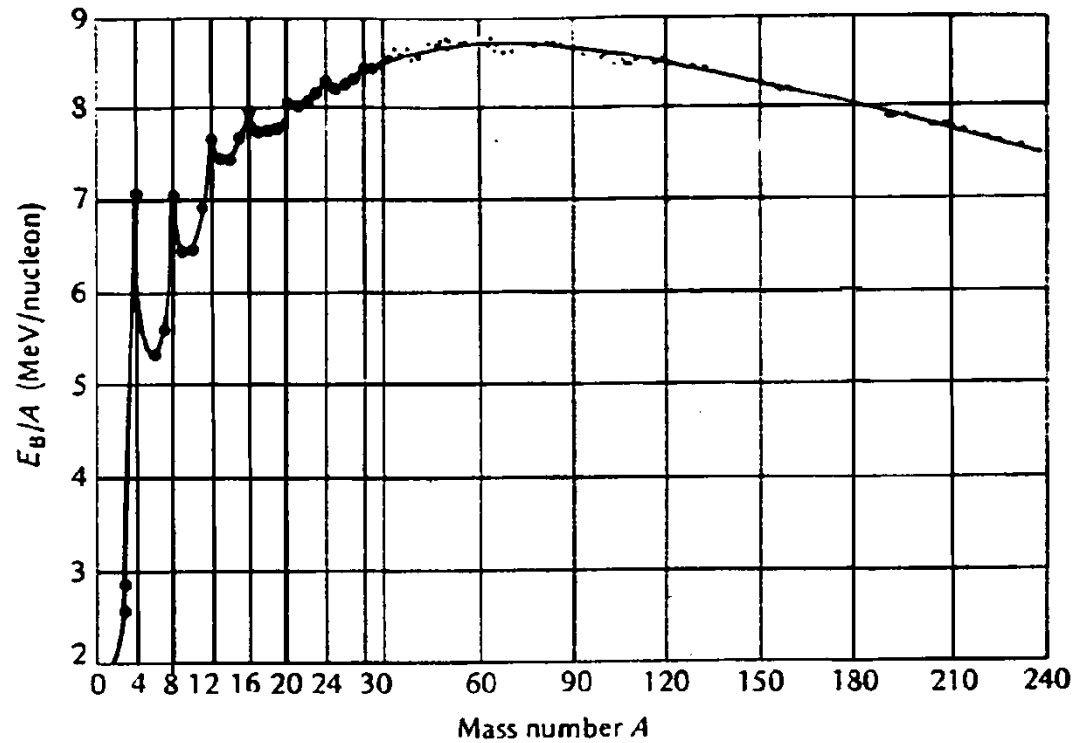
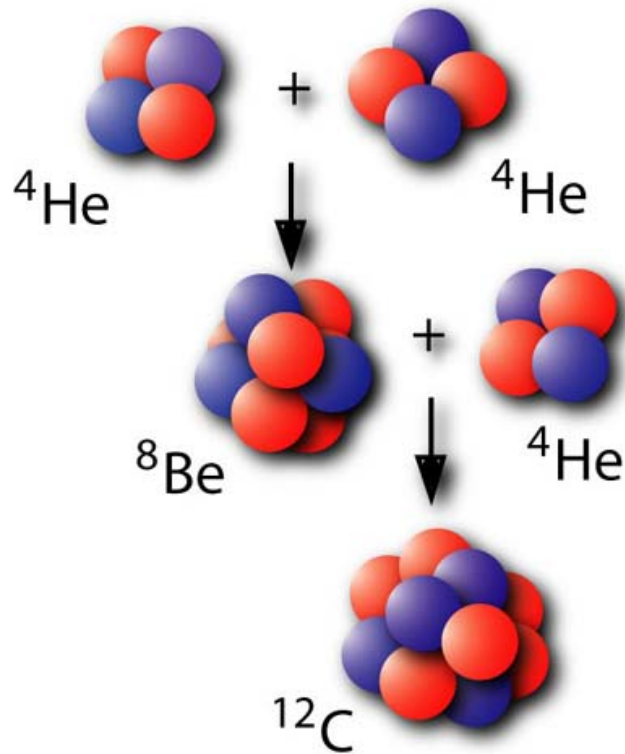
En stjärna föds...



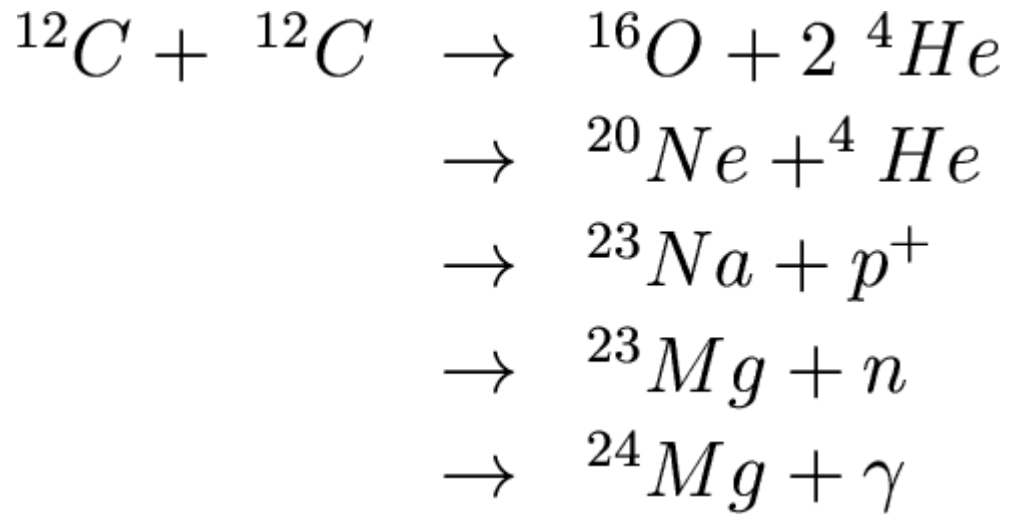
Hubble teleskopet



Trippel alfa processen

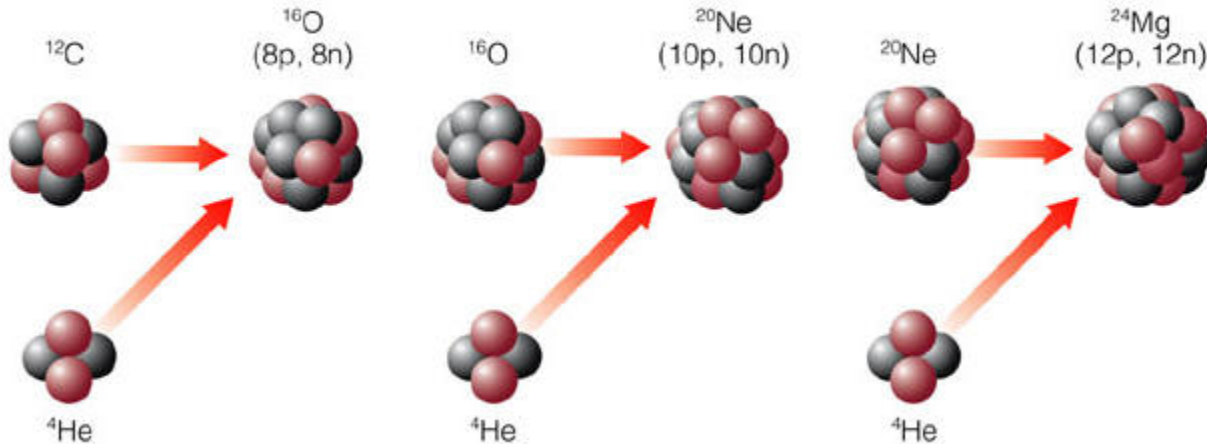


${}^8\text{Be}$ extremt kortlivad ($\sim 10^{-16}\text{s}$)

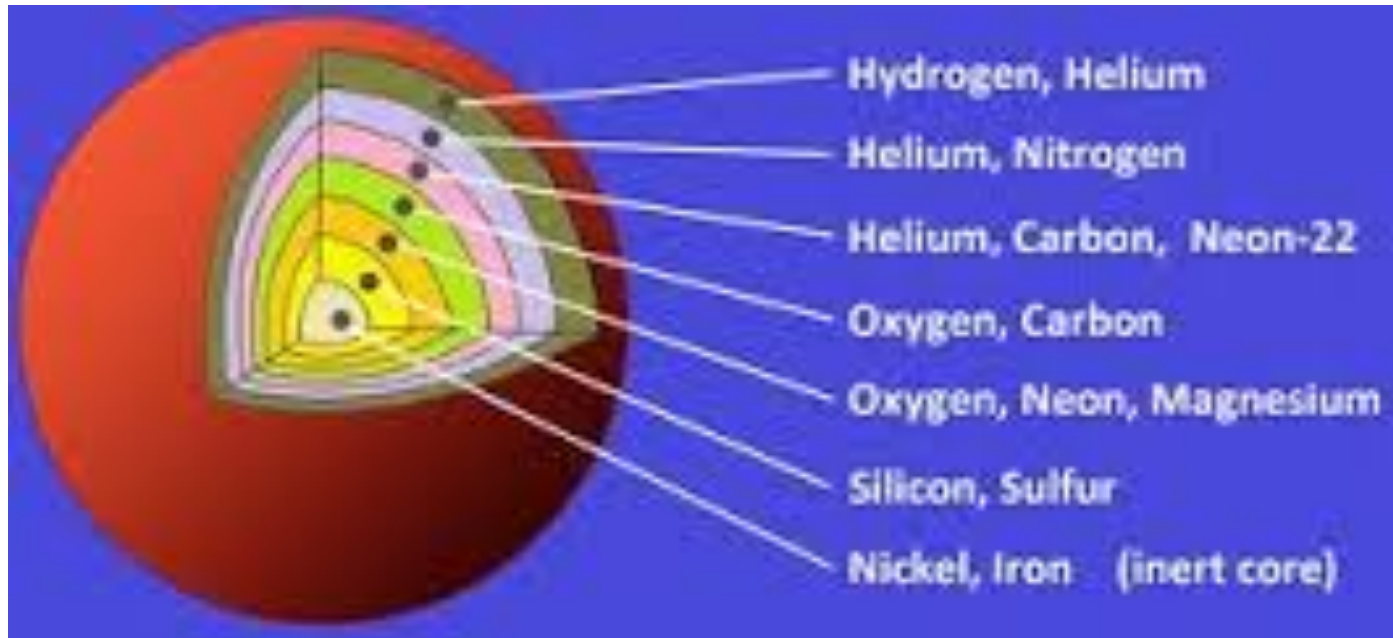


Kolförbränning,
Syreförbränning,...

Helium-capture reactions



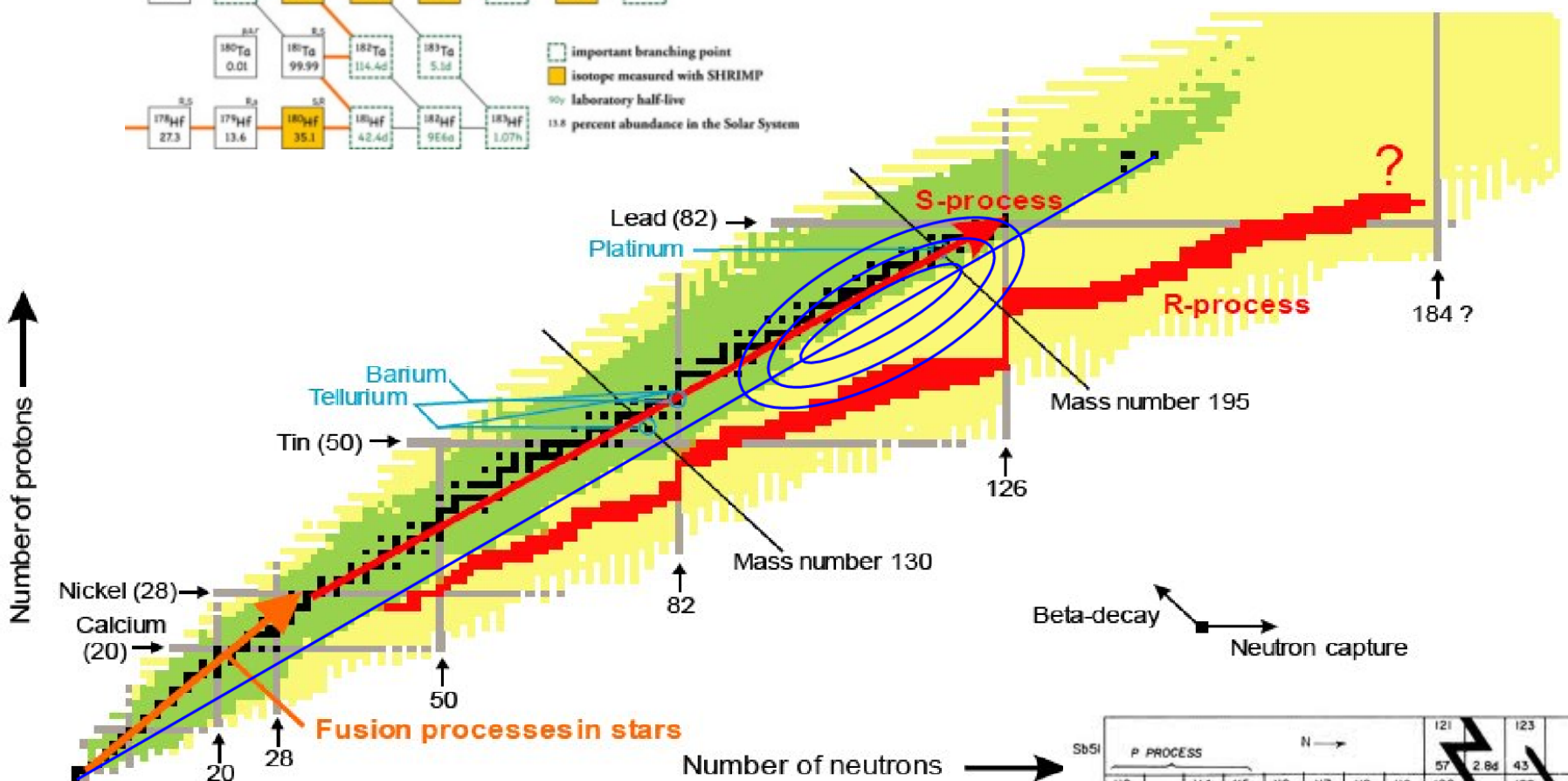
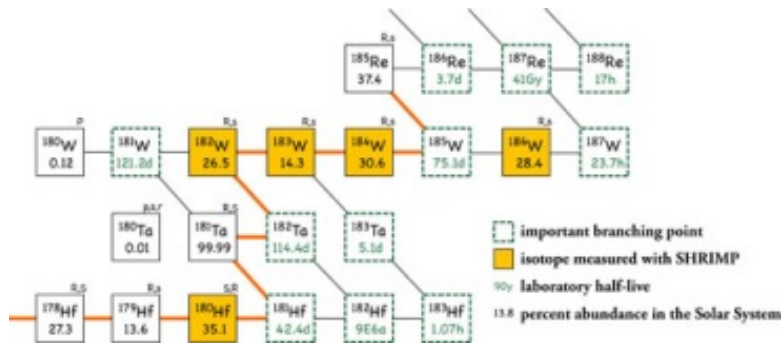
Fe i centrum



The Brightest Supernova Ever



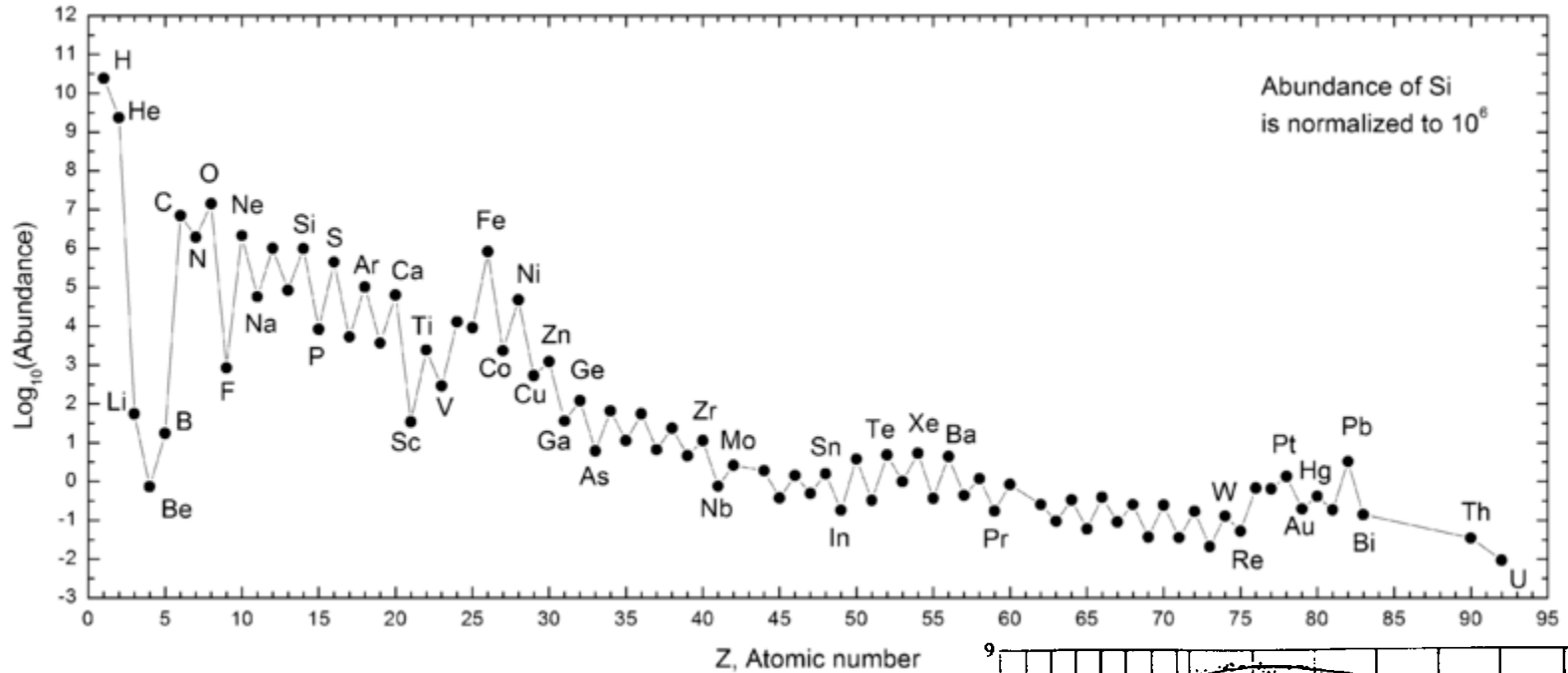
May 7, 2007: The brightest stellar explosion ever recorded may be a long-sought new type of supernova, according to observations by NASA's Chandra X-ray Observatory and ground-based optical telescopes. This discovery indicates that violent explosions of extremely massive stars were relatively common in the early universe, and that a similar explosion may be ready to go off in our own galaxy.



	P PROCESS								N →				
Sb51									121	123			
	112	114	115	116	117	118	119	120	57	2.8d	43		
Sn50	1.02%	112d	0.69%	0.38%	14.3%	7.6%	24.1%	8.5%	32.5%	27h	4.8	6.1	
Z ↓		113		115									
In49			4.2%	95.8									
				13s									
Cd48	12.4	12.8%	24.0%	12.3%	28.8%	54h	7.6%						

SLOW PROCESS PATH
 RAPID PROCESS

Grundämnenas förekomst i solsystemet



N.B:
Li/Be/B brist
Udda-jämn effect
Även ämnen tyngre än Fe

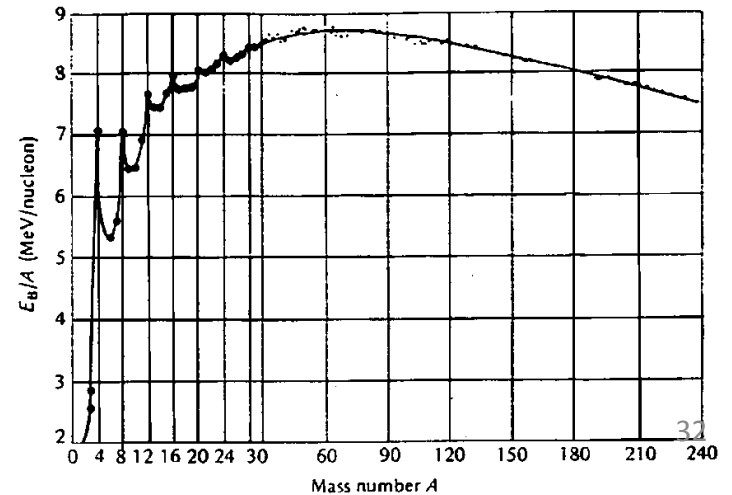
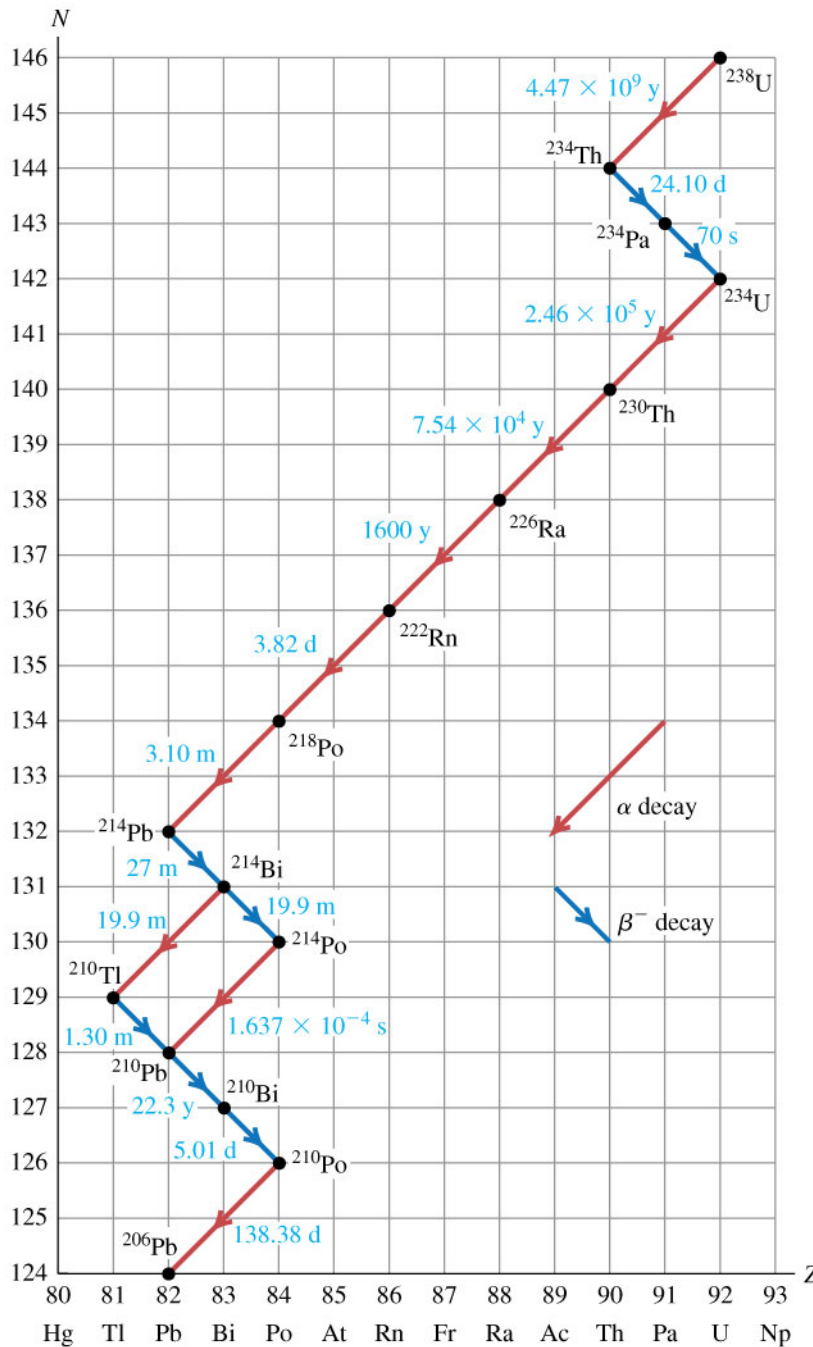


Figure 43.7

Uranium series



4 series in nature

Uranium
Actinium
Thorium
Neptunium

All end in Pb isotope