$$A=Z+N$$

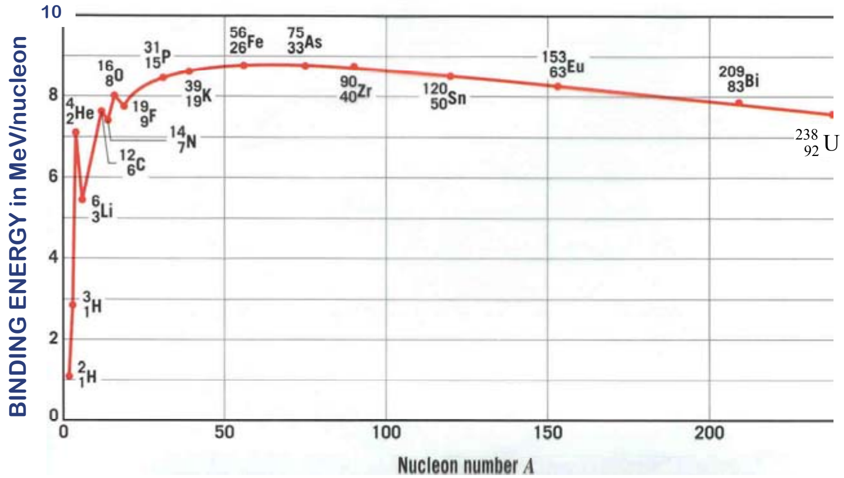
$$r = r_0 A^{1/3}$$

gdzie r_0=1.2 fm

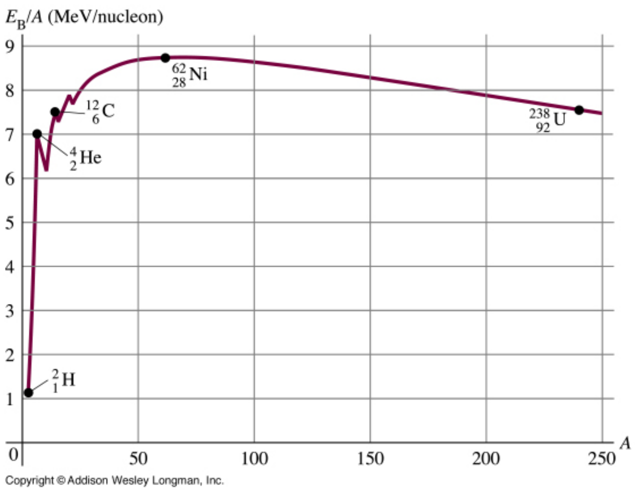
$$\Delta E_B = \sum\left(mc^2\right) - Mc^2$$

Energia wiązania

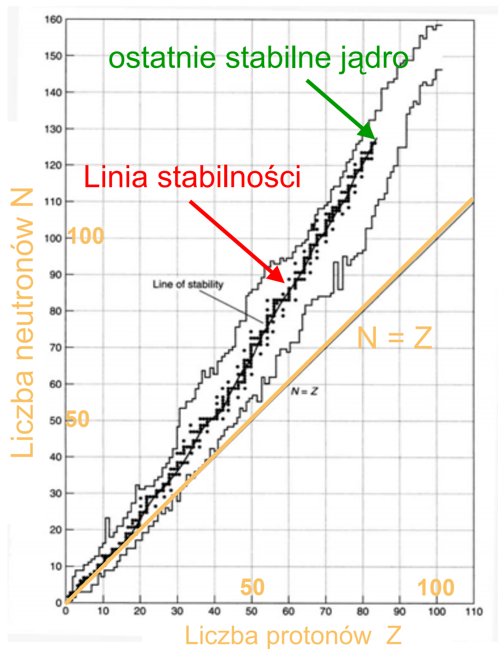
Żelazo (Fe) ma najwyższą wartość energii wiązania na jeden nukleon .



Nikiel (Ni) ma najwyższą wartość energii wiązania na jeden nukleon ok.. 8.8 MeV



- 3000 znanych izotopów ale jedynie 266 stabilnych!
  - jądra o Z > 83 nie są stabilne!
- Wyjątkowa stabilność dla „liczb magicznych"
  - Z, N = 2, 8, 20, 28, 50, 82, 126



$$\Delta N = -\lambda N \Delta t$$

$$\frac{dN}{dt} = -\lambda N$$

$$\int_{No}^{N} \frac{dN}{N} = -\lambda \int_{0}^{t} dt$$

$$\ln\left(\frac{N}{No}\right) = -\lambda t$$

$$\boxed{N = N_0 \; e^{-\lambda t}}$$

$$R = \left|\frac{dN}{dt}\right| = N_0 \lambda e^{-\lambda t} = R_0 e^{-\lambda t}$$

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

- λ = stała rozpadu
  $\tau = 1/\lambda$ = czas życia ,
- $t_{1/2}$ = czas połowicznego rozpadu

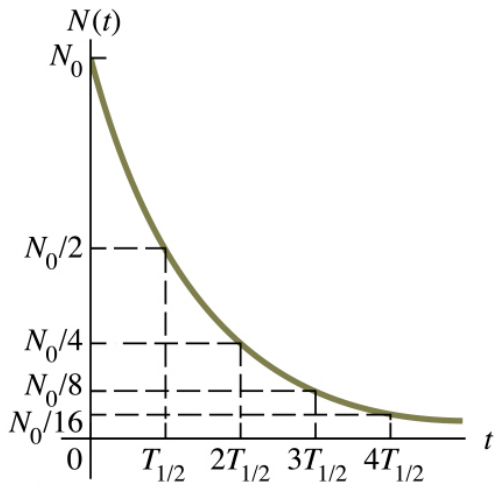


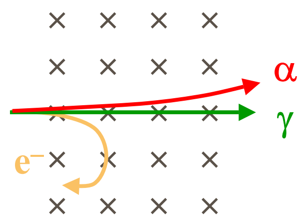
Table 3.7 Half-Lives of Some Radioisotopes

Element	Radioisotope	Half-Life	Type of Radiation
Naturally Occurring Radioisotopes			
Carbon	^{14}C	5730 yr	β
Potassium	^{40}K	1.3×10^9 yr	β, γ
Radium	^{226}Ra	1600 yr	α, γ
Uranium	^{238}U	4.5×10^9 yr	α, γ
Some Medical Radioisotopes			
Carbon	^{11}C	20 min	β^{+} [a]
Chromium	^{51}Cr	28 days	γ
Iodine	^{131}I	8 days	β, γ
Iodine	^{125}I	60 days	γ
Iron	^{59}Fe	46 days	β, γ
Phosphorus	^{32}P	14 days	β
Oxygen	^{15}O	2 min	β^{+} [a]
Potassium	^{42}K	12 hr	β, γ
Sodium	^{24}Na	15 hr	β, γ
Strontium	^{85}Sr	64 days	γ
Technetium	^{99m}Tc	6.0 hr	γ

[a] Note: β^{+} is a positron, which has the same mass as an electron but has a positive charge.

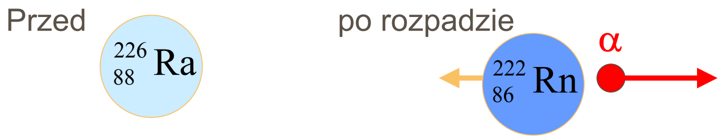
Rozpady: α, β, γ

Typ rozpadu	Ładunek/masa	Zasięg
alpha α = jądro He (2p + 2n)	$+2e/4m_p$	kartka papieru
beta β = electron lub pozyton	$-e/m_e$ lub $+e/m_e$	kilka mm w metalu
gamma γ = fotony	bez ładunku	kilka cm w ołowiu



B field

Rozpad: α



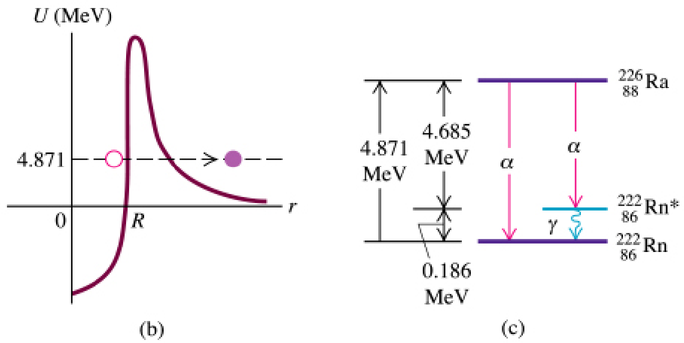
$$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}\alpha$$

$$^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}D \; + \; ^{4}_{2}He$$

$$Q = \left[M\left(^{A}_{Z}X\right) - M\left(^{A-4}_{Z-2}D\right) - M\left(^{4}_{2}He\right) \right] c^2$$

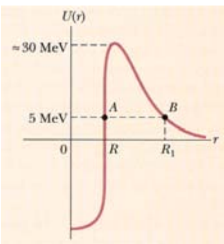
$Q = 4.87$ MeV

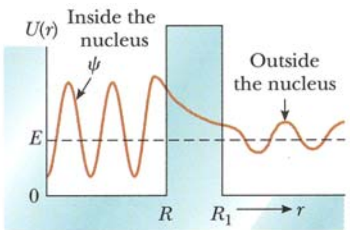
Rozpady: α



$$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}\alpha$$

Mechanizm rozpadów: α





Rozpady: β minus

$$^{A}_{Z}X \rightarrow ^{A}_{Z+1}D \; + e^{-} + \bar{\nu}$$

$$Q\ (MeV) = \left[Mass\left(^{A}_{Z}X\right) - Mass\left(^{A}_{Z+1}D\right) \right] c^2$$

$$\boxed{n \rightarrow p + e^{-} + \tilde{\nu}_e}$$

$$^{80}Br \rightarrow ^{80}Kr \; + \; e^{-} \; + \underline{\nu}_e$$

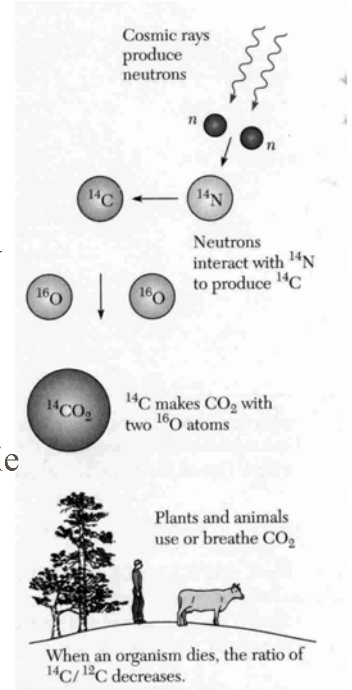
$Q(\beta^-) = M(^{80}Br)c^2 - M(^{80}Kr)c^2 =$ **2.00 MeV**

Datowanie

- β^- rozpad ^{14}C

$$\boxed{^{14}C \rightarrow {}^{14}N + e^- + \bar{\nu}_e}$$

- Promienie kosmiczne generują ^{14}C w górnych warstwach atmosfery . W gazowym CO_2 stosunek $^{14}C/^{12}C$ jest stały
  ^{14}C / ^{12}C $= 1.2\times10^{-12}$
  - W organizmach nieżywych ^{14}C nie jest dalej absorbowane i stosunek $^{14}C/^{12}C$ maleje z czasem.
  - Czas połowicznego zaniku ^{14}C $t_{1/2} = 5730$ lat.



Rozpady: β plus

$$\boxed{p \rightarrow n + e^+ + \nu_e}$$

$${}^A_Z X \rightarrow {}^{A}_{Z-1}D + e^+ + \nu$$
$$Q\,(MeV) = \left[Mass\left({}^A_Z X\right) - Mass\left({}^{A}_{Z-1}D\right) - 2m_e \right]c^2$$

$$^{80}Br \rightarrow {}^{80}Se + e^+ + \nu_e$$

$Q(\beta^+) = M(^{80}Br)c^2 - M(^{80}Se)c^2 - 2m_ec^2 =$ **0.85 MeV**

Wychwyt elektronu

$${}^7_4Be + {}^{0}_{-1}e \rightarrow {}^7_3Li$$

$${}^A_Z X + e^- \rightarrow {}^{A}_{Z-1}D + \nu$$
$$Q\,(MeV) = \left[Mass\left({}^A_Z X\right) - Mass\left({}^{A}_{Z-1}D\right) \right]c^2$$

$$\boxed{p + e^- \rightarrow n + \nu_e}$$

Wychwyt elektronu

$$\boxed{p + e^- \rightarrow n + \nu_e}$$

$$^{80}Br + e^- \rightarrow {}^{80}Se + \nu_e$$

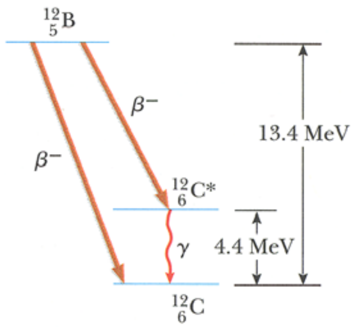
$Q(ec) = M(^{80}Br)c^2 - M(^{80}Se)c^2$

$= 79.918528\ uc^2 - 79.916519\ uc^2$

Q(ec) $= (0.002009\ uc^2)\ (931.5\ MeV/uc^2) =$ **1.87 MeV**

Emisja γ

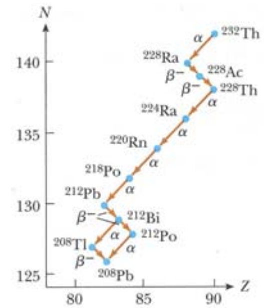
$$\boxed{X^* \rightarrow X + \gamma}$$



Promieniotwórczość naturalna

TABLE 45.4 The Four Radioactive Series

Series		Starting Isotope	Half-Life (years)	Stable End Product
Uranium	Natural	$^{238}_{92}U$	4.47×10^9	$^{206}_{82}Pb$
Actinium	Natural	$^{235}_{92}U$	7.04×10^8	$^{207}_{82}Pb$
Thorium	Natural	$^{232}_{90}Th$	1.41×10^{10}	$^{208}_{82}Pb$
Neptunium		$^{237}_{93}Np$	2.14×10^6	$^{209}_{83}Bi$



Rozpad uranu U-238

$$^{238}_{92}U \xrightarrow{\alpha} {}^{234}_{90}Th$$

$$^{234}_{90}Th \xrightarrow{\beta} {}^{234}_{91}Pa$$

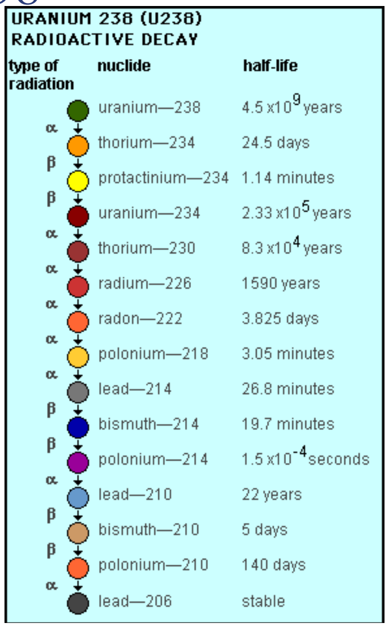
$$^{234}_{91}Pa \xrightarrow{\beta} {}^{234}_{92}U$$

$$^{234}_{92}U \xrightarrow{\alpha} {}^{230}_{90}Th$$

$$^{230}_{90}Th \xrightarrow{\alpha} {}^{226}_{88}Ra$$

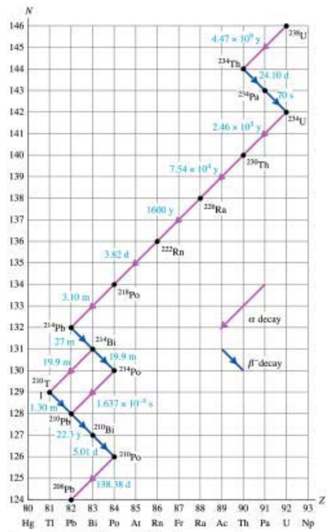
$$^{226}_{88}Ra \xrightarrow{\alpha} {}^{222}_{84}Rn$$

$$^{222}_{84}Rn \xrightarrow{\alpha} {}^{218}_{80}Po$$



URANIUM 238 (U238)
RADIOACTIVE DECAY

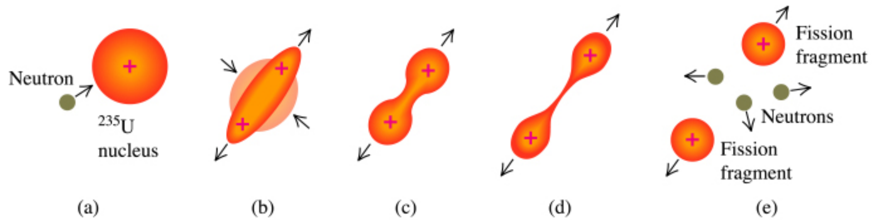
type of radiation	nuclide	half-life
	uranium—238	4.5 x10^9 years
α	thorium—234	24.5 days
β	protactinium—234	1.14 minutes
β	uranium—234	2.33 x10^5 years
α	thorium—230	8.3 x10^4 years
α	radium—226	1590 years
α	radon—222	3.825 days
α	polonium—218	3.05 minutes
α	lead—214	26.8 minutes
β	bismuth—214	19.7 minutes
β	polonium—214	1.5 x10^{-4} seconds
α	lead—210	22 years
β	bismuth—210	5 days
β	polonium—210	140 days
α	lead—206	stable



Izotopy uranu

Izotop	Ilość %	Czas połowicznego rozpadu (lata)
^{238}U	99.284	4.46 10^6
^{235}U	0.711	704 10^3
^{234}U	0.0055	245,000
^{239}Pu	93/57	24,110

Rozszczepieni jąder uranu



$$n+{}^{235}_{92}U \rightarrow {}^{142}_{56}Ba+{}^{91}_{36}Kr+3n+Q$$

$$n+{}^{235}_{92}U \rightarrow {}^{140}_{54}Xe+{}^{94}_{38}Sr+2n+Q$$

$$\boxed{Q \approx 200 MeV}$$

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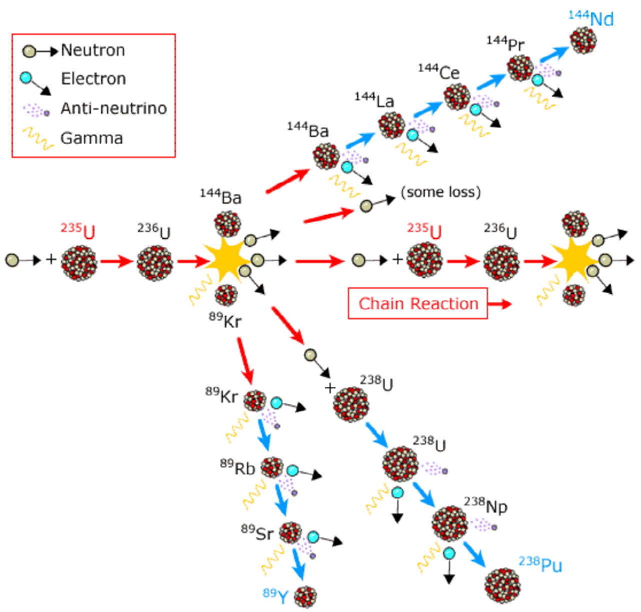
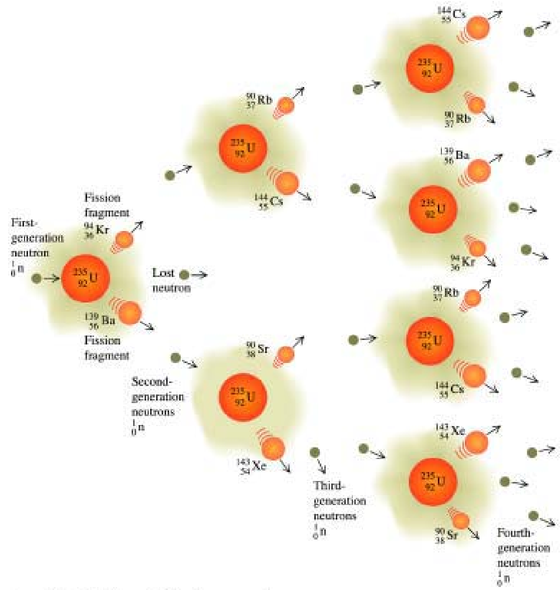
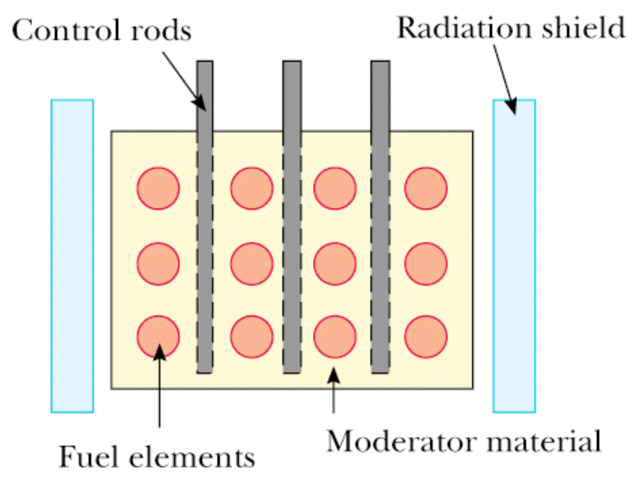
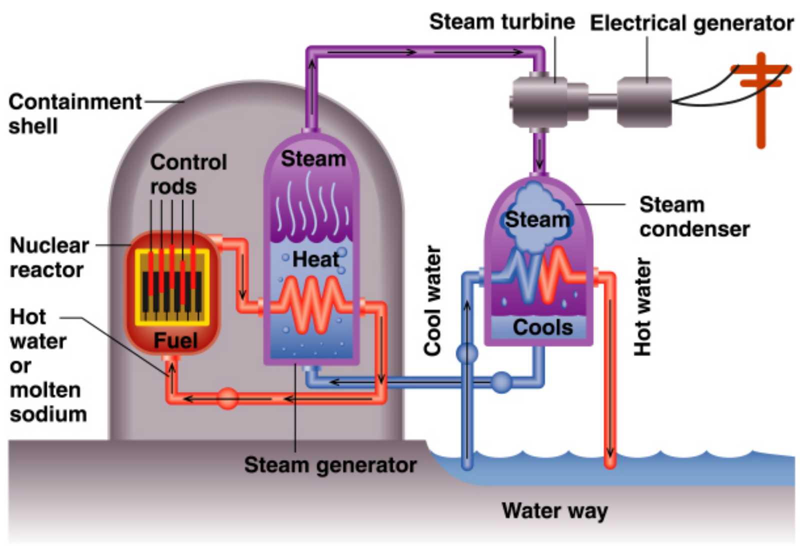




W wyniku rozszczepienia 1 kg Uranu można otrzymać 22 miliony kWh energii

Reaktor jądrowy





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