Jedrske reakcije

1. Kadar pri obsevanju zraka z žarki α (^4_2He) vpadni delec α zadene ob jedro dušikovega izotopa ($^{14}_7N$), ki ga je v zraku največ, steče naslednja reakcija: $^{14}_7N + ^4_2He \rightarrow ^{17}_8O + p$. Atomska masa dušika je 14,003074 u, masa helija 4,002603 u, masa kisika 16,999133 u, masa vodika 1,007825 u, masa protona 1,007276 u in masa nevtrona 1,008665 u.

   a) Koliko energije (MeV) je potrebno za vsako reakcijo? (1,19 MeV)
   b) Kolikšna je vezavna energija dušikovega jedra $^{14}_7N$? (104,66 MeV)

2. Radioaktivni polonij seva delce α z razpolovnim časom 138 dni: $^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + \alpha$. Atomska masa $^{210}_{84}$Po je 209,982876 u, $^{206}_{82}$Pb 205,974455 u, $^1_1$H 1,007825 u, masa delca α je 4,002603 u in masa nevtrona 1,008665 u.

   a) Kolikšna je vezavna energija $^{210}_{84}$Po? (1645 MeV)
   b) Koliko MeV energije se sprosti pri razpadu jedra polonija $^{210}_{84}$Po? (5,42 MeV)
   c) Koliko reakcij steče, če se porabi 1 g $^{210}_{84}$Po? ($2{,}87 \cdot 10^{21}$)

3. Kadar pri obsevanju aluminijeve plošče z delci α (^4_2He) vpadni delec zadene ob jedro aluminijevega izotopa $^{27}_{13}Al$, steče naslednja reakcija: $^{27}_{13}Al + ^4_2He \rightarrow ^{30}_{15}P + n$. Masa atoma $^{27}_{13}Al$ je 26,981539 u, masa ^4_2He je 4,002603 u, masa $^{30}_{15}P$ je 29,978317 u in masa nevtrona je 1,008665 u.

   a) Koliko energije se porabi pri jedrski reakciji? (2,645 MeV)
   b) Koliko reakcij mora steči, da dobimo 1 mg fosforja $^{30}_{15}P$? ($2 \cdot 10^{19}$)

4. Pri obstreljevanju jedra ^{7}Li s protoni energije 1,7 MeV nastaneta dva delca α, ki imata vsak po 9,5 MeV kinetične energije. Kolikšna je masa jedra ^{7}Li? Masa protona je 1,00727647 u in delca α 4,00150618 u. (7,014 u)

5. Jedri tritija in devterija se spojita v helijevo jedro. (2,0141018; 3,0160493; 4,002603; 1,008665)

   a) Zapiši reakcijo!
   b) Kolikšna energija se sprosti?
   c) Koliko energije bi se sprostilo v 1 g vode, če bi vsako jedro devterija reagiralo s tritijem? Naravna koncentracija devterija je $k = 1{,}5 \cdot 10^{-4}$.

   a) $^2\text{D} + ^3\text{T} \rightarrow ^4\text{He} + \text{n}$
   b) $W = \Delta mc^2 = (m_D + m_T - m_{He} - m_n)c^2 = 0{,}018874\ \text{uc}^2 =$ **17,6 MeV**
   c) $W = N_{devterij}\, W_1 = 2N_{molekul}\, k\, W_1 = 2\, mN_A / M \cdot k\, \Delta mc^2 =$ **28 MJ**

6. Koliko energije nastane na gram urana pri reakciji $n + ^{235}_{92}U \rightarrow ^{95}X + ^{139}Y + 2n$? Masa urana je 235,124 u, nevtrona 1,0086 u, masi atomov X in Y pa 94,945 u in 138,955u.

   $W = \Delta mc^2 = (m_U + m_n - m_X - m_Y - 2m_n)c^2 = 0{,}215\ \text{uc}^2 =$ **200 MeV**

7. Koliko jeder urana $^{235}_{92}U$ se mora razcepiti v eni sekundi, da se v uranu sprošča toplotna moč P=100 MW? Pri vsaki cepitvi se sprosti 200 MeV energije. ($3{,}1 \cdot 10^{18}\ \text{s}^{-1}$)

(1.)

$\alpha - {}^{4}_{2}He$

ATOMSKE MASE

$m_{He} = 4{,}002603\ u$

$m_N = 14{,}003074\ u$

$m_O = 16{,}999133\ u$

$m_H = 1{,}007825\ u$

$m_p = 1{,}007276\ u$

$m_n = 1{,}008665\ u$

$Q = ?$

$${}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + p \;(\text{proton} \rightarrow {}^{1}_{1}H)$$

(m_L — levo, m_D — desno)

$$\Delta m = m_{ZAČ.} - m_{KON.}$$

$$\Delta m = (m_{He} + m_N) - (m_O + m_H)$$

$$\Delta m = (4{,}002603u + 14{,}003074u) - (16{,}999133u + 1{,}007825\ u)$$

$$\boxed{\Delta m = -0{,}001281\ u}$$

↓ nakazuje na to, da

je $\boxed{m_D > m_L}$! energija se je porabila → vnos!

$$Q = \Delta m c^2 \quad J \rightarrow [kg] \left[\frac{m^2}{s^2}\right]$$

$$Q = 0{,}0012891 \cdot u \cdot (300 \cdot 10^6)^2$$

a)

$$Q = 1{,}9117 \cdot 10^{-13}\ J \rightarrow eV: = \boxed{1{,}193244\ MeV}$$

b) ${}^{14}_{7}N$ $A = 14$, $Z = 7$ $\Rightarrow N = A - Z = 7$

$W_{VN} = ?$

$$W_V = \Delta m c^2 \qquad \Delta m = Z \cdot m_H + N \cdot m_n - m_N$$

$$\Delta m = 7 \cdot 1{,}007825u + 7 \cdot 1{,}008665u - 14{,}003074u$$

$$\boxed{\Delta m = 0{,}112356\ u}$$

$$W_{VN} = 0{,}112356 \cdot u \cdot (300 \cdot 10^6)^2$$

$$W_{VN} = 1{,}676822 \cdot 10^{-11}\ J \rightarrow eV: = \boxed{104{,}6589\ MeV}$$

(2.)

$\alpha = {}^{4}_{2}He$

$t_0 = 138$ dni $\qquad {}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + \alpha$

ATOMSKE MASE

$m_{Po} = 209{,}982876\,u$

$m_{Pb} = 205{,}974455\,u$

$m_H = 1{,}0078250\,u$

$m_\alpha = 4{,}002603\,u$

$m_n = 1{,}008665\,u$

$\Delta m_{Po} = Z \cdot m_H + N \cdot m_n - m_{Po}$

$\Delta m_{Po} = 84 \cdot 1{,}0078250\,u + 126 \cdot 1{,}008665\,u - 209{,}982876\,u$

$\boxed{\Delta m_{Po} = 1{,}7662136\,u}$

a) $W_{vPo} = ?$

$W_{vPo} = \Delta m_{Po} \cdot c^2$

$W_{vPo} = 1{,}7662136 \cdot u \cdot (300 \cdot 10^6)^2$

$W_{vPo} = 2{,}63593 \cdot 10^{-10}\,J \rightarrow eV: = \boxed{1645{,}2179\,MeV}$

b) ${}^{210}_{84}Po$

$Q = ?$

${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + \alpha$

$\rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$

$\Delta m = m_{Po} - (m_{Pb} + m_{He})$

$\Delta m = 209{,}982876\,u - (205{,}974455\,u + 4{,}002603\,u)$

$\boxed{\Delta m = 0{,}005818\,u}$

$Q = \Delta m \cdot c^2 = 8{,}68289 \cdot 10^{-13}\,J \rightarrow eV: = \boxed{5{,}419433\,MeV}$

c) ${}^{210}_{84}Po$

$N_{reakcij} = ?$

$N = \frac{m}{A} \cdot N_A = \frac{1\,g}{210\,\frac{g}{mol}} \cdot 6{,}02 \cdot 10^{23}\,\frac{atomov}{mol} = \boxed{2{,}86768 \cdot 10^{21}\ atomov}$

$= reakcij$

(3.) $^{27}_{13}Al$ $\quad {}^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + n$

$m_{Al} = 26,981539\ u$

$m_{He} = 4,002603\ u$

$m_p = 29,978317\ u$

$m_n = 1,008665\ u$

$\Delta m = (m_{Al} + m_{He}) - (m_p + m_n)$

$\Delta m = 26,981539u + 4,002603u - (29,978317u + 1,008665u)$

$\Delta m = \ominus 0,00284\ u$

↓ povečala se energija

a) $Q = ?$

$Q = \Delta m \cdot c^2 = 4,23847 \cdot 10^{-13}\ J$

$\rightarrow eV = \boxed{2,645443\ MeV}$

b) $m = 1\ mg = 1 \cdot 10^{-6}\ kg = 1 \cdot 10^{-3}\ g$

$^{30}_{15}P$

$N = ?$

$N = \frac{m}{A} \cdot N_A = \frac{1 \cdot 10^{-3}\ g}{30\ \frac{g}{mol}} \cdot 6,02 \cdot 10^{23}\ \frac{atomov}{mol}$

$\boxed{N = 2,00723789 \cdot 10^{19}\ atomov}$ = št. neutronov

11.

$p = {}^1_1H$

^7Li $\qquad {}^7_3Li + p \rightarrow \alpha + \alpha$

$W_p = 1,7\ MeV$

$W_\alpha = 9,5\ MeV$ $\qquad \Delta m = m_{ZAČ} - m_{KON} = W_{KON} - W_{ZAČ}$

$m_{^7Li} = ?$ $\qquad {}^7_3Li + {}^1_1H \rightarrow 2\,{}^4_2He$

$m_p = 1,007276647\ u$

$m_\alpha = 4,001506184\ u$

$\Delta m = 2W_\alpha - W_p$

$W = \Delta m c^2$ $\qquad \Delta m = 2 \cdot 9,5\ MeV - 1,7\ MeV$

$\Delta m = 17,3\ MeV \quad / \cdot 1eV = 1,6 \cdot 10^{-19}\ J$

$\Rightarrow 2,77 \cdot 10^{-12}\ J \quad / : c^2 \ / : u$

$\Rightarrow \boxed{0,0185723\ u}$

$\Delta m = (m_p + m_{^7Li}) - 2m_\alpha$

$m_{^7Li} = \Delta m + 2m_\alpha - m_p$

$m_{^7Li} = 0,0185723u + 2 \cdot 4,001506184u - 1,007276647u$

$\boxed{m_{^7Li} = 7,014308819\ u}$

5.)

Tritij $T = {}^3_1H$ $\quad {}^3T + {}^2D \rightarrow {}^4He + n$

Deuterij $D = {}^2_1H$

$m_T = 2,0141018\,u$ $\quad W_v = \Delta m c^2$

$m_D = 3,01604934\,u$

$m_{He} = 4,002603\,u$ $\quad \Delta m = (m_T + m_D) - (m_{He} + m_n)$

$m_n = 1,0086654\,u$ $\quad$ a)

$\boxed{\Delta m = 0,0188831\,u}$

b) $W_v = \Delta m c^2 = 2,8181498 \cdot 10^{-12}\ J$

$= \boxed{17,5895\ MeV}$

c) $\boxed{D = {}^2_1H}$

$m = 1g$ $\quad N = \frac{m}{A} \cdot N_A = \frac{1g}{2\ \frac{g}{mol}} \cdot 6,02 \cdot 10^{23}\ \frac{atoma}{mol} = \boxed{3,011068 \cdot 10^{23}\ atoma}$

$W_1 = \Delta m \cdot c^2 = 1,49 \cdot 10^{-10}\ J = 931,083\ MeV$

$\Delta m = Z m_p + N m_n - m_j$

$\Delta m = Z m_H + N m_n - m_A = -0,9995593\,u$

?

6.

$$n + {}^{235}_{92}U \rightarrow {}^{95}X + {}^{139}Y + 2n$$

$m_U = 235,124\ u$

$m_n = 1,0086\ u$

$m_x = 94,945\ u$

$m_y = 138,955\ u$

$$\Delta m = (m_n + m_U) - (m_x + m_y + 2 \cdot m_n)$$

$$\boxed{\Delta m = 0,2154\ u}$$

$$W_1 = \Delta m c^2 = \boxed{3,21467 \cdot 10^{-11}\ J}$$

$$\boxed{= 200,644\ MeV}$$

$\frac{W_1}{g} = ?$

$m = 1\ g$

$$N = \frac{m}{A} N_A = \frac{1\ g}{235 \frac{g}{mol}} \cdot 6,02 \cdot 10^{23} \frac{atom}{mol} = \boxed{2,5626 \cdot 10^{21}\ atoma}$$

$$\frac{W_1}{1g} = W_1 \cdot N_{1g} = \boxed{82,38\ GJ}$$

(7.)

$^{235}_{92}U$

$P = 100\ MW$ (toplotna)

$W_1 = 200\ MeV$

$\frac{N}{t} = ?$

$P = \frac{W}{t} = \frac{N \cdot W_1}{t}$

$\frac{N \cdot W_1}{t} = P$

$\Rightarrow \frac{N}{t} = \frac{P}{W_1} = \frac{100 \cdot 10^6\ W}{200 \cdot 10^6\ eV} = \frac{6,2415 \cdot 10^{23}\ eV}{200 \cdot 10^6\ eV}$

$\boxed{\frac{N}{t} = 3,12 \cdot 10^{17}} \Rightarrow \boxed{N = 3,12 \cdot 10^{17}\ s^{-1}}$