

## Jedrske reakcije

1. Kadar pri obsevanju zraka z žarki  $\alpha$  ( ${}^4_2\text{He}$ ) vpadni delec  $\alpha$  zadene ob jedro dušikovega izotopa ( ${}^{14}_7\text{N}$ ), ki ga je v zraku največ, steče naslednja reakcija:  ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{17}_8\text{O} + p$ . 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  ${}^{14}_7\text{N}$ ? (104,66 MeV)

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

a) Kolikšna je vezavna energija  ${}^{210}_{84}\text{Po}$ ? (1645 MeV)

b) Koliko MeV energije se sprosti pri razpadu jedra polonija  ${}^{210}_{84}\text{Po}$ ? (5,42 MeV)

c) Koliko reakcij steče, če se porabi 1 g  ${}^{210}_{84}\text{Po}$ ? ( $2,87 \cdot 10^{21}$ )

3. Kadar pri obsevanju aluminijeve plošče z delci  $\alpha$  ( ${}^4_2\text{He}$ ) vpadni delec zadene ob jedro aluminijevega izotopa  ${}^{27}_{13}\text{Al}$ , steče naslednja reakcija:  ${}^{27}_{13}\text{Al} + {}^4_2\text{He} \rightarrow {}^{30}_{15}\text{P} + n$ . Masa atoma  ${}^{27}_{13}\text{Al}$  je 26,981539 u, masa  ${}^4_2\text{He}$  je 4,002603 u, masa  ${}^{30}_{15}\text{P}$  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  ${}^{30}_{15}\text{P}$ ? ( $2 \cdot 10^{19}$ )

4. Pri obstreljevanju jedra  ${}^7\text{Li}$  s protoni energije 1,7 MeV nastaneta dva delca  $\alpha$ , ki imata vsak po 9,5 MeV kinetične energije. Kolikšna je masa jedra  ${}^7\text{Li}$ ? Masa protona je 1,00727647 u in delca  $\alpha$  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 sprostil v 1 g vode, če bi vsako jedro devterija reagiralo s tritijem? Naravna koncentracija devterija je  $k=1,5 \cdot 10^{-4}$ .

a)  ${}^2\text{D} + {}^3\text{T} \rightarrow {}^4\text{He} + n$

b)  $W = \Delta mc^2 = (m_{\text{D}} + m_{\text{T}} - m_{\text{He}} - m_n)c^2 = 0,018874 \text{ uc}^2 = 17,6 \text{ MeV}$

c)  $W = N_{\text{devterij}} W_1 = 2N_{\text{molekul}} k W_1 = 2 mN_A / M \cdot k \Delta mc^2 = 28 \text{ MJ}$

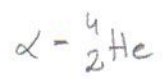
6. Koliko energije nastane na gram urana pri reakciji  $n + {}^{235}_{92}\text{U} \rightarrow {}^{95}\text{X} + {}^{139}\text{Y} + 2n$ ? Masa urana je 235,124 u, nevtrona 1,0086 u, masi atomov X in Y pa 94,945 u in 138,955 u.

$W = \Delta mc^2 = (m_{\text{U}} + m_n - m_{\text{X}} - m_{\text{Y}} - 2m_n)c^2 = 0,215 \text{ uc}^2 = 200 \text{ MeV}$

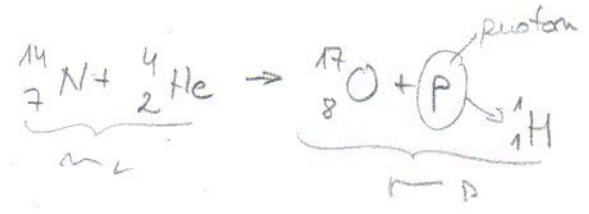
7. Koliko jeder urana  ${}^{235}_{92}\text{U}$  se mora razcepiti v eni sekundi, da se v uranu sprošča toplotna moč  $P=100 \text{ MW}$ ? Pri vsaki cepitvi se sprosti 200 MeV energije. ( $3,1 \cdot 10^{18} \text{ s}^{-1}$ )



1.



- ATOMSKA MASE
- $m_{\text{He}} = 4,002603 \text{ u}$
- $m_{\text{N}} = 14,003074 \text{ u}$
- $m_{\text{O}} = 16,999133 \text{ u}$
- $m_{\text{H}} = 1,007825 \text{ u}$
- $m_{\text{p}} = 1,007276 \text{ u}$
- $m_{\text{n}} = 1,008665 \text{ u}$



$\Delta m = m_{\text{ZAC.}} - m_{\text{KON.}}$

$\Delta m = (m_{\text{He}} + m_{\text{N}}) - (m_{\text{O}} + m_{\text{H}})$

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

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

malozuje na to, da

je  $m_{\text{O}} > m_{\text{L}}$ ! energija se je  
 posvubila  $\rightarrow$  vmes!

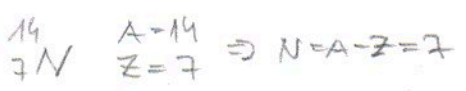
Q = ?

$Q = \Delta m c^2$

$Q = 0,001281 \cdot \text{u} \cdot (300 \cdot 10^6)^2$

$Q = 1,19117 \cdot 10^{-13} \text{ J} \rightarrow \text{eV: } = 1,193244 \text{ MeV}$

b)



$W_{\text{in}} = ?$

$W_{\text{in}} = \Delta m c^2$

$\Delta m = Z \cdot m_{\text{H}} + N \cdot m_{\text{n}} - m_{\text{N}}$

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

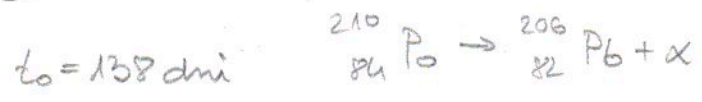
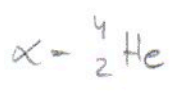
$\Delta m = 0,112356 \text{ u}$

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

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



2.)



ATOMSKO MASE

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

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

$$m_{\text{H}} = 1,007825 \text{ u}$$

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

$$m_{\text{M}} = 1,008665 \text{ u}$$

$$\Delta m_{\text{Po}} = Z \cdot m_{\text{H}} + N \cdot m_{\text{M}} - m_{\text{Po}}$$

$$\Delta m_{\text{Po}} = 84 \cdot 1,007825 \text{ u} + 126 \cdot 1,008665 \text{ u} - 209,982876 \text{ u}$$

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

a)  $W_{\text{Po}} = ?$

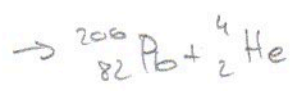
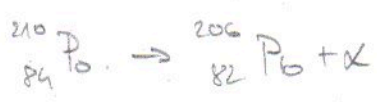
$$W_{\text{Po}} = \Delta m_{\text{Po}} \cdot c^2$$

$$W_{\text{Po}} = 1,7662136 \text{ u} \cdot (300 \cdot 10^8)^2$$

$$W_{\text{Po}} = 2,63593 \cdot 10^{-10} \text{ J} \rightarrow \text{eV} = 1649,2179 \text{ MeV}$$

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

Q = ?



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

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

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

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

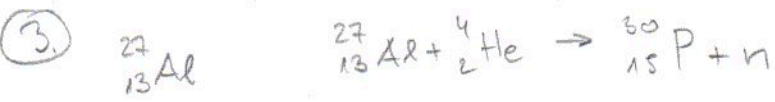
c)  ${}^{210}_{84}\text{Po}$

$N_{\text{reakcij}} = ?$

$$N = \frac{m}{A} \cdot N_A = \frac{1 \text{ g}}{210 \frac{\text{g}}{\text{mol}}} \cdot 6,0210^{23} \frac{\text{atoma}}{\text{mol}} = 2,86768 \cdot 10^{21}$$

= reakcij





$m_{\text{Al}} = 26,981539 \text{ u}$   
 $m_{\text{He}} = 4,002603 \text{ u}$   
 $m_{\text{P}} = 29,978317 \text{ u}$   
 $m_{\text{n}} = 1,008665 \text{ u}$

$\Delta m = (m_{\text{Al}} + m_{\text{He}}) - (m_{\text{P}} + m_{\text{n}})$   
 $\Delta m = 26,981539 \text{ u} + 4,002603 \text{ u} - (29,978317 \text{ u} + 1,008665 \text{ u})$   
 $\Delta m = -0,00284 \text{ u}$   
 ↓  
 porabnja se energija

a) Q = ?

$Q = \Delta m \cdot c^2 = 4,23847 \cdot 10^{-13} \text{ J}$   
 $\rightarrow \text{eV} = \underline{\underline{2,645443 \text{ MeV}}}$

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

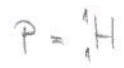
${}_{15}^{30}\text{P}$   
 $N = ?$

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

$N = \underline{\underline{2,0073789 \cdot 10^{19} \text{ atoms}}} = \text{st. neutral}$



(11)

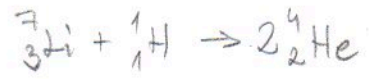


$W_p = 1,7 \text{ MeV}$

$W_\alpha = 9,5 \text{ MeV}$

$\Delta m = m_{\text{ZAE}} - m_{\text{KON}} = W_{\text{KON}} - W_{\text{ZAE}}$

$m_{\text{Li}} = ?$



$m_p = 1,00727647 \text{ u}$

$m_\alpha = 4,00150618 \text{ u}$

$W = \Delta m c^2$

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

$\Delta m = 2 \cdot 9,5 \text{ MeV} - 1,7 \text{ MeV}$

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

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

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

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

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

$m_{\text{Li}} = 0,0185723 \text{ u} + 2 \cdot 4,00150618 \text{ u} - 1,00727647 \text{ u}$

$\boxed{m_{\text{Li}} = 7,01430819 \text{ u}}$



5.



$m_T = 3,0160492 \text{ u}$

$m_D = 2,014101778 \text{ u}$

$m_{\text{He}} = 4,002603254 \text{ u}$

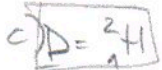
$m_n = 1,008664915 \text{ u}$

$W_v = \Delta m c^2$

a)  $\Delta m = (m_T + m_D) - (m_{\text{He}} + m_n)$

$\Delta m = 0,01888314 \text{ u}$

b)  $W_v = \Delta m c^2 = 2,8181498 \cdot 10^{-12} \text{ J}$   
 $= 17,5895 \text{ MeV}$



$m = 1 \text{ g}$

$N = \frac{m}{A} \cdot N_A = \frac{1 \text{ g}}{2 \frac{\text{g}}{\text{mol}}} \cdot 6,02 \cdot 10^{23} \frac{\text{atoms}}{\text{mol}} = 3,011065 \cdot 10^{23} \text{ atoms}$

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

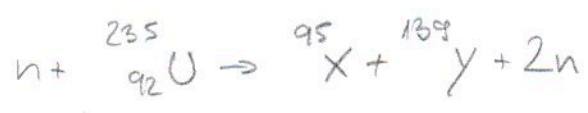
$\Delta m = Z m_p + N m_n - m_A$

$\Delta m = Z m_H + N m_n - m_A = -0,9998593 \text{ u}$

?



6.



$$m_U = 235,124 \text{ u}$$

$$m_n = 1,00866 \text{ u}$$

$$m_X = 94,945 \text{ u}$$

$$m_Y = 138,955 \text{ u}$$

$$\Delta m = (m_n + m_U) - (m_X + m_Y + 2 \cdot m_n)$$

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

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

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

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

$$m = 1g$$

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

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



7.



$$P = 100 \text{ MW (topleshen)}$$

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

$$W_1 = 200 \text{ MeV}$$

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

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

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

$$\frac{N}{t} = 3,12 \cdot 10^{18}$$

$$\Rightarrow N = 3,12 \cdot 10^{18} \text{ s}^{-1}$$

