Jedro, masni defekt, vezavna energija

1. Koliko energije ustreza 1 atomski masni enoti? In kolikšna masi elektrona?

$W = mc^2 = uc^2 = 1{,}660 \cdot 10^{-27}\,kg \cdot 931{,}5\ MeV/u = 931{,}5\ MeV$
$W_{el} = mc^2 = 0{,}000549\ u \cdot 931{,}5\ MeV/u = 0{,}511\ MeV$

2. Oceni gostoto atomskih jeder! $\rho = m/4\pi r^3/3 = 3u/4r_o^3 = 4 \cdot 10^{17}\,kg/m^3$ $m = Au$, $r = r_o A^{1/3}$

3. Določi vezavno energijo devterona ^2H. Atomske mase vodika, nevtrona in devterija so: 1,007825 u, 1,008665 u, 2,0141018 u. Masa protona je 1,007276 u, masa nevtrona 1,008665 u in masa devterona je 2,013553 u. Devterij je atom težkega vodika, devteron pa njegovo jedro, u je atomska masna enota. Vsaj kolikšno valovno dolžino mora imeti foton, da razbije devteron?

z jedrskimi masami: (običajno jedrskih mas nimamo podanih)
$\Delta m = m_p + m_n - m_j = (1{,}007276 + 1{,}008665 - 2{,}013553)\ u = 0{,}002388\ u$
$W_v = \Delta mc^2 = 0{,}002388\ uc^2 = \mathbf{2{,}2\ MeV}$ $(uc^2 = 931{,}494013\ MeV)$

z atomskimi masami:
$\Delta m = m_{p+e} + m_n - m_{j+e} = m_H + m_n - m_{devterij}$
$\Delta m = (1{,}0078250 + 1{,}008665 - 2{,}0141018)\ u = 0{,}002388\ u$
$W_v = \Delta mc^2 = \mathbf{2{,}2\ MeV}$ $(uc^2 = 931{,}494013\ MeV)$

$W_v = W_f = hc/\lambda \rightarrow \lambda = hc/W_v = 563\ fm$

4. Določi specifično vezavno energijo na nukleon jedra ^{12}C.

$\Delta m = 6m_p + 6m_n - m_j = 6(m_H + m_n) - m_C$
$\Delta m = [6(1{,}007825 + 1{,}008665) - 12{,}000000)]u = 0{,}098940\ u$
$W_v = \Delta mc^2 = \mathbf{92{,}1\ MeV}$ $w_v = W_v/A = 92{,}1\ MeV/12 = \mathbf{7{,}7\ MeV}$ / nukleon

5. Kolikšna sta masni defekt in vezavna energija jedra helijevega atoma? Masa helijevega atoma ^4_2He je 4,00260 u, masa protona 1,007276 u, masa nevtrona 1,008579 u, masa elektrona 0,000549 u in masa vodika ^1_1H je 1,007825 u.

$\Delta m = 2m_p + 2m_n - m_j = 2m_p + 2m_n - (m_{He} - 2m_e)$
$\Delta m = 2m_H + 2m_n - m_{He}$
$\Delta m = 0{,}03\ u$ $W_v = \Delta mc^2 = \mathbf{27{,}9\ MeV}$

6. Kadmij ^{113}Cd absorbira počasni nevtron. Koliko energije se pri tem sprosti? Koliko energije pa bi se sprostilo v 1 g ^{113}Cd, če je izkoristek pretvorbe v ^{114}Cd enak 10^{-8}. Atomske mase ^{113}Cd, ^{114}Cd in nevtrona so 112,9406 u, 113,94013 u in 1,00898 u.

$^{113}Cd + n \rightarrow {}^{114}Cd$
$\Delta m = (m_{^{113}Cd} + m_n) - (m_{^{114}Cd}) = 0{,}009135\ u$
$W_1 = \Delta mc^2 = 0{,}009135\ u \cdot 931{,}5\ MeV/u = 8{,}51\ MeV$
$N = \frac{m}{M} N_A = \frac{1\,g}{113\,g/mol} 6{,}02 \cdot 10^{23}\,atomov/mol = 5{,}33 \cdot 10^{21}\,atomov$
$W = N\eta W_1 = 4{,}54 \cdot 10^{20}\ eV = 72{,}6\ J$

1.

Vezana energija $W = \Delta m c^2$

Atomska enota mase: $u = \frac{1}{12} C^{12} = 1{,}660565 \cdot 10^{-27}\,kg$ ← Ogljik

$m_e = 5{,}4857\,u$

$W_u = m_u \cdot c^2$

$N_A\ [mol^{-1}]$

$W_u = 1 \cdot 1{,}660565 \cdot 10^{-27}\,kg \cdot 300 \cdot 10^6\,m/s$

$1g = N_A\,u$

$\cdot eV \,/\, \div$

$W_u = 1{,}49244 \cdot 10^{-10}\,J \Rightarrow eV$

$eV = 1{,}602\,17733 \cdot 10^{-19}\,J$

$\Downarrow$

$W_u = \frac{1{,}49244 \cdot 10^{-10}\,\cancel{J}\,eV}{1{,}602\,17733 \cdot 10^{-19}\,\cancel{J}} = 931{,}51 \cdot 10^6\,eV = \boxed{931{,}51\ MeV}$

$W_e = m_e \cdot u \cdot c^2 = \boxed{1{,}35952 \cdot 10^{-40}\,J}$

$=//=$

$\Rightarrow W_e = 510999\,eV \neq 0{,}511\ MeV$

3.) u - atomska masna enota [kg]

^2_1H

$^2_1H \; ^A_Z X \Rightarrow A-2$

$Z = 1$

$A = Z + N \Rightarrow N = A - Z = 1$

$W_v = ?$ $\lambda_{min} = ?$ da razbije devteron? ($W_v = W_f$)

$m_H = 1{,}007825\ u$

$m_n = 1{,}008665\ u$

$m_{devt.} = 2{,}0141018\ u$

$m_p = 1{,}0072764\ u$

$m_{dev.} = m_j = 2{,}013553\ u$

$W_v = \Delta m_H \cdot c^2$ $\quad \Delta m = Z \cdot m_p + N \cdot m_n - m_j$

$\Delta m = (1{,}007276 + 1{,}008665 - 2{,}013553)\ u$

$\Delta m = 0{,}023388\ u$

$W_v = 0{,}023388\ u \cdot \left(300 \cdot 10^6 \frac{m}{s}\right)^2$ $\quad \frac{kg\,m^2}{s^2} = J$

[J] $W_v = 3{,}56389 \cdot 10^{-13}\ J$ // $1eV = 1{,}60217 \cdot 10^{-19} J$ // eV

[eV] $W_v = 2{,}2244\ MeV$

$\lambda_{min} = ?$ $\quad W_v = W_f \Rightarrow$ minimalna energija za razpršitev devterona

$W_f = \frac{hc}{\lambda_{min}} \Rightarrow \lambda_{min} = \frac{hc}{W_v}$ $\quad [Jm]$ / $[J]$

$\lambda_{min} = \frac{6{,}626 \cdot 10^{-34} \cdot 300 \cdot 10^6}{3{,}56389 \cdot 10^{-13}} = 557{,}38\ fm$

(H.)

$^{A}_{Z}X$ $\quad A = Z + N$

$N = A - Z = \boxed{6}$

$^{12}_{6}C$

$W_v = \Delta m c^2$ $\qquad m_c = 12u$

$W_v = ?$

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

$\Delta m = Z \cdot m_H + N \cdot m_n - m_c$

$\Delta m = (6 \cdot 1{,}007825 + 6 \cdot 1{,}008665 - 12)u$

$\boxed{\Delta m = 0{,}098940\ u / kg}$

$W_v = \Delta m c^2$

$W_v = 0{,}098940 \cdot u[kg] \cdot \left(300 \cdot 10^6 \cdot \left[\frac{m}{s}\right]\right)^2$

$\boxed{W_v = 1{,}476599 \cdot 10^{-11}\ J}$

$\boxed{W_v = 92{,}162\ MeV}$

Skupaj naboj!

$w_n = \frac{W_v}{A} = \frac{92{,}162\ MeV}{12} = \boxed{7{,}68\ MeV}$

na nukleon

(5.)

$^{4}_{2}He \quad ^{A}_{Z}X$

$m_{He} = 4,00260\ u$

$m_p = 1,007276\ u$

$m_n = 1,008579\ u$

$m_e = 0,000549\ u$

$m_H = 1,007825\ u$

$\Delta m_{He} = ?$

$W_v = ?$

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

$$\Delta m = (2 \cdot 1,007825 + 2 \cdot 1,008579 - 4,00260)\ u$$

$$\Delta m = 0,030208\ u$$

$$W_v = \Delta m \cdot c^2$$

$$W_v = 0,030208\ u\,[kg] \cdot \left(300 \cdot 10^6 \left[\frac{m}{s}\right]\right)^2$$

$$W_v = 4,508299 \cdot 10^{-12}\ J$$

$$\boxed{W_v = 28,139\ MeV}$$

(6.)

^{113}Cd

$$^{113}Cd + 1n \rightarrow {}^{114}Cd$$

$\eta = 1 \cdot 10^{-8}$

$m = 1g = 1 \cdot 10^{-3}\ kg$

$m_{^{113}Cd} = 112,9406\ u$

$m_{^{114}Cd} = 113,94013\ u$

$m_n = 1,00898\ u$

$W_{1n} = ?$ ~ energija nevtrona

$W_{1g} = ?$ ~ energija nastanka v 1g

$$\Delta m = m_{^{113}Cd} + m_n - m_{^{114}Cd}$$

$$\Delta m = (112,9406 + 1,00898 - 113,94013)\ u$$

$$\Delta m = 0,00945\ u$$

$$W_{1n} = 0,00945\ u\,[kg] \cdot \left(300 \cdot 10^6 \left[\frac{m}{s}\right]\right)^2$$

$$W_{1n} = 1,410336 \cdot 10^{-12}\ J$$

$$\boxed{W_{1n} = 8,80262\ MeV}$$

Število nukleonov v 1g;

$$N = \frac{m}{A} \cdot N_A = \frac{1g}{113 \frac{g}{mol}} \cdot 6,02 \cdot 10^{23} \frac{atomov}{mol}$$

$$\boxed{N = 5,3293 \cdot 10^{21}\ atomov}$$

ter nato izračunati energijo posameznega:

$$W_{1g} = N \cdot \eta \cdot W_{1n} = 4,6912 \cdot 10^{20}\ eV = \boxed{75,16\ J}$$