TEORIJA → M1

1) Vjerojatnost raspada jezgre potpuno je neovisna o trenutku njenog formiranja. N

2) Snop fotona ne gubi en. dok prolazi kroz materiju, samo gubi na intenzitetu. T

3) Sve jezgre jednog radioa. niza nastaju raspadima koji počinju od jezgre najdužeg vremena poluraspada. T

4) Gotovo sva en. nab. čestica gubi se kroz kulonsku interakciju s e^- u atomu. T

5) Gama-raspad → EM zračenje kod kojeg se ne mijenja redni broj i atomska masa jezgre. T

6) Teške nabijene čestica pri prolasku kroz materiju gube en. vršeći ionizaciju. T

7) prodiranje teške nabijene čestice → put koji prevale do zaustavljanja.

8) prodiranje EM zračenja → en. se ne gubi postepeno zato EM zračenje nema doseg. T

9) tvorba parova → foton iščezava, njegova en. za stvaranje para e^--pozitron. T

10) Fotoel. ef. moguć samo na slobodnim e^- N

11) model kapljice T → kao kap tekućine...

12) Comptonovo raspršenje → na vezanim e^- N → slobodnim i mirnim e^-

13) Beta raspad jezgre → ${}^{A}_{Z}M \rightarrow {}^{A-4}_{Z-2}M + {}^{4}_{2}He$ → N to je α-raspad

14) vrijeme poluraspada → 0.693 od poč. broja N
↓
to je srednje
stanje života

$$\frac{d\sigma}{d\Omega} = \left(\frac{2Z\,ze^2}{4\pi\varepsilon_0 M_0 v^2}\right)^2 \frac{1}{16\sin^4\frac{\theta}{2}}$$ → Rutherfordovo raspršenje

Z → atomski broj → broj elektrona u neutralnom atomu

z → elektronski naboj → za α-česticu = 2

θ → kut raspršenja

M_0 → masa jezgre

V → volumen

9.) $^3_1H + ^2_1H \to ^4_2He + n$

$a \quad x \quad y \quad b$

oslobođena en. ?

$$m_a c^2 + m_x c^2 + E_{kp} = m_b c^2 + m_y c^2 + E_{kk}$$

$m_x(^2_1H) = 2.013553u$

$m_a(^3_1H) = 3.010492u$

$m_b(n) = 1.008665u$

$m_y(^4_2He) = 4.002602u$

$u = 1.6605 \cdot 10^{-27} kg$

$m_a c^2 = 931.494 MeV$

$$Q = E_{kk} - E_{kp}$$

$$Q = (m_a + m_x - m_b - m_y)c^2 =$$

$$= 0.018335 u \cdot c^2 = \underline{\underline{17.1 MeV}}$$

ZAD.

$Rn^{222}_{86} \to \alpha$ raspad $\to Po^{218}_{84}$

$t = ? \to \underline{\underline{N_{max}}}$

$T_{\frac{1}{2}} Ra = 3.85$ dana , $T_{\frac{1}{2}} Po = 3.15$ dana

$$\lambda_1 = \frac{\ln 2}{T_{\frac{1}{2}} Ra} = 0.18 \text{ dan}^{-1}$$

$$\lambda_2 = \frac{\ln 2}{T_{\frac{1}{2}} Po} = 0.22 \text{ dan}^{-1}$$

$$\frac{dN_2}{dt} = \lambda_1 N_1 - \lambda_2 N_2$$

$$\frac{dN_2}{dt} + \lambda_2 N_2 = \lambda_1 N_1 \cdot \frac{1}{e^{\lambda_2 t}}$$

$$N_2(t) = \frac{\lambda_1 N_1(0)}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right) = 0$$

$$\lambda_1 e^{-\lambda_1 t} = \lambda_2 e^{-\lambda_2 t}$$

$$t_{max} = \frac{1}{\lambda_2 - \lambda_1} \ln \frac{\lambda_2}{\lambda_1} = 33 \text{ min}$$

10.) $\Delta = ?$

$m = 1\,kg$ ugljen $\rightarrow$ 30 MJ

$$\Delta m = \frac{E}{c^2} = \frac{30\,MJ}{(3\cdot 10^8)^2} = 3.33\cdot 10^{-10}\,kg$$

11.) $n = 1.000293$

$v_e = \frac{c}{n}$

$$E_k = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2 = \frac{mc^2}{\sqrt{1-(\frac{1}{n})^2}} - mc^2 = 20.6\,MeV$$

6.) $^{128}I \rightarrow$ tablica

$\lambda = ?$ $T_{\frac{1}{2}} = ?$

$A_0 = 392.2\,Bq$

$t = 32\,min = 1920\,s$

$A(t) = 161.4\,Bq$

$$A(t) = A_0 e^{-\lambda t}$$

$$\lambda = -\frac{\ln\frac{A(t)}{A_0}}{t} = 4.6244\cdot 10^{-4}\,s^{-1} = 1.66\,h^{-1}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = 1498\,s \approx 25\,min$$

7.) $m(K) = 600\,mg$

$w(^{40}K) = 0.0117\,\%$

$T_{\frac{1}{2}} = 1.25\cdot 10^{9}\,god = 3.942\cdot 10^{16}\,s$ $\qquad A = ? \rightarrow$ radioaktivnost

$$m(^{40}K) = m(K)\cdot w(^{40}K) = 70.2\,\mu g$$

$$A = \lambda N$$

$$A = \frac{\ln 2}{T_{\frac{1}{2}}}\cdot\frac{m(^{40}K)}{M(^{40}K)} = \frac{\ln 2}{3.942\cdot 10^{16}}\cdot\frac{70.2\,\mu g}{6.63617\cdot 10^{-23}\,g} = 18.6\,Bq$$

ZZV → Z1

1.) ${}^{7}_{3}Li$ → bombardirana protonom ⇒ 2 α -čestice ${}^{4}He$

a) en. reakcije?

b) en. reakcije za ${}^{4}_{2}He + {}^{14}_{7}N \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$

→ iz periodnog sustava!

a)
$$M({}^{7}_{3}Li) = 7.016004\,u$$
$$M({}^{1}_{1}H) = 1.007825\,u$$
$\Big\}$ $8.023829\,u$

$$M({}^{4}_{2}He) = 4.002603\,u \rightarrow \times 2 = 8.005206\,u$$

$u = 1.6605 \cdot 10^{-27}\,kg$

$$E = (8.023829\,u - 8.005206\,u) \cdot c^2 = 2.78 \cdot 10^{-12}\,J = 17.39\,MeV$$

2.) en. vezanja po nukleonu za ${}^{120}_{50}Sn$?

$$M({}^{120}_{50}Sn) = 119.91\,u$$

$$E = \left[(50\,m_p + 70\,m_n) - (M({}^{120}_{50}Sn) - 50\,m_e)\right] c^2$$

$$E = 1.02054\,GeV \rightarrow E_n = \frac{E}{120} = 8.5\,MeV/nukleon$$

3.) FISIJSKI DOGAĐAJ $\quad {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{a}_{c}X + {}^{b}_{d}Y + 2\,{}^{1}_{0}n$

protoni: $92 \rightarrow c+d$

neutroni: $143+1 \rightarrow (a-c) + (b-d) + 2$

$142 \rightarrow a-c+b-d$

$142 \rightarrow a+b-(c+d)$

$234 \rightarrow a+b$

12.) $^{236}_{92}U$, $^{239}_{92}U$

en. aktivacije = ?

$$E_a = 0.89\,A^{2/3} - 0.02\,\frac{Z^2}{A^{1/3}}$$

$$E_a(^{236}_{92}U) = \underline{\underline{6.6\ \text{MeV}}}$$

$$E_a(^{239}_{92}U) = \underline{\underline{7\ \text{MeV}}}$$

8.) 1.2 kg prima 0.4 mSv   RBE = 1 rem/rad

a) ekv. doza u mrem?

$$ED = \frac{0.4\cdot\cancel{10^{-3}}\ \cancel{Sv}}{0.01\ \cancel{Sv}/\text{mrem}} = \underline{\underline{40\ \text{mrem}}}$$

b) aps. doza (mrad) $= \dfrac{40\ \text{mrem}}{1\ \text{rem/rad}} = \underline{\underline{40\ \text{mrad}}}$

$$\frac{0.4\ \text{mSv}}{1\ \text{Sv/Gy}} = 0.4\ \text{mGy} = 4\cdot 10^{-4}\ \text{J/kg}$$

c) $E_x = 50\ \text{keV}$ n fotona = ?

$4\cdot 10^{-4}\ \text{J/kg}\cdot 1.2\ \text{kg} = 3\cdot 10^{15}\ \text{eV}$ → uk. en. zračenja (apsorbirana!)

$$\frac{3\cdot 10^{15}}{50\cdot 10^{3}} = \underline{\underline{6\cdot 10^{10}\ \text{fotona}}}$$

5.) $R = 1\,fm = 10^{-15}\,m$

$K \rightarrow$ kin en.

a) $K = ?$ → da se zaustave jedna do druge

$$F = \frac{q_1 q_2}{r^2} \cdot k$$

$r = 2R \rightarrow$ udaljenost između protona

$$E = K = F \cdot s = F \cdot R$$

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{4R^{\cancel{2}}} \cdot \cancel{R} = 360.48\,keV$$

b) $K = 400\,keV$

$T = ?$

$$E = K = \frac{3}{2}\,\frac{R}{N_A} \cdot T \Rightarrow T = \frac{2}{3}\,\frac{N_A}{R} \cdot K = 3 \cdot 10^9\,K$$

4.) $P_T = 3400\,MW$

$P_e = 1100\,MW$

$m = 8.6 \cdot 10^4\,kg$

$t = 5.7 \cdot 10^4$

$w = 3\%$

a) $\eta = ?$

$$\eta = \frac{1100}{3400} = 0.3235 \rightarrow 32.35\,\%$$

b) brzina fisije ?

$P_T = 3400\,MW = 3.4 \cdot 10^9\,J/s$ $\quad Q = 200\,MeV/fisiji = 200 \cdot 10^6 \cdot 1.6 \cdot 10^{-19}\,J/fisiji$

$$R = \frac{P}{Q} = 1.1 \cdot 10^{20}\ fisija/s \rightarrow 1.0625 \cdot 10^{20}$$

c) brzina nestajanja goriva (kg/dan) ?

$$1.0625 \cdot 10^{20} \cdot \left(1 + \left(\frac{1}{4}\right)\right) = 1.328 \cdot 10^{20}\ atom/s$$

uhvat neutrona

$$m\left({}^{235}_{92}U\right) = 235\,u = 235 \cdot 1.6605 \cdot 10^{-27}\ kg/atom\,U = 3.9 \cdot 10^{-25}\ kg/atom\,U$$

$$\frac{dM}{dt} = \left(1.328 \cdot 10^{20}\ atom/s\right) \cdot \left(3.9 \cdot 10^{-25}\ kg/atom\right) = 5.18 \cdot 10^{-5}\ kg/s = 4.48\ kg/dan$$

~~[illegible]~~ | ~~[illegible]~~, 30 + zad za 3 → na F2N-u

ONF → MI

AV 1 → prvi na MI

1) E_0, E_{uk}, $\frac{E}{E_0}$, v, p = ? (en. mirovanja; brzina; kol. gibanja)

$C = 300000\ km/s = 300 \cdot 10^6\ m/s$

$E_{kin} = 6.55 \cdot 10^{-13}\ J$ $\boxed{1eV = 1.6 \cdot 10^{-19} J}$ $1J = 6.25 \cdot 10^{18} eV$

$V(r) = -\int_\infty^r \vec{E}(r) d\vec{r} = -\int_\infty \frac{F}{q} dr \,/ q \rightarrow V(r) \cdot q = -\int_\infty^r F dr$

$\boxed{E_0 = mc^2} = 8.199 \cdot 10^{-14} J = m_e \cdot (300 \cdot 10^6)^2 = \ldots 0.511\ MeV$ (03 u cašu)

$E_{uk} = E_0 + E_{kin} = 4.605\ MeV$

$\frac{E}{E_0} = \frac{\gamma mc^2}{mc^2} = \gamma \approx 9 \longrightarrow \boxed{\gamma = \frac{1}{\sqrt{1-\beta^2}}} \rightarrow \beta = 0.994$

$p = \frac{h}{\lambda} = \frac{2\pi h}{2\pi\lambda} = \hbar \cdot k$

$\boxed{v = 0.994 \cdot c} = 2.98 \cdot 10^8\ m/s$

$k = \frac{2\pi}{\lambda}$ $p = \hbar k$

$\boxed{p = \gamma \cdot m_e \cdot v = 2.44 \cdot 10^{-21}\ kg/s}$

AV 2

HEISENBERGOVO NAČELO NEODREĐENOSTI

$\Delta x \cdot \Delta p \geq \hbar$ $\Delta E \cdot \Delta t \geq \hbar$

1) Položaj čestice određen je do vrijednosti njene Debroglieve duljine. Neodređenost brzine?

$\Delta v = ?$

$p = \frac{h}{\lambda} \rightarrow \lambda = \frac{h}{p} = \frac{h}{mv}$

$\Delta p = m\Delta v$

$\Delta x \Delta v \geq \hbar$

$\frac{h}{mv} \cdot m\Delta v \geq \frac{h}{2\pi}$

$\frac{\Delta v}{v} \geq \frac{1}{2\pi} = 0.159$

2) Linearna dimenzija atoma?

$E^2 = \frac{p}{2m}$ $\quad \Delta E = \frac{\Delta p^2}{2m}$

$\Delta x \Delta p \geq \hbar/2$

$\Delta x^2 (2m\Delta E) \geq \hbar^2$

$\Delta x \geq \frac{\hbar}{\sqrt{2m\Delta E}}$

a) elektron u atomu?

$\Delta x \sim \frac{t}{\sqrt{2m 10 eV}} =$

3.) vrijeme poluraspada $T_{\frac{1}{2}} = 2 \cdot 10^{-23} s$

$E_0 = 1385 MeV$

u kojem rasponu se može uzeti en. mirovanja?

$\Delta E = ?$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \rightarrow \tau = \frac{1}{\lambda} = \frac{T_{\frac{1}{2}}}{\ln 2} = 2.885 \cdot 10^{-23} s$

konst. poluraspada

$\Delta E \Delta t \geq \hbar \rightarrow \frac{\hbar}{\Delta t} = 23 MeV \rightarrow \{E_0 \pm \Delta E\} = \{1362, 1408\} MeV$

$\hbar \rightarrow$ u [J] $\rightarrow$ potrebno pretvoriti u eV !

PREDAVANJE 3

en. osnovnog stanja nukleona u jezgri $a = 10^{-14} m$

$E_n = \frac{\hbar^2 \pi^2 n^2}{2ma^2}$ $\rightarrow$ en. kvantnog stanja (1,0)

$E_1 = \frac{\hbar^2 \pi^2}{2ma^2} = \frac{(\frac{h}{2\pi})^2 \pi^2}{2ma^2} = \frac{h^2}{8ma^2} = \frac{\dots}{8 \cdot 1.66 \cdot 10^{-27} \cdot 10^{-28}} = 2.065 MeV$

calc!

$E_n = \frac{h^2}{8ma^2}\underbrace{(n_x^2 + n_y^2 + n_z^2)}_{1+1+1} = 3 \cdot \frac{h^2}{8ma^2}$

Udarni presjek: $\Theta = \sigma \cdot n_p$

$\Theta = \int n_D \sigma \cdot dv$

$I = \emptyset S = n_p \cdot v S$

$R = N\sigma\emptyset \rightarrow \sigma = \frac{R}{N\emptyset}$ $\rightarrow$ ef. povr. po jezgri mete

$w = \frac{R}{I} = \frac{N\sigma\emptyset}{\emptyset S} = \frac{N\sigma}{S}$ $\rightarrow$ ef. povr. svih jezgara mete

Weizsäckerova formula za en. vezanja jezgre

$$E_B(MeV) = 14A - 13A^{\frac{2}{3}} - 0.58\frac{Z^2}{A^{\frac{1}{3}}} - 19\frac{(A-2Z)^2}{A} + \frac{33.5}{A^{\frac{3}{4}}}\delta$$

$\delta = +1 \rightarrow$ parni A i Z

$\delta = 0 \rightarrow$ neparni A

$\delta = -1 \rightarrow$ neparni Z, parni A

en. po nukleonu : $\frac{E_B}{A}$

max en. vezanja $\left.\frac{\partial E}{\partial Z}\right|_{A=konst} = 0$

Odnos broja neutrona i protona , $\frac{A-Z}{Z} = \frac{A}{Z} - 1 = \ldots$

$\boxed{\text{PRED 4}}$

$$p = \frac{Ze^2}{2\pi b v_{\check{c}} \varepsilon_0}$$

$v_{\check{c}} \rightarrow$ brz. nabijene čestice

$b \rightarrow$ put na kojem nabijena čestica prolazi pored e^-

$Z \rightarrow$ redni broj nabijene čestice

$\downarrow$

impuls koji nabijena čestica predaje e^-

$$E_{kin} = \frac{p^2}{2m_e} = \frac{Z^2e^4}{8\pi^2\varepsilon_0^2 b^2 v_{\check{c}}^2 m_e}$$

ZAD. Bi^{210}_{83} $T_{\frac{1}{2}} = 4.97\,d$ $1mg$ Bi $t = 10d$

$A(10\,dana) = ?$ $\rightarrow$ aktivnost

$N_0 = \frac{m}{A} N_A \rightarrow$ poč. broj jezgara

$\Delta N = N_0 - N(\tau) \rightarrow$ broj raspadnutih jezgri

$N_A = 6.022 \cdot 10^{23}$ atom/mol

$N(\tau) = N_0 e^{-\tau\lambda}$ broj nakon $t = \tau$ $\tau = \frac{T}{\ln 2}$ $\lambda = \frac{\ln 2}{T}$

$$N(t) = N_0 e^{-\frac{\ln 2}{T}t} = \frac{m}{A} \cdot N_A \cdot e^{-\frac{\ln 2}{T}t}$$

III.

1) R (radijus) jezgre bakra Cu^{58}

$\boxed{R_0 = 1.2 \cdot 10^{-15} m}$ $R = R_0 A^{\frac{1}{3}} = 4.7\ fm \rightarrow f = 10^{-15}$

2) R jezgre Ge 2x veći od Be. Broj nukleona u jezgri Ge?

$R_G = 2R_{Be}$

$A_G = ?$ $R_0 A_G^{\frac{1}{3}} = 2R_0 A_{Be}^{\frac{1}{3}} \rightarrow A_{Ge} = 72$

9 → iz periodnog sus. elemenata

A → nukleonski broj najčešćeg izotopa

Z → protonski broj

3.) en. vezanja jezgre deuterija, tricija i Be^9, poznat je defekt mase $\Delta = M - A = 0.0141u$, 0.01605, 0.01219 AJM (atom. jed. mase)

$$\boxed{\begin{aligned} M(A,Z) &= Zm_p + (A-Z)\cdot m_n - \Delta M \\ E_B &= \Delta M c^2 \end{aligned}}$$

1 AJM = $1.6605 \cdot 10^{-27}$ kg

$u \cdot c^2 = 931.5 MeV$

$m_p = 1.0078u$ $m_n = 1.0087u$

a) deuterij $A = 2$ $Z = 1$ $N = 1$ → $\boxed{A - Z = N}$

$M(2,1) = \Delta + A = 2.0141\ u$

$\Delta M = m_p + m_n - 2.0141\ u$

$E_B = \Delta M \cdot c^2 = \ldots$

4.) min. en. za razbijanje jezgre? O^{16} na 4 dijela $\Delta = M - A = -0.00509$ $He^4 = 0.00260$

O_8^{16} na $4 He_2^4$

$E_{min} = E_{B(a)} - 4E_B = 14.43\ MeV$

a) $A = 16$ $Z = 8$

$M(16,8) = 16m_p + 8m_n - \Delta M = A + \Delta = 15.99491u$

$\Delta M = 0.13701u$

$E_B = \Delta M \cdot c^2 = 127.6248\ MeV$

b) He_2^4 $A = 4$ $Z = 2$ $M(4,2) = A + \Delta$

$\Delta M = -M(4,2) + 4m_p + 2m_n$

$E_B = 28.29\ MeV$

ZAD. $\rightarrow m = 32g$ 30d raspadanje, 1g je ostalo $T_{\frac{1}{2}} = ?$

$$N_0 = \frac{m_0}{A} N_A$$

$$(t = 30 \text{ dana}) \quad N(t_1) = N_0 e^{\lambda t_1} \rightarrow \frac{m}{M} N_A = \frac{m_0}{M} N_A e^{-\lambda t_1}$$

$$m = m_0 e^{-\lambda t_1}$$

$$\lambda = \frac{1}{t_1} \ln\left(\frac{m_0}{m}\right) \frac{1}{30} \ln\left(\frac{32g}{1g}\right) = 0.1155 \text{ dan}^{-1}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = 6 \text{ dana}$$

3 *

ZBIRKA

29.) $_{71}Lu^{176}$, kvadrupolni moment $= 700 fm^2 = Q_2$

$$Q_2 = \frac{4}{5} Z\eta R^2 \qquad Z\eta = \frac{5}{4} Q_2 \frac{1}{R^2} = 23$$

odredjuje ef. broj protona

$R = 1.2 \cdot 10^{-15} m$

32.) min udaljenost na koju se može približiti α-čestica en 9 MeV jezgri urana $_{92}U^{235}$?

$$E_k = \frac{Mv^2}{2} = \frac{Z\, ze^2}{4\pi\varepsilon_0 r} = 9 \text{ MeV}$$

$$r = \frac{92 \cdot 2 e^2}{4\pi\varepsilon_0 \cdot 9 \text{ MeV}} \qquad \varepsilon_0 = 8.854 \cdot 10^{-12} \frac{As}{Vm} \qquad 1eV = 1.6 \cdot 10^{-19} J$$

$$r = 29.48 \text{ fm}$$

45.) Crvena granica fotoefekta $\lambda = 0.577 \mu m$ $E_{min} = ?$

$$E_m = W = h\nu \Rightarrow \frac{c}{\lambda} = \frac{3 \cdot 10^8}{0.577 \cdot 10^{-6}} = 519.9 \cdot 10^{12} Hz$$

$$E = h \cdot \nu = 2.15 eV \qquad h = 4.14 \cdot 10^{-15} eV$$

33.) min. kin. en. α-čestica da bi osjetile utjecaj nuklearne sila? → obasjavamo jezgre Al

utjecaj će se osjetiti na $R' = R + 1\ fm$ od centra jezgre !

$$E_k = \frac{Z z e^2}{4\pi\varepsilon_0 R'} = 8.1\ MeV$$

34.) $E = 10 MeV$ $d = 10^{-11} m$

$E_B = ?$

$$p = \frac{Z e^2}{2\pi\varepsilon_0 b v_c^2}$$ predana vel. gibanja

predana en. $$E = \frac{p^2}{2m} = \frac{Z^2 e^4}{8\pi^2\varepsilon_0^2 b^2 v_c^2 \cdot m} \Rightarrow \frac{Z^2 e^4 Mc^2}{16\pi^2\varepsilon_0^2 v_c^2 \cdot mc^2} \frac{1}{b^2}$$

$$m = \frac{Mc^2}{2\,mc^2}$$

$$\boxed{E = 3.1\ eV}$$

$mc^2 = 0.599\ MeV$

$Z = 1$

$$\frac{e^4}{16\pi^2\varepsilon_0^2} = 1.66\ MeV\ fm$$

39.) 12 MeV i 15 MeV

$R = 1.8E - 6.8$

$E_p = 3.5\ MeV$ → domet protona ?

$12 < E < 15$

$$\frac{R_p}{R_\alpha} = \frac{M_p}{M_\alpha} \cdot \frac{Z_\alpha^2}{Z_p^2} = \frac{M_p}{4M_p} \cdot \frac{(2 Z_p)^2}{Z_p^2} = 1$$

$$R_p = 1.8E - 6.8 = R_\alpha = 1.8 \frac{1}{2} M_\alpha v_p^2 - 6.8$$

$$= 1.8 \frac{1}{2} 4 \left(\frac{1}{2} M_p v_p^2\right)_{3.5} - 6.8 =$$ $$E_{kin} = \frac{1}{2} M_p v_p^2$$

$= ~~18.4\ cm~~\ 1.8 \cdot 4 \cdot 3.5 - 6.8 = 18.4\ cm$ ✓

48.) 28 barn

$Z = 74 \quad Z = 13 \rightarrow$ barn?

$$\sigma \sim \frac{Z^5}{E^{\frac{7}{2}}} \qquad Z_{Pb} = 82$$

$$\sigma_{Pb} : \sigma_W : \sigma_{Al} = Z_{Pb}^5 : Z_W^5 : Z_{Al}^5$$

$\sigma_W = 17$ barn $\quad \sigma_{Al} = 28$ barn

$$\frac{\sigma_{Pb}}{\sigma_W} = \left(\frac{Z_{Pb}}{Z_W}\right)^5 = 1.671 \rightarrow 46.76 \text{ barn}$$

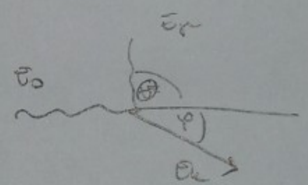
$$\frac{\sigma_{Al}}{\sigma_W} = \left(\frac{13}{74}\right)^5 = 2.8 \text{ mbarn}$$

49.) detektor pod kutem $90° = \theta$

beta brojač → kut?

$E_\gamma = 1.33$ MeV

$\varphi = ?$



$$E_\gamma' = \frac{E_0}{1 + \frac{E_0}{mc^2}(1 - \cos\vartheta)}$$

$$\cancel{E_\gamma = E_\gamma' + E_k}$$

$$\cancel{h\nu = h\nu' + E_k}$$

$E_k = E_\gamma - E_{\gamma'}$

$$\cancel{p_\gamma = p_\gamma' \cos\theta + p_e \cos\varphi}$$

$E_{\gamma'} = 0.369$ MeV

$$\cancel{0 = p_\gamma' \sin\theta - p_e \sin\theta}$$

$E_k = 0.96$ MeV

$$\cancel{\frac{h\nu}{c} = \frac{h\nu'}{c}\cos\theta + p_e \cos\varphi}$$

$$\cancel{0 = \frac{h\nu'}{c}\sin\theta - p_e \sin\varphi}$$

$1 J = 6.25 \cdot 10^{18}$ eV

$P_\gamma = P_{\gamma'} \cos\theta + P_e \cos\varphi$

$P_\gamma' \sin\theta = P_e \sin\varphi$

$\varphi = 15.5°$

$$\sin\varphi = \frac{P_\gamma' \sin\theta}{P_e} = \frac{E_\gamma' \sin\theta}{P_e \cdot c}$$

$$P_e c = \sqrt{E^2 - (mc^2)^2} = \sqrt{(mc^2 + E_k)^2 - (mc^2)^2} = \sqrt{2mc^2 E_k + E_k^2}$$

46.) $r = 10\,cm$

$B = 2 \cdot 10^{-2}\,T$

$E_k = 87.8\,keV$

$E_\gamma = ?$

$$\frac{mv^2}{r} = evB \qquad p = eBr$$

cavio

$$\frac{p}{mc} = \frac{eBr}{mc} = 1.17 > 1 \rightarrow \text{relativistički}$$

$$pc = 1.17\,mc^2 = 0.597\,MeV$$

$$E_k = \sqrt{(pc)^2 + m^2c^4} - mc^2 = 0.274\,MeV$$

$$E_\gamma = E_k + E_k = 361\,keV$$

47.) $E = 0.51\,MeV$

$\varphi = 60°$

$10\,\frac{barn}{ster}$, $80\,keV \rightarrow$ dif. presjek?

$$\beta = \frac{v}{c} = \sqrt{1 - \left(\frac{1}{\left(\frac{E_k}{mc^2}\right)+1}\right)^2}$$

$$\left(\frac{d\sigma}{d\Omega}\right)_1 : \left(\frac{d\sigma}{d\Omega}\right)_2 = \frac{\overset{0.75}{\sin^2\varphi}}{1-\beta_1\underbrace{\cos\varphi}_{0.5}} : \frac{\overset{0.75}{\sin^2\varphi}}{1-\beta_2\underbrace{\cos\varphi}_{0.5}}$$

$$\frac{\left(\frac{d\sigma}{d\Omega}\right)_1}{\left(\frac{d\sigma}{d\Omega}\right)_2} = \frac{2-\beta_1}{2-\beta_2} \quad \beta_1 = 0.865,\ \beta_2 = 0.502 \rightarrow \left(\frac{d\sigma}{d\Omega}\right)_2 = 7.6\,\frac{barn}{ster}$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \rightarrow \beta = \sqrt{1-\frac{1}{\gamma^2}} \qquad \gamma = \frac{E}{E_{kin}} + 1 =$$

51. $\lambda = 0.03\,\text{Å} = 3\cdot10^{-12}\,m$ $\boxed{\text{Å} = 10^{-8}\,cm = 10^{-10}\,m}$!

$\theta = 60, 90$ i $180°$

$E_{er} = ? \rightarrow E_k$

$E = h\nu = h\cdot\frac{c}{\lambda}$ $h = 4.14\cdot10^{-15}\,eVs$ $E_\gamma = h\cdot\frac{c}{\lambda} = 414\,keV$

$E_k = E_\gamma - E_\gamma'$ ← $E_\gamma' = \dfrac{E_\gamma}{1+\frac{E_\gamma}{mc^2}(1-\cos\theta)} = 0.295\,MeV$

$\theta \to 60°$

$\downarrow$

$E_k = 0.119\,MeV$

$\boxed{Z1}$

53. udarni presjek: $\dfrac{d\sigma}{d\Omega} = \dfrac{r_0^2}{2}\left(\dfrac{E_\gamma}{E_0}\right)^2\left(\dfrac{E_0}{E_\gamma} + \dfrac{E_\gamma}{E_0} - \sin^2\vartheta\right)$

$E_\gamma = \dfrac{E_0}{1+\frac{E_0}{mc^2}(1-\cos\theta)}$

54. $E_\gamma = 3\,MeV$

$B = 0.1\,T$

$r = ?$

$E_\gamma = 2m_ec^2 + 2E_{kp}$ $2mc^2$!

za stvaranje para e^- - pozitron utroši se 1.02 MeV

$E_k = \frac{1}{2}(E_\gamma - 2mc^2) = 0.99\,MeV$

$\dfrac{mv^2}{r} = evB$ $\boxed{eBr = p}$

$r = \dfrac{p}{eB} = \dfrac{pc}{eBc} = \dfrac{\sqrt{E-(mc^2)^2}}{eBc}$ ← $E = E_k + mc^2 = 1.5\,MeV$

$r = 4.7\,cm$

61.) $\rho x = 0.1\ g/cm^2$

$E = 0.773\ MeV$

2% raspršenih zraka

izotop?

$$E_{max} = \sqrt[5]{Z} \cdot 0.54 \longrightarrow 0.773 = 0.54\ Z^{\frac{1}{5}}$$

$$Z^{\frac{1}{5}} = 1.431 \quad /^5$$

$$Z = 6.01 \approx 6 \rightarrow \underline{\text{ugljik}}$$

$\rightarrow$ izotop?

$$\sigma_T = \frac{8\pi}{3} r_0^2 = \frac{8\pi}{3}\left(2.818 \cdot 10^{-15}\right)^2 = 67 \cdot 10^{-30}\ m^2 = \underline{0.67\ barn}$$

$$M = A \cdot \rho \cdot Z \cdot \sigma_T \frac{1}{\frac{\Delta N}{N}} = 12.04 \Rightarrow {}^{12}_{6}C \qquad \frac{\Delta N}{N} = 0.02$$

62.) $x\rho = 0.436\ g/cm^2 = R_0$

$$\boxed{E = \frac{R_0 + 0.09}{0.52}} = 1.012\ MeV$$

$$E_{max} = 0.54\ Z^{\frac{1}{5}}$$

$$\underline{Z = 23} \rightarrow \text{vanadij!}$$

63.) $$l_{rad} = \frac{137}{4 r_0^2 N Z^2 \ln\frac{183}{Z^{1/3}}} \qquad E = E_0 e^{-\frac{x}{l_{rad}}} \qquad \frac{dE}{dx} = -\frac{E}{l_{rad}}$$

64.) $X = 5\ mm$

$E = 42\ MeV$

$E_0 = ?$

$$\frac{\Delta E_{rad}}{\Delta E_{ioniz}} = \frac{ZE}{800} \approx 5$$

$$E = E_0 e^{-\frac{x}{l_{rad}}} \approx 1 \approx E_0 e^{-1} \Rightarrow \underline{E_0 = 114\ MeV}$$

57.) $\rho x = 1.4\ g/cm^2$

$E_1 = 0.4\ MeV$

$E_2 = 1.5\ MeV$

---

broj neapsorbiranih gama zraka

$$\boxed{\begin{aligned} N &= N_0 e^{-\frac{\mu}{\rho}(x\rho)} \\ \eta &= \frac{N_0 - N}{N_0} = 1 - e^{-\frac{\mu}{\rho}\rho x} \end{aligned}}$$

$\eta(0.4) : \eta(1.5) = \ldots$

$$\left.\begin{aligned} \frac{\mu_1}{\rho}(0.4) &= 0.0953\ cm^2/g \quad \rightarrow \text{maseni koef.} \\ \frac{\mu_2}{\rho}(1.5) &= 0.0518\ cm^2/g \end{aligned}\right\} \text{iz tablica !}$$

58.) izvor 1 Curie / 1g radij

$3.7 \cdot 10^{10}$ raspad/sec

$\frac{\mu}{\rho} = 0.042\ cm^2/g$

$R = 3\ m$

$I = 10^{-6} I_0$

$\rho = 11.3\ g/cm^3$

$\frac{\Phi_2}{\Phi_1} = ?$

$$\frac{I}{I_0} = 10^{-6} = e^{-\mu x} = e^{-\frac{\mu}{\rho}\cdot\rho x} \Rightarrow x = 0.29\ m$$

$I \bullet \!\!\xrightarrow{\ r\ }\!\!)$

$$\Phi = \frac{I}{4\pi r^2}$$

$$\frac{\Phi_2}{\Phi_x} = \frac{\frac{I}{4\pi R^2}}{\frac{I}{4\pi x^2}} = \frac{x^2}{R^2} = \frac{0.29^2}{3^2} = \underline{\underline{9.3 \cdot 10^{-3}}}$$

59.) $E = 1.5\ MeV$

$x = ?$

$I = 4 I_0$

$\frac{\mu}{\rho} = 0.05\ cm^2/g \qquad \rho = 11.3\ g/cm^3$

$$\mu = \frac{\mu}{\rho} \cdot \rho = 0.565\ cm^{-1}$$

$$\frac{I_0}{I} = \frac{I_0}{4 I_0} = e^{-\mu x} \Rightarrow \underline{\underline{x = 2.45\ cm}}$$

84.) $^{10}_{5}B / n, \alpha / ^{7}_{3}Li + 2.3 MeV \rightarrow ^{10}_{5}B (n, \alpha) ^{7}_{3}Li + \underbrace{2.3 MeV}_{Q}$

$\rho x = 2 mg/cm^2$

$A = 1 cm^2$

$E_n = 20 MeV$

$\Phi = 10^5 neutr./cm^2 s$

$\sigma = 20 barn = 20 \cdot 10^{-24} cm^2$

$P = ?$

$$Q = E_{kk} - E_{kp}$$

kin kon, kin poč

$N_A = 6.022 \cdot 10^{23} mol^{-1}$

$\hookrightarrow E_{kk} = Q + E_{kp} = 22.3 MeV$

$mol = 0.012 kg$

volumna gustoća: $m_v = \frac{\rho N_A}{A} \Big/ \cdot x$

$1000 g = 1 kg$

$1 mg = 10^{-6} kg$

površinska gustoća: $m_l = \frac{(\rho x) N_A}{A} \Rightarrow N = 1.204 \cdot 10^{21}$ atoma

reaction rate: $R = N(\sigma \cdot \Phi) = 2408$

$$P = R \cdot E_{Q} = R \cdot E_{kk} = 8.59 \cdot 10^{-9} W$$

? 85.) $v = 2200 m/s \rightarrow \sigma = 98.8$ barn

$E = 1 keV \rightarrow \sigma = ?$

$\sigma \sim \frac{1}{v}$

$\sigma_1 v_1 = \sigma_2 v_2$

$\sigma_2 = 0.464$?

$E = \frac{m v^2}{2}$

~~4.686 · 10^{18}~~

81.) Čerenkovljev efekt : $v \geq \frac{c}{n}$

$$E_k = mc^2 - m_0c^2$$

$$m = \frac{m_0}{\sqrt{1-(\frac{v}{c})^2}}$$

$$E_k = m_0c^2 \left[\frac{1}{\sqrt{1-(\frac{1}{n})^2}} - 1 \right]$$

$$n = 1.000293$$

$$E_k = \underbrace{m_0c^2}_{\cdot 6.25 \cdot 10^{18}} \cdot 40.31 = 20.65 \text{ MeV}$$

82.) Q vrijednost $^{206}Pb / d, p / ^{207}Pb \rightarrow 4.5 \text{MeV}$

$^{206}Pb / n, \gamma / ^{207}Pb$ $E_\gamma = ?$ $E_v = 2.23 \text{ MeV}$

$$\left.\begin{aligned} &\rightarrow \text{prva reakcija}: (\cancel{^{206}Pb} + \cancel{p} + \cancel{n}) \cancel{c^2} - 2.23 \text{ MeV} = 4.5\text{MeV} + \cancel{c^2} (\cancel{^{207}Pb} + \cancel{p}) \\ &\rightarrow \text{druga reakcija}: (\cancel{^{206}Pb} + \cancel{n}) \cancel{c^2} = \cancel{^{207}Pb} + E_\gamma \end{aligned}\right\} -$$

$$-2.23 \text{ MeV} = 4.5 \text{ MeV} - E_\gamma$$

$$\boxed{E_\gamma = 6.73 \text{MeV}}$$

83.) $^7_3Li / p, n / ^7_4Be$

$Q = -1.647$ MeV

prag reakcije?

$$p_p = p(^7Li + p) \qquad E_{PRAG} = |Q| + E_{Be}$$

$$E_{Be} = \frac{p_p^2}{2M_{Be}}$$

$$\Rightarrow E_{Be} = \frac{m_p E_{PRAG}}{M_{Be}} \Rightarrow E_{PRAG} = |Q| \frac{M_{Be}}{M_{Be} - m_p} = 1.92 \text{ MeV}$$

$M_{Be} \rightarrow 7u$, $M_{Be} \rightarrow 7u$, $m_p \rightarrow 1u$

(21)

→ nuklearne reakcije → bombardiranje česticama → ne spontano !

→ ne radi se o elastičnim sudarima → uk. početna masa nije jednaka uk. konačnoj

$Q > 0$ egzoergične → oslobađa se en.

$Q < 0$ endoergične → ne može se desiti ako poč. E_k nije jednaka $|Q|$ → en. prag

→ en. fosilnih goriva → oslobađanje pri promjeni rasp. e^- oko jezgara koje se ne mijenjaju

→ fisija → raspad na 2 dijela usporedivih masa

→ moderatori → materijali koji služe da se neutronima u sudarima s jezgrama smanji en.

→ vjv izazivanja fisije je veća sa sporim neutronima

→ glavni mehanizam za gubitak en. brzih neutrona → el. raspršenje na jezgri

→ oslobađanje neutrona u fisiji otvara mogućnost lančane reakcije → svaki novi neutron može potencijalno započeti novu fisiju

→ frakcija izgubljenih e^- je smanjena kada se reducira omjer povr./volumen ($6/a$ za kocku)

→ fisija → najefektivnija sa termičkim neutronima

→ brzi neutroni moraju biti usporeni

→ rezonancije ⇒ emisije gama-zraka → neutron uklonjen iz fisijskog lanca

↳ gorivo i moderator moraju biti odvojeni u reaktoru

→ fuzija → spajanje 2 lakše u 1 težu jezgru

↳ oslobađanje en. jer jezgre nastale fuzijom imaju manju masu od mase polaznih čestica

→ potrebno savladati njihovu odbojnu silu (el.)

→ uspješno funkcioniranje termonukl. reaktora:

1.) visoka gustoća čestica

2.) visoka temp. plazme T

3.) veliko vrijeme ograničavanja τ