

vè; k; 13

ukfHkd



13.1 Hkrfiedk

fi Nysvè; k; ea geusi < k gsfid iR; d i jek. kqdk /ukos'k ?kuhHkr gksdj bl oð oðæ eal oðæær gls tkrk gsvlç i jek. kqdk ukfHkd cukrk gð ukfHkd dk oðy l kb" k i jek. kqoð l kb" k dh rgyuk ea dklkdh de gkrk gð α-d. kka oð izdh. kzu l æz' h iz kska us ; g inE' kr fd; k gsfid ukfHkd dh f=K; k] i jek. kq dh f=K; k dh rgyuk ea 10⁴ xps l sHh de gksuh pkrfg, A bl dk vFKZ gsfid ukfHkd dk vk; ru i jek. kqoð vk; ru oð 10⁻¹² xps oð yxHkx gð nu' js' kCnka eadgaris i jek. kq ea vf/dkkr% fjDr LFku gh gð ; fn ge i jek. kq dk l kb" k c<kdj d{kk oð dejs oð cjkj dj narls ukfHkd bl ea, d fi u oð 'kn" kZ oð l kb" k dk fn [kkbz nskA rFkkfi] i jek. kq dk yxHkx l ä wkZ æ0; eku (99.9% l s vf/d) ukfHkd ea gh l ekfgr gkrk gð

i jek. kq dh l çpuk oð l e: i D; k ukfHkd dh Hkh dkkZ l çpuk gð ; fn , ç k gsrks bl oð vo; o D; k&D; k gð os ijLij fdl izdkj tçs gð bl vè; k; ea ge bl izdkj oð izuka oð mükj [kstus dk iz, kl djæd ge ukfHkd ka oð fof' k'V xq kq tç s çmuoð l kb" k] æ0; eku rFkk LFkkf; Ro dh ppkZ oð l kfk bul s l æ¼ jsm; ks sDVork] fo [kæ/ u , oa l ay; u tç h ukfHkdh; i fj?kVukvla dh Hkh foopu djæd

13.2 i jek. kq æ0; eku , oa ukfHkd dh l çpuk

i jek. kq dk nð; eku fdykske dh rgyuk ea cgr de gkrk gð mnkgj. k oð fy,] dkcü oð i jek. kq ¹²C dk nð; eku 1.992647 x 10⁻²⁶ kg gð bruh Nks/h jkf' k; ka dks eki us oð fy,

fdylskte cgr I fpoëktud ek-kd ugha gÅ vr% ijek.kq nD; ekuka dks 0; Dr djus oÅ fy, nD; eku dk , d vl; ek-kd iLrF fd; k x; kA bl ek-kd dks ijek.kq nD; eku ek-kd (u) dgrs gÅ bl dks ¹²C ijek.kq oÅ nD; eku oÅ ckjgoa 1/12th Hkx l s 0; Dr djrs gÅ vr% bl ifjHkk"kk oÅ vuq kj

$$\begin{aligned}
 1u &= \frac{{}^{12}\text{C ijek.kq dk nD; eku}}{12} \\
 &= \frac{1.992647 \times 10^{-26} \text{ kg}}{12} \\
 &= 1.660539 \times 10^{-27} \text{ kg} \qquad (13.1)
 \end{aligned}$$

ijek.kq æ0; eku ek-kd (u) ea 0; Dr djus ij fofHkku rRoka oÅ ijek.kq æ0; eku] gkbMst u ijek.kq oÅ æ0; eku oÅ iwiz xqkt oÅ fudV ik, tkrsgÅ ijarqbl fu; e oÅ vucl i Hkko'kkyh viokn Hkh gÅ mnkgj.k oÅ fy,] Dylgju dk ijek.kq æ0; eku 35.46 u gÅ

ijek.kq æ0; ekuka dk ; FkFkZ eki u] æ0; eku o. kZeeeki h (Li DVkshVj) }kjk fd; k tkrk gÅ ijek.kq æ0; ekuka oÅ eki u l sirk pyrk gSfd , d gh rRo oÅ fofHkku izdkj oÅ , d s ijek.kq/ka dk vLrRo gSftuoÅ jkl k; fud xqk rls l eku gkrs gÅ ij buoÅ æ0; ekuka ea varj gkrk gÅ , d gh rRo dh , d h ijek.kq iztkfr; k ftuoÅ æ0; ekuka ea varj gkrk gS l eLFkfd dgykrh gÅ (; wkuh 'kcn vkbl k/vk d k vFkZ`gnh ea l eLFkfd gS ; g uke blga bl fy, fn; k x; k gS D; kkd rRokadh vkorZ l kj.kh ea; s l Hkh , d gh LFku ij ik, tkrsgÅ A 'ks' l sirk pyk fd iR; d rRo 0; kogkfj d : i l s dbZ l eLFkfdka dk feJ.k gÅ fofHkku l eLFkfdka dh l ki s k cgyrk rRo cnyus oÅ l kfk cnyrh gÅ

mnkgj.k oÅ fy,] Dylgju oÅ nls l eLFkfd gÅftuoÅ nD; eku Øe'k% 34.98 u , oa 36.98 u gS tksfd gkbMst u ijek.kq nD; eku oÅ iwiz xqkt oÅ l fludV gÅ bu l eLFkfdka dh l ki s k cgyrk Øe'k% 75.4 , oa 24.6% gÅ bl izdkj] i kÑfrd Dylgju ijek.kq dk nD; eku bu l eLFkfdka dk Hkfr&vk r gÅ vr% i kÑfrd Dylgju ijek.kq dk nD; eku]

$$\begin{aligned}
 &= \frac{75.4 \times 34.98 + 24.6 \times 36.98}{100} \\
 &= 35.47 \text{ u}
 \end{aligned}$$

ogh eku gS tks Dylgju dk ijek.kq æ0; eku gÅ

; gk rd fd l clsgyoÅ rRo gkbMst u oÅ Hkh rhu l eLFkfd gÅftuoÅ nD; eku 1.0078 u, 2.0141 u , oa 3.0160 u gÅ l clsgyoÅ gkbMst u ijek.kq ft l dh l ki s k cgyrk 99.985 % gS dk ukfHkd] i k/vk dgykrk gÅ , d i k/vk dk nD; eku gS

$$m_p = 1.00727 \text{ u} = 1.67262 \times 10^{-27} \text{ kg} \qquad (13.2)$$

; g gkbMst u ijek.kq oÅ nD; eku 1.00783 u ea l s bl ea fo l eku , d byDVrnu oÅ nD; eku $m_e = 0.00055 \text{ u}$ dks ?k/vk l s i k r nD; eku oÅ cjkj gÅ gkbMst u oÅ nD; jsnls l eLFkfd M; wfhj; e , oa VRbV; e dgykrsgÅ VRbV; e ukfHkd vLFk; h gks oÅ dkj.k i Ñfr ea ugha ik, tkrsvkS oÅ ke fof/; ka }kjk iz kx'kkyk vka ea fufeZ fd, tkrsgÅ

ukfHkd ea/u vkosk i k/vkka dk gh gkrk gÅ i k/vk ij , dkd eny vkosk gkrk gS vkS ; g LFk; h d.k gÅ igys; g fopkj Fk fd ukfHkd eabyDVrnu gkrs gÅ ij Dok/e fl ¼kr ij vkekfjr rdkeoÅ dkj.k bl ekW; rk dksudkj fn; k x; kA fdl h ijek.kq oÅ l Hkh byDVrnu ml oÅ ukfHkd oÅ ckj gkrs gÅ ge tkurs gÅ fd l h ijek.kq oÅ ukfHkd oÅ ckj bu byDVrnu ka dh l s ; k

ml oð i jek. kq Øekad **Z**, oð cjkj gsrh gð vr% i jek. kq ea byðVRNUka dk ofy vkošk (-**ze**) ml oð ukfHkd oð ofy vkošk (+**ze**) oð cjkj gsrk gð D; kðd i jek. kqfo | qh; : i l smnl hu gsrk gð bl fy, fd l h i jek. kq oð ukfHkd ea i ts/KUka dh l ð; k] rF; r% bl dk i jek. kq Øekad] **Z** gsrh gð

U; w/RNU dh [kkst

D; kðd M; w/hfj; e , oa VRbfV; e gkbMRstU oð gh l eLFkkfud gð buea l s i R; d oð ukfHkd ea, d i ts/KU gskuk pfg, A yfdu gkbMRstU] M; w/hfj; e , oa VRbfV; e oð ukfHkdka oð nð; ekuka ea vuqkr 1 : 2 : 3 gð bl fy, M; w/hfj; e , oa VRbfV; e oð ukfHkdka ea i ts/KU oð vrfjDr oðN mnkl hu nð; Hkh gskuk pfg, A bu l eLFkkfudka oð ukfHkdka ea fo|eku mnkl hu vukfo"V nð; dh ek-k dks i ts/KU&nð; eku oð ek-kdka ea 0; Dr dja rks Øe'k% , d , oa nks ek-kdka oð yxHkx gsrk gð ; g rF; bñxr djrk gsf d i jek. kq/ka oð ukfHkdka ea i ts/KUka oð vrfjDr fo|eku jgus okyk ; g mnkl hu æ0; Hkh , d eny ek-kd oð xqktka oð : i ea gh gsrk gð bl ifjdYiuk dh i f"V] 1932 eð tEl pð/fod }kj dh xbZ ftUgkous nðkk fd tc cðjfy; e ukfHkdka ij , yHk d. ka (, yHk d. k] ghfy; e ukfHkd gsrk gð ftuoð fo"ka; ea ge vxysvuHkx ea pplz djæð dh cðNkj dh tkrh gð rks bul s oðN mnkl hu fofdj. k mRI ftz gsrk gð ; g Hkh ik; k x; k fd ; s mnkl hu fofdj. k] ghfy; e] dkcZ , oa ukbVRstU tð s gy oð ukfHkdka l s Vdjkdj mul s i ts/KU ckgj fudkyrs gð ml l e; rd Kkr , d elek mnkl hu fofdj. k i Qs/KU (fo|q pðdh; fofdj. k) gh Flk Åtlz , oa l øx l j (k. k oð fu; eka dk iz kx djus ij irk pyk fd ; fn ; s mnkl hu fofdj. k i Qs/KUka oð cus gsrk rks budh Åtlz mu fofdj. ka dh ryuk ea cgr vf/d gsrh tks cðjfy; e ukfHkdka ij , yHk d. ka dh cðNkj l s i klr gsrk gð bl l el; k oð l ek/ku dk l w] ft l s pð/fod us l rksktud <x l s gy fd; k] bl dYiuk ea l ekgr Flk fd mnkl hu fofdj. ka ea , d u, izkj oð mnkl hu d. k gsrk gð ftUga U; w/RNU dgrs gð Åtlz , oa l øx l j (k. k fu; eka dk mi; kx dj] mUgkous bl u, d. k dk æ0; eku Kkr djus ea l i Øyrk i klr dh] ft l s i ts/KU oð æ0; eku oð yxHkx cjkj ik; k x; ka

vc ge U; w/RNU dk æ0; eku vR; f/d ; FkFkzrk l s tkurs gð ; g gð

$$m_n = 1.00866 u = 1.6749 \times 10^{-27} \text{ kg} \tag{13.3}$$

U; w/RNU dh [kkst oð fy, pð/fod dks 1935 oð ukcsy ij l d l j l s l eekfur fd; k x; ka , d eðr i ts/KU oð foijhr , d eðr U; w/RNU vLFkk; h gsrk gð ; g , d i ts/RNU , d byðVRNU , oa, d ifru; w/uls (vU; eny d. k) oð : i ea {kf; r gls tkrk gð bl dh vks r vk; q yxHkx 1000 s gsrh gð rFkfi] ukfHkd oð Hkhrj ; g LFkk; h gsrk gð

vc] ukfHkd dh l j puk fuEufyf[kr inka , oa l øðr fpEka dk mi; kx djoð l e>k; h tk l drh gð

$$\mathbf{Z} - \text{i jek. kq Øekad} = \text{i ts/KUka dh l ð; k} \tag{13.4(a)}$$

$$\mathbf{N} - \text{U; w/ku l ð; k} = \text{U; w/RNUka dh l ð; k} \tag{13.4(b)}$$

$$\mathbf{A} - \text{æ0; eku l ð; k} = \mathbf{Z} + \mathbf{N} = \text{U; w/RNUka , oa i ts/KUka dh ofy l ð; k} \tag{13.4(c)}$$

i ts/KU , oa U; w/RNU oð fy, U; wDy; KU 'kcn dk Hkh mi; kx fd; k tk l drk gð vr% fd l h i jek. kq ea U; wDy; KU l ð; k ml dh æ0; eku l ð; k A gsrh gð

fd l h ukfHkd; iztkfr ; k ukfHkd dks l øðr fpÉ $\frac{A}{Z} X$ }kj inf'kz fd; k tkrk gð tgl; x ml iztkfr dk jkl; fud fpÉ gð mnkgj. k oð fy,] Lo. k&ukfHkd dks l øðr $^{197}_{79}\text{Au}$ }kj 0; Dr djrs gð bl ea 197 U; wDy; KU gsrk gð ftuea 79 i ts/KU , oa 118 U; w/RNU gsrk gð

vc fdl h rRo oð LeLFKfudka dh l jþuk dls l jyrk ls le>k; k tk l drk gð fdl h fn, x, rRo oð LeLFKfudka oð ukfHkdka ea i k/ku ka dh l ð; k rks leku gkrh gð i jarq os, d&nl js ls U; wRNUka dh l ð; k dh nf"V ls fHKUu gkrh gð M; wHfj; e ${}^2_1\text{H}$ tks gkbMstus dk, d LeLFKfud gð blea, d i k/ku, oa, d U; wRNU gkrh gð bl oð nl js LeLFKfud VRbfV; e ${}^3_1\text{H}$ ea, d i k/ku, oanks U; wRNU gkrh gð rRo Lo. l z oð 32 LeLFKfud gkrh gð ftudh æ0; eku l ð; k; kvka dk i jkl $A = 173$ ls $A = 204$ rd gkrh gð ; g ge igys gh crk pðð gð fd rRoka oð jkl k; fud xqk muoð byðVNUud fol; kl ij fuHkj djrs gð pðð] LeLFKfud i jek. kq/ka oð byðVNUud fol; kl leku gkrh gð mudk jkl k; fud 0; ogkj Hkh, d tð k gkrh gð vlg bl fy, mudks vkorz l kj. kh ea, d gh LFku ij j[kk tkrk gð

, d s l Hkh ukfHkd ftudh æ0; eku l ð; k A leku gkrh gð leHkfjd dgykrs gð mnkgj. kfkj ukfHkd ${}^3_1\text{H}$, oa ${}^3_2\text{He}$ leHkfjd gð, d sukfHkd ftudh U; wRNU l ð; k ${}^2_1\text{H}$ leku gks yfðu i jek. kq Øekad z fHKUu gks leU; wRNUud dgykrs gð mnkgj. kfkj ${}^{198}_{80}\text{Hg}$, oa ${}^{197}_{79}\text{Au}$ leU; wRNUud gð

13.3 ukfHkd dk l kb" k

tð k geus vè; k; 12 ea n[kk gð jnji O&MZ og vxz kh oðKkfud Fls ftUglaus i jek. kq ukfHkd oð vflrRo dh ifjdYiuk, oa LFkkiuk dha jnji O&MZ oð l ðko ij xhxj, oa ekl Mu us Lo. l z oð ood ij, YHKK d. kka oð izdh. kú ls l æð/r ifl ¼ iz; l x fd; ka muoð iz; l xka l s; g Li "V gqk fd 5.5 Mev xfrt Åtkz oð, YHKK d. kka dh Lo. l z ukfHkdka oð fudVLFk igpp dh njih yxHkx 4.0×10^{-14} m gð Lo. l z dh ijr ls α -d. kka oð izdh. kú dks jnji O&MZ us; g ekudj le>k; k fd izdh. kú oð fy, oðoy dnykðe dk ifrd"l z k cy gh mÚjnk; h gð pðð] /ukRed vkosk ukfHkd ea fufgr gkrh gð ukfHkd dk oklrfod l kb" k 4.0×10^{-14} m l s de gksuk pfg, A

; fn ge 5.5 Mev ls vf/d Åtkz oð α -d. k iz; l x dja rks buoð Lo. l z ukfHkdka oð fudVLFk igpp dh njih vlg de gks tk, xh vlg rc izdh. kú vyi i jkl ukfHkdh; cyka ls iHkkfor gksus yxsk vlg jnji O&MZ }kj fd, x, ifjdyuka ls ikr eku cny tk, xð jnji O&MZ oð ifjdyu, YHKK d. kka, oa Lo. l z ukfHkdka oð /ukosk ; ðr d. kka oð chp yxus okys 'kq4 dnykðe ifrd"l z k cy ij vk/kfjr gð ml njih oð }kj ftl ij jnji O&MZ oð ifjdyuka ea vkus okys varj Li "V gksus yxrs gð ukfHkdh; l kb" kka oð fo" k; ea fu" d" l z fudkyk tk l drk gð

, d s izdh. kú iz; l x djoð ftuea α -d. kka oð LFku ij rhoz xfr byðVNUka dh fofHKUu rRoka oð Åij c&Nkj dh xbz gð bu rRoka oð ukfHkdh; l kb" k vR; r ifj' kq4rk ls Kkr fd, x, A ; g ik; k x; k fd A æ0; eku l ð; k oð ukfHkd dh f=kt; k gð %

$$R = R_0 A^{1/3} \tag{13.5}$$

tgk $R_0 = 1.2 \times 10^{-15}$ mA bl dk vfkz gðfd ukfHkd dk vk; ru (tks R^3 oð vuðekuq krh gð) æ0; eku l ð; k A oð vuðekuq krh gkrh gð vr% ukfHkd dk ?kuRo fu; r gkrh gð vfkz] l Hkh ukfHkdka oð fy, bl dk eku A ij fuHkj ugha djrk gð fofHKUu ukfHkd bl fu; r ?kuRo oð æo dh çm dh rjg gkrh gð ukfHkdh; æ0; dk ?kuRo 2.3×10^{17} kg m⁻³ oð l fludV gkrh gð l keU; i nkFks dh rgyuk ea ?kuRo dk ; g eku cgr vf/d gkrh gð tð sty oð fy, ?kuRo oðoy 10^3 kg m⁻³ gh gkrh gð bl rF; dls vkl kuh ls le>k Hkh tk l drk gð D; kðd ; g ge igys gh n[kk pðð gðfd i jek. kq vf/dkð kr% Hkhrj l sfjDr gkrh gð l keU; i jek. kq/ka l s cus æ0; ea cMð ek=kk ea fjDr LFku gkrh gð

mngj. k 13.1 yksoð ukfHkd dk æ0; eku 55.85u , oaA=56 g) bl dk ukfHkd; ?kuRo Kkr dhft, A

gy

$$m_{Fe} = 55.85$$

$$u = 9.27 \times 10^{-26} \text{ kg}$$

$$\text{ukfHkd; ?kuRo} = \frac{\text{æ0; eku}}{\text{vk; ru}} = \frac{9.27 \times 10^{-26}}{(4\pi/3)(1.2 \times 10^{-15})^3} \times \frac{1}{56}$$

$$= 2.29 \times 10^{17} \text{ kg m}^{-3}$$

U; WNU rkjs (, d [lksy HKSrdh; fiM) eainkFkz dk ?kuRo bl ?kuRo oð l kfk rgyuh; gð ; g n'kkz gSfd bu rkja eaæ0; bl l hek rd l á hfMr glsx; k gSfd U; WNU rkjs Lo; a, d cMð ukfHkd dh rjg 0; ogkj djrs gð

13.4 æ0; eku&mQtKz rFkk ukfHkd; cæku&mQtKz

13.4.1 æ0; eku&Åtkz

vkblVku us viusfof'k"V vki s{kdrk fl ¼kr oð vk/kj ij ; g n'kkz k fd æ0; eku Åtkz dk gh , d n'jk : i gð fo'k"V vki s{kdrk fl ¼kr l sigys; g euk tkrk Fk fd fd l h vfHkF; k eaæ0; eku , oaÅtkz vyx&vyx l jf{kr gksr gð i jarq vkblVku us; g n'kkz k fd æ0; eku oðoy Åtkz dk n'jk : i gsvlS ge æ0; eku&Åtkz dls Åtkz oð vl; : i k ts puxfrt Åtkz eð ifjofr dj l drsgarFk foijhr i ðe vfkr Åtkz dls æ0; eku ea: i krfjr djuk Hk l lko gð bl oð fy, vkblVku us tks ifl ¼ æ0; eku&Åtkz l erf; rk l æ' fn; k og gS%

$$E = mc^2 \tag{13.6}$$

; gk E, æ0; eku m oð l erf; Åtkz gS, oa c fuokz ea izk'k dk ox gSft l dk l fludv eku $3 \times 10^8 \text{ m s}^{-1}$ gð

mngj. k 13.2 1 g inkfKz oð l erf; Åtkz dls ifjdfyr dhft, A

gy

$$\text{Åtkz } E = 10^{-3} \times (3 \times 10^8)^2 \text{ J}$$

$$E = 10^{-3} \times 9 \times 10^{16} \text{ J} = 9 \times 10^{13} \text{ J}$$

bl izkj] ; fn , d xte inkfKz dls Hk Åtkz ea: i krfjr fd; k tk, rlsbl l sÅtkz dh fo'ky ek=kk eðr gsrh gð

vkblVku oð æ0; eku&Åtkz l æ' dh i k; kSxd i q"V U; WNU; kkk ukfHkd k byðVNUka , oa vl; gky gh ea [ksts x, d. kka oð chp gksus okyh ukfHkd; vfHkF; kvka oð vè; ; u ea gks pph gð fd l h vfHkF; k ea Åtkz l j{k. k fu; e l svfHki k; gSfd ; fn æ0; eku l sl æ¼ Åtkz dls Hk ifjdyuka eal ffe fyr djarks i kjHkd Åtkz vñre Åtkz oð cjkcj gsrh gð ; g l adYi ukj ukfHkd dh i kjLi fj d vl; kð; fØ; kvka , oa ukfHkd; æ0; eku dls l e>us oð fy, egroi ukz gð ; gh vxys oðN vuhkkka dh fo"K; &olrq gð

13.4.2 ukfHkd; cæ'u&Åtkz

vuhkkx 13.2 ea geus nS'k fd ukfHkd U; WNU , oa i kS/WU dk cuk gð vr% ; g vi s{kr gSfd ukfHkd dk nð; eku bl eafo | eku U; WNUka , oa i kS/WUka oð nð; eku oð oðy ; kx Σm oð cjkcj gkskA yfdu] ukfHkd; nð; eku m, l nð Σm l sde i k; k tkrk gð mngj. k oð fy,] vkb,

$^{16}_8\text{O}$ dls ya bl ea 8 i ks/ku , oa 8 U; w/ru gð vr%

8 U; w/ru ka dk nð; eku = $8 \times 1.00866 \text{ u}$

8 i ks/ku ka dk nð; eku = $8 \times 1.00727 \text{ u}$

8 byðv/ ru ka dk nð; eku = $8 \times 0.00055 \text{ u}$

bl fy, $^{16}_8\text{O}$ oð ukfHkd dk vi s{kr æ0; eku = $8 \times 2.01593 \text{ u} = 16.12744 \text{ u}$

æ0; eku o. kðeeki h oð iz; ks/ka }kjk i klr $^{16}_8\text{O}$ dk i jek. kqæ0; eku 15.99493 u gð bl ea

l s 8 byðv/ ru ka dk æ0; eku ($8 \times 0.00055 \text{ u}$) ?k/vkus ij $^{16}_8\text{O}$ oð ukfHkd dk i k; k/sxd eku 15.99053 u gð

vr%ge i krs gðfd vki l htu $^{16}_8\text{O}$ ukfHkd dk æ0; eku] bl oð ?k/vdka oð oþy æ0; eku l s 0.13691 u de gð ukfHkd oð æ0; eku, oa bl oð ?k/vdka oð æ0; eku oð v rj ΔM , dls æ0; eku {kfr dgrsgð v/s bl dk eku bl çdkj 0; Dr fd; k tkrk gS%

$$\Delta M = [Zm_p + (A - Z)m_n] - M \quad (13.7)$$

æ0; eku {kfr dk vFlz D; k gS ; gha ij vkb/vkbu dk æ0; eku & Åtkl l erþ; rk fl ¼kr viuh Hkfedk fuHkrk gð pfd] vki l htu ukfHkd dk æ0; eku bl oð ?k/vdka oð æ0; eku oð ; ks (vci/r volFlk ea 8 i ks/ku , oa 8 U; w/ru dk) l s de gkrk gð vki l htu ukfHkd dh l erþ; Åtkl bl oð ?k/vdka dh l erþ; Åtkl/ka oð ; ks l s de gkrh gð ; fn vki vki l htu ukfHkd dls 8 i ks/ku ka, oa 8 U; w/ru ka ea fo[kamr djuk pka rls vki dls ; g vfrfjDr Åtkl $\Delta M c^2$, bl ukfHkd dls inku djuh gkschA bl oð fy, vko' ; d ; g Åtkl E_b , æ0; eku {kfr l s fuEufyf[kr l ehdj.k }kjk l æ0/r gkrh gS%

$$E_b = \Delta M c^2 \quad (13.8)$$

mngkj. k **13.3**, d i jek. kqæ0; eku ekkd oð l erþ; Åtkl dk eku igystw v/s fi 0j Mev ea klr dhft, A bl dk mi ; ks djoð $^{16}_8\text{O}$ dh æ0; eku {kfr Mev/c² ea0; Dr dhft, A

gy

$$1u = 1.6605 \times 10^{-27} \text{ kg}$$

bl dls Åtkl oð ekhdka ea i fjofrþ djus oð fy, ge bl dls c² l s xqkk djrs gð, oa i krs gð fd bl oð

$$\begin{aligned} \text{l erþ; } \dot{A}tkl &= 1.6605 \times 10^{-27} \times (2.9979 \times 10^8)^2 \text{ kg m}^2/\text{s}^2 \\ &= 1.4924 \times 10^{-10} \text{ J} \end{aligned}$$

$$= \frac{1.4924 \times 10^{-10}}{1.602 \times 10^{-19}} \text{ eV}$$

$$= 0.9315 \times 10^9 \text{ eV}$$

$$= 931.5 \text{ MeV}$$

vFlk 1u = 931.5 MeV/c²

$$\begin{aligned} ^{16}_8\text{O} \text{ oð fy, } \Delta M &= 0.13691 \text{ u} = 0.13691 \times 931.5 \text{ MeV}/c^2 \\ &= 127.5 \text{ MeV}/c^2 \end{aligned}$$

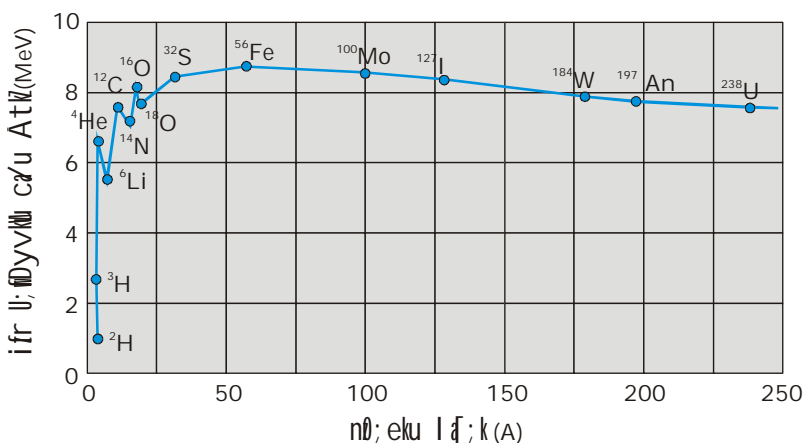
∴ $^{16}_8\text{O}$ dls bl oð ?k/vdka ea foHkrftr djus oð fy, vko' ; d Åtkl 127.5 MeV/c² gð

; fn oðN U; w/ru ka, oa i ks/ku ka dls i kl & i kl ykdj] fuf'pr vko'sk, oanð; eku okyk, d ukfHkd cuk; k tk, rls bl i f0; k ea ΔE_b m0tkl eþr gkschA ; g m0tkl ΔE_b ukfHkd dh

cæku&m0tkz dgykrh gA ; fn gea fdl h ukfHkd o0 ukfHkd&d. kka dks vvx&vyx djuk gks rks gea bu d. kka dks ofy m0tkz E_b , inku djuh gksxA ; |fi ukfHkd dks ge bl izdkj rksM+ ugha l dr3 fi 0j Hkh] ukfHkd dh cæku&m0tkz ; g rks crkrh gh gSfd fdl h ukfHkd ea U; fDy; kU ijLij fdruh vPNh rjg l s tPis gA ukfHkd o0 d. kka dh cæku 'kfDr dk , d vk3 vfeld mi; ksch eki cæku&m0tkz ifr U; fDy; kU] E_{bn} gS tks fd ukfHkd dh cæku&m0tkz E_b , oa bl ea fo |eku U; fDyv kUka dh l 4; k A dk vuq kr gA

$$\Delta E_{bn} = \Delta E_b / A \tag{13.9}$$

ge ifr U; fDy; kU cæku&m0tkz dks , d k eku l drs gA fd ; g fdl h ukfHkd dks bl o0 U; fDyv kUka ea i fKDÑr djus o0 fy, vko' ; d vk3 r m0tkz gA



fp-k 13.1 æ0; eku l 4; k o0 i0yu o0 : i ea ifr U; fDy; kU cæu&Åtkz

fp-k 13.1 ea cgr l s ukfHkdka o0 fy, ifr U; fDy; kU cæku m0tkz E_{bn} , oa n0; eku l 4; k A ea xki 0 fn [kk; k x; k gA bl xki 0 ea gea fuEufyf[kr y{k.k ij fo' ksk n' Vxkpj gksrgA

- (i) e0; orhZ æ0; eku l 4; k vka (30 < A < 170) o0 fy,] ifr U; fDy; kU cæku&Åtkz E_{bn} , dk eku 0; kogkfjd : i ea fu; r jgrk gS vfkZr ijek.kq 0ekad o0 l kfk i fjoFrZ ugha gsrk gA o0 A = 56 o0 fy, yxHlx 8.75 MeV dk vf/dre eku , oa A = 238 o0 fy, 7.6 MeV n' kZrk gA
- (ii) gyo0 ukfHkdka (A < 30) , oa Hkhjh ukfHkdka (A > 170) nkska o0 fy, gh E_{bn} dk eku e0; orhZ ijek.kq 0ekad o0 ukfHkdka dh rgyuk ea vi3kÑr de gsrk gA

bl izdkj fuEu fu"d"ke: ij igp l drs gA %

- (i) ; g cy vkd"khZ gSrFk ifr U; fDy; kU o0N MeV cæu mri lu djus o0 fy, i ; kZr 3cy gA
- (ii) 30 < A < 170 o0 ijkl ea cæu&Åtkz dh vprk bl rF; dk ifj. ke gSfd ukfHkdh; cy y?kqijkl h cy gksrgA cMs ukfHkd o0 Hkhrj fLFkr fdl h U; fDy; kU ij fopkj dhft, A ; g viusikl & iMl o0 o0oy mu U; fDyv kUka l s i Hkkrfor gksk tks bl o0 ukfHkdh; cy o0 ifjlj ea vkrsgA ; fn dksZ vU; U; fDy; kU bl fo' k'V U; fDy; kU o0 ukfHkdh; cy o0 ifjlj l svf/d njih ij gS rks ; g fopkj/hu ukfHkd dh cæu&Åtkz dks rfud Hkh i Hkkrfor ugha djxkA ; fn fdl h ukfHkd o0 ukfHkdh; cy o0 ifjlj ea vfeldre p U; fDy; kU gks l drs gl3 rks bl dh cæu&Åtkz p o0 vu0ekuq krh gksxA ekuk fd fdl h ukfHkd dh cæu&Åtkz pk gS tgk k , d fu; rkd gSft l dh foek, j ogh gA tks Åtkz dh gsrh gA vc ; fn ge U; fDy; kUka dh l 4; k c < kdj A dk eku c < k, } rks bl l sukfHkd o0 Hkhrj U; fDy; kUka dh cæu&Åtkz i Hkkrfor ugha gksxA D; kfd] fdl h Hkh cMs ukfHkd ea vfeldk k U; fDy; kU bl o0 Hkhrj jgrsgSrFk i "B dh vi3k] ukfHkd dh cæu&Åtkz ij A dh of¼ dk ofy i Hkko ux. ; jgrk gA vr% ifr U; fDy; kU cæu&Åtkz fu; r jgrh

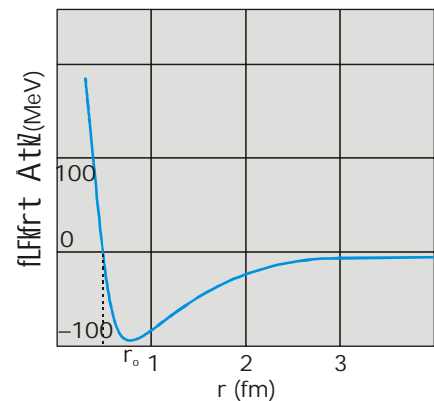
gSvlg bl dk l fludV eku **pk** oð cjkj gsrk gð ukfHkdla dk og xqk ftl oð dkj. k dksz ukfHkd oðoy vi usfudV oð ukfHkdla dksgh i Hkkfor djrk gð ukfHkd; cyka dk l rfr xqk dgykrk gð

- (iii) , d vr; f/d Hkkjh ukfHkd] tS s $A = 240$, dh ifr U; fDy; klu ca/u&Åtlz $A = 120$ oð ukfHkd dh rgyuk eade gsrh gð vr% ; fn $A = 240$ dk dksz ukfHkd] $A = 120$ oð nls ukfHkdla eaVvrk gsrk bueal; fDy; klu vf/d n<rk l sifj ¼ gkæd ; g bñx djrk gsf d bl i fØ; k ea Åtlz foedr gsrhA ; g fo [klu } jkj Åtlz foedr gks dh egroi wZ l bkkouk dks vfHk; Dr djrk gsf ftl oð fo" k; ea ge vutkx 13.7.1 ea pplz djæd
- (iv) dYiuk dhft, fd nls gyoð ukfHkd ($A \leq 10$) l ay; r gkæd , d Hkkjh ukfHkd cukrs gð l ay; u } jkj cus bl Hkkjh ukfHkd dh ifr U; fDy; klu ca/u&Åtlz gyoð ukfHkdla dh ifr U; fDy; klu çaku Åtlz l svf/d gsrh gð bl dk vFZ; g gprk fd vñre fudk; ead. k i kjæHkd fudk; dh rgyuk ea vf/d n<rk l scñ/r gð ; gk l ay; u dh bl i fØ; k ea Hk Åtlz foedr gsrhA ; gh l wZ dh Åtlz dk l r gsf ftl oð fo" k; ea ge vutkx 13.7.3 ea pplz djæd

13.5 ukfHkd; cy

og cy tks i jek. kqea byDV klu dh xfr fu; ðr djrk gSgekjk l qj fpr dnykæ cy gð vutkx 13.4 ea geus nqk fd vls r æo; eku oð ukfHkd oð fy, ifr U; fDy; klu ca/u&Åtlz yxHkx 8 MeV gS tks i jek. kq dh ca/u&Åtlz dh rgyuk ea çgy vf/d gð vr% ukfHkd ea d. ka dks ijLij çk/sj [kus oð fy, , d fHku izdkj oð 'kDr' kkyh vkd"lz k cy dh vko' ; drk gð ; g cy bruk vf/d 'kDr' kkyh gsk pkfg, fd (/uko' kr) i klu oð chp yxs ifrd"lz k cyka l svf/d i Hkkoh gkæd i klu, oal; wru kankak dks ukfHkd oð l qe vk; ru ea çk/sj [k l oð ge ; g igysgh nqk ppe gsf d ifr U; fDy; klu ca/u Åtlz dh vpjrk dks bu cyka dh y?k ijkl h i ñfr l sle>k tk l drk gð ukfHkd; ca/u cyka oð oqN vfHky {k. ka dks l qis ea uhpfn; k x; k gð ; g Kku 1930 l s 1950 oð chp fd, x, fo fHku iz kxka } jkj i l r gprk gð

- (i) ukfHkd; cy vko' kka oð chp yxus okys oðy kæ cy , oaz o; eku oð chp yxus okys x#rok d"lz k cy dh rgyuk ea vr; f/d 'kDr' kkyh gsrk gð ukfHkd; ca/u cy dks ukfHkd oð Hkrj i klu oð chp yxus okys oðy kæ ifrd"lz k cy ij vkf/i r; djuk gsrk gð ; g bl hfy, l bko gls i krk gð D; kãd ukfHkd; cy oðy kæ cyka dh rgyuk ea vr; f/d çcy gsrk gð x#rok d"lz k cy rks oðy kæ cy dh rgyuk ea Hk vr; r nqz gsrk gð
- (ii) U; fDy v klu oð chp njh c<kdj oqN i SEV kHVj l svf/d dju s ij muoð chp yxus okyk ukfHkd; cy r s' h l s?KVdj 'klu; gsk tkrk gð bl dkj. k] vls r vFkok cMs l kb" k oð ukfHkdla ea ^cyka dh l r r r k dh flFfr vk tkrh gS ftl oð i j. kelo: i ifr U; fDy; klu ca/u&Åtlz fu; r gsk tkrh gð nls ukfHkdla dh flFfrt Åtlz vlg muoð chp dh njh ea l ea' n' kuz okyk , d vi fj" ñr vkjçk fpæ 13.2 ea n' kZ; k x; k gð yxHkx 0.8 fm dh njh r_0 ij flFfrt Åtlz dk eku U; wre gsrk gð bl dk vFZ; g gprk fd ; fn ukfHkdla oð chp njh 0.8 fm l svf/d gsrh gsrk; scy vkd"lz k cy gsrk gð vlg 0.8 fm l s de nñj; ka oð fy, ; s ifrd"lz k cy gsrk gð



fpæ 13.2 , d ukfHkd; ; ðe dh flFfrt Åtlz muoð chp dh njh oð i ðy oð : i ea r_0 l svf/d njh gks ij cy vkd"lz k cy gsrk gS, oar, l s de njh ij rho: ifrd"lz k cy vkd"lz k cy l okZ/d çcy rc gsrk gS tc ukfHkdla oð chp dh njh r_0 gsrh gð

(iii) U; $\nu_{\text{RNU}} \& \text{U}; \nu_{\text{RNU}} \text{ U}; \nu_{\text{RNU}} \& \text{i } \nu_{\text{RNU}} \text{ , oa i } \nu_{\text{RNU}} \& \text{i } \nu_{\text{RNU}} \text{ o\ddot{a}} \text{ chp yxus okys ukfHkdh; cy yxHlx l eku ifjek.k o\ddot{a}} \text{ glrs g\ddot{a}} \text{ ukfHkdh; cy fo|r vko\ddot{s} ka ij fuHkj ugha djr\ddot{a}} \text{ o\ddot{a}} \text{ yk\ddot{a}} \text{ o\ddot{a}} \text{ fu; e vFlok U; Wu o\ddot{a}} \text{ x\ddot{a}Roh; fu; e dh Hk\ddot{a}fr ukfHkdh; cyka dk dksz l jy xf.krh; : i ugha g\ddot{a}}$

13.6 j\ddot{s}M; k\ddot{s} \ddot{s}DVork

j\ddot{s}M; k\ddot{s} \ddot{s}DVork dh [k\ddot{s}t , -, p- c\ddot{o}b\ddot{a}jy us l u-1896 ea l a k\ddot{s}o'k dh\ddot{a} ; k\ddot{s}x dka dksn' ; idk'k l sfodh\ddot{e}.kr djo\ddot{a}} \text{ mudh i frnhflr , oa Li \ddot{a}jnhflr dk v\ddot{e}; ; u djrs g\ddot{a}} \text{ c\ddot{o}b\ddot{a}jy us, d jkpd i fj?kVuk n\ddot{s}k\ddot{a} ; j\ddot{s}u; e\ddot{a} i k\ddot{s}'k; e l Yi \ddot{a}v o\ddot{a}} \text{ o\ddot{a}N V\ddot{a}pM\ddot{a} ij n' ; idk'k Mkyus o\ddot{a}} \text{ ckn ml us mudk\ddot{s} dks dks'k ea yi\ddot{v} fn; ka bl i \ddot{a}v v\ddot{a}g\ddot{a}} \text{ H\ddot{a}k\ddot{s}/k\ddot{s}k\ddot{f}H\ddot{a}d ly\ddot{v} o\ddot{a}} \text{ chp , d plqh dk V\ddot{a}pM\ddot{a} j [k\ddot{a} bl h idkj dbz ?k\ddot{a}v\ddot{r}d j [kus o\ddot{a}} \text{ ckn tc H\ddot{a}k\ddot{s}/k\ddot{s}k\ddot{f}H\ddot{a}d ly\ddot{v} dks M\ddot{o}syi fd; k x; k rks ; g ik; k x; k fd ; g ly\ddot{v} dkyh i M+p\ddot{a}ph Fk\ddot{a} ; g fd l h , \ddot{a} h ph'k o\ddot{a}} \text{ dkj.k g\ddot{a}v\ddot{a}k glsk\ddot{a} t\ddot{k} ; k\ddot{s}x d l smRI ft\ddot{z} g\ddot{a}z glsk\ddot{a} rFk\ddot{a} dks dks'k v\ddot{a}g\ddot{a}} \text{ plqh nks\ddot{a} dks H\ddot{a}n dj H\ddot{a}k\ddot{s}/k\ddot{s}k\ddot{f}H\ddot{a}d ly\ddot{v} rd i g\ddot{a}p xbz glsk\ddot{a}}

ckn ea fd , x , iz k\ddot{s}ka us n' k\ddot{z} k fd j\ddot{s}M; k\ddot{s} \ddot{s}DVork , d ukfHkdh; i fj?kVuk g\ddot{s} ft l ea vLFk\ddot{a}; h ukfHkd {k; r glsk\ddot{a} g\ddot{a} bl s j\ddot{s}M; k\ddot{s} \ddot{s}DVo {k; dgrs g\ddot{a} i \ddot{N}fr ea rhu idkj o\ddot{a}} j\ddot{s}M; k\ddot{s} \ddot{s}DVo {k; glrs g\ddot{a} %

- (i) α -{k; } ft l ea ghfy; e ukfHkd (^4He) mRI ft\ddot{z} glrs g\ddot{a}
- (ii) β -{k; } ft l ea by\ddot{D}V\ddot{R}M vFlok i k\ddot{a}h\ddot{v}R\ddot{M} (, \ddot{a} sd.k ft l dk \ddot{a}o; eku rks by\ddot{D}V\ddot{R}M o\ddot{a}} \text{ cjk\ddot{a}j gh glsk\ddot{a} g\ddot{s} ij vko\ddot{s}k Bh\ddot{a}d by\ddot{D}V\ddot{R}M o\ddot{a}} \text{ foijhr glsk\ddot{a} g\ddot{s} mRI ft\ddot{z} glrs g\ddot{a}}
- (iii) γ -{k; } ft l ea mPp \ddot{A}t\ddot{z} (100 keV vFlok vf/d) i \ddot{a}k\ddot{a} mRI ft\ddot{z} glrs g\ddot{a} buea i R; \ddot{a}d idkj o\ddot{a}} {k; ij v\ddot{a}k\ddot{e}h mi vu\ddot{a}k\ddot{a} ea fopkj fd; k tk, x\ddot{a}

13.6.1 j\ddot{s}M; k\ddot{s} \ddot{s}DVo {k; rk dk fu; e

fd l h j\ddot{s}M; k\ddot{s} \ddot{s}DVo ueus ea ft l ea α, β vFlok γ -{k; } gls jgk gl\ddot{s} ; g ik; k tkrk g\ddot{s}fd , dka\ddot{a} l e; ea {k; r gls okys ukfHkd\ddot{a} dh l \ddot{a}; k] ueus ea fo|eku o\ddot{a}} \text{ ukfHkd\ddot{a} dh l \ddot{a}; k o\ddot{a}} \text{ vu\ddot{a}k\ddot{a} krh glsk\ddot{a} g\ddot{a} ; fn fn, x, ueus ea ukfHkd\ddot{a} dh l \ddot{a}; k \ddot{N} gls v\ddot{a}g\ddot{a}} \Delta t l e; ea \Delta \ddot{N} ukfHkd {k; r gls jgs gla rks

$$\frac{\Delta N}{\Delta t} \propto N$$

$$\text{vFlok, } \Delta \ddot{N} / \Delta t = \lambda \ddot{N} \tag{13.10}$$

tg\ddot{a} λ j\ddot{s}M; k\ddot{s} \ddot{s}DVo {k; & fLFkj\ddot{a}d vFlok fo?kVu&fLFkj\ddot{a}d g\ddot{a}

Δt l e; ea fn, x, ueus* ea ukfHkd\ddot{a} dh l \ddot{a}; k ea g\ddot{a}v\ddot{a}k i fjor\ddot{z} g\ddot{s} d\ddot{N} = - \Delta \ddot{N} \text{ vr\ddot{a}} (tc $\Delta t \rightarrow 0$) rks \ddot{N} ea i fjor\ddot{z} dh nj g\ddot{a}

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

* $\Delta \ddot{N}$ {k; r ukfHkd\ddot{a} dh l \ddot{a}; k g\ddot{s} vr\ddot{a} bl dk eku l n\ddot{b} /uk\ddot{r}ed glsk\ddot{a} g\ddot{a} \ddot{a}\ddot{N}, \ddot{N} ea i fjor\ddot{z} g\ddot{s} v\ddot{a}g\ddot{a} bl dk dksz H\ddot{h} fp\ddot{E} gls l drk g\ddot{a} ; g\ddot{a}; g $\frac{1}{2}$. k\ddot{r}ed g\ddot{s}d; k\ddot{f}d] ey \ddot{N} ukfHkd\ddot{a} ea \Delta \ddot{N} {k; r gls tkr\ddot{s} g\ddot{a} v\ddot{a}g\ddot{a}} (\ddot{N} - \Delta \ddot{N}) 'k\ddot{s} jgrs g\ddot{a}

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

bl l ehdj.k dk nksuka vlg l ekdyu djus ij]

$$\int_{N_0}^N \frac{dN}{N} = -\lambda \int_{t_0}^t dt \tag{13.11}$$

$$vFkok \ln N - \ln N_0 = -\lambda (t - t_0) \tag{13.12}$$

; gk N_0 , fdl h ; knfPNd {k.k t_0 ij jSM; ks SDVo ukfHkdla dh l λ ; k gB $t_0 = 0$ j [kdj

l ehdj.k (13.12) dks i q0; bflFkr djus ij]

$$\ln \frac{N}{N_0} = -\lambda t \tag{13.13}$$

ftl l sgea i klr gsrk gB

$$N(t) = N_0 e^{-\lambda t} \tag{13.14}$$

è; ku nss ; k ; ckr ; g gSfd fo | r cYc , d sfd l h pj ?krkadh {k; fu; e dk ikyu ugha djrWA ; fn ge 1000 cYcadh vk; q (og dky foLrfr ft l oB ckn osY; wk gkrs) dk i jh{k.k dja rts ge ; g vk'kk djars fd ; s l Hkh yxHkx , d l kfk {kf; r (Y; wk) gks tk, xA jSM; ks ukfHkdla dk {k; , d i wkr-% fHku fu; e] ml jSM; ks SDVo & {k; rk fu; e oB vuq kj gsrk gB tks l ehdj.k (13.14) }kjk 0; Dr fd; k x; k gB

gekjh #fp ik; % N , oB LFku ij {k; rk nj $R (= -dN/dt)$ tkuus ea vfekd gsrh gB

bl l sgea i fr , dhkd l e; ea {kf; r gksokys ukfHkdla dh l λ ; k i klr gsrh gB mnkgj.k oB fy,] eku yhf, gekjs ikl jSM; ks SDVo inkfz dh oBN ek-kk gB gea ; g tkuus dh vko'; drk ugha gSfd ml eafdrus ukfHkd gB yfdu ge fn, x, l e; varjky 10 l oBM ; k 20 l oBM eabl l smRI ftz gksokys α, β ; k γ d.kkadh l λ ; k eki l drsgB vxj ge l e; varjky dt oB fy, eki u dja vlg vius eki d ; ak ea {kf; r d.kkadh l λ ; k $\Delta N (= -dN)$ ik, j rts {k; rk nj R dks ge fuEuor i fjHkr"kr dj l drsgB

$$R = -\frac{dN}{dt}$$

l ehdj.k (13.14) dk vodyu djus ij]

$$R = -\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$$

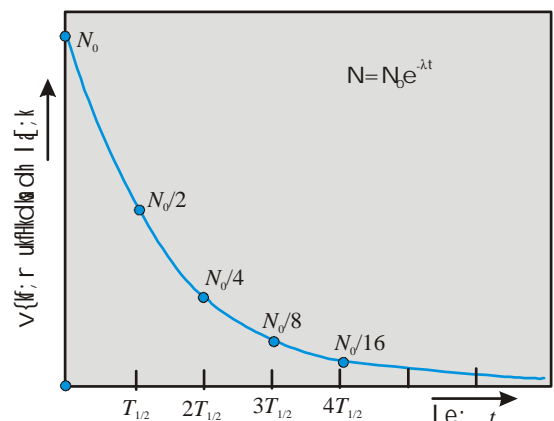
$$vFkok R = R_0 e^{-\lambda t} \tag{13.15}$$

; g jSM; ks SDVo {k; rk fu; e l ehdj.k (13.14) dk , d oBfyid : i gB ; gk R_0 l e; $t = 0$ ij jSM; ks SDVo {k; rk nj , oa R, t l e; ckn {k; rk nj gB vc ge l ehdj.k (13.10) dks ueus dh {k; rk nj R oB inkæ eabl izkj fy [k l drsgB

$$R = \lambda N \tag{13.16}$$

tgk R vlg {kf; r gks l scps jSM; ks SDVo ukfHkdla dh l λ ; k , d gh {k.k ij kkr dh tkuh pfg, A

, d ; k vfekd jSM; ks ukfHkdla oB fdl h ueus dh oBy {k; rk nj ml ueus dh l f0; rk (, SDVork) dgykrh gB , SDVork dk si ekhd chBjy (irhd Bq) gS tks jSM; ks SDVork oB vloBkd gsjh chBjy dh lefr eafuf'pr fd; k x; k gB



fp=k 13.3 jSM; ks SDVo iztkfr; ka dk pj?krkadh {k; A iR; d $T_{1/2}$ l e; oB i'pkr nh xbz iztkfr dh l λ ; k vk/h jg tkrh gB

1 cðbjy = 1Bq = 1 {k; ifr l oðM

, d nlljk ekkd D; yjh (irhd ci) Hkh l keld; ipyu ea gð

1 D; yjh = 1 Ci = 3.7 x10¹⁰ Bq



eðh LDyMkðdk D; yjh (1867-1934)

eðh LDyMkðdk D; yjh (1867-1934) i kyM ea tlehA HkðrdfoKkuh , oajl k; uK nkuka: ila ea igpku feyhA 1896 ea gsjh cðbjy }kjk jðM; k; sDVork dh [kst useðh vð muds ifr fi ; jsD; yjh dks muoð vuð a'kuka , oa fo' ySk. Ma oð fy, ifjr fd; kj ftl oð iðyLo: i rRokp jðM; e , oa i kyku; ep dk i FkDdj.k l ðlko gðvA og i Fke oKkfud FkafUgans ukcsy ijLdkj i klr gq % igyk 1903 ea Hkðrdh oð fy, vð nlljk 1911 ea jlk; ufoKku oð fy, A

, d fn, x, izlkj dk jðM; kskfHkd fdruh nj cuk jgðk bl seki us oð nlljk keld; eki nlljk gð , d gðml dh v/ðvk; q (T_{1/2}) ; g og le; gðftl eð N , oa R nkuka eal s i R; d] vius vkjðHkd eku dk vkðk jg tkrk gð vð nlljk eki nlljk gðvð rðvk; q(τ) ; g og le; gð ftl ea N , oa R vius vkjðHkd eku oð e⁻¹ gsk tkrsgð

v/ðvk; q(T_{1/2}) , oafowu&fu; rkd (λ) eal æk LFkfi r djusoð fy, ge lehdj.k (13.15) ea t = T_{1/2} , oa R = (1/2) R₀ j [krsgð vð T_{1/2} dk eku fudkyrs gð rc

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} \tag{13.17}$$

vð r vk; q; k ekè; vk; q dk eku lehdj.k (13.14) dk mi ; kx djoð Hkh Kkr fd; k tk l drk gð dky&vrjky t , oa (t + Δt) ea {kf; r gks okys ukfHkdla dh l ð; k R(t)Δt = (λN₀e^{-λt}Δt) gð bu ea l s i R; d t le; rd fo leku jgk gð vr% bu l Hkh ukfHkdla dk oðy thou dky t λN₀e^{-λt} Δt gskA ; g Li "V gðfd bu ea l soðN ukfHkd vYidky oð fy, tcfv vð; viðkkr nh?kdky rd cus jgkA bl fy, ekè; vk; q Kkr djusoð fy, geabl 0; ad dkj o l s ∞ rd oð le; ka oð fy,] ; kx (; k lekyu) djoð ml s t = 0 ij ukfHkdla dh oðy l ð; k N₀ l s foHkfrtr djuk gskA vr%

$$\tau = \frac{\lambda N_0 \int_0^{\infty} te^{-\lambda t} dt}{N_0} = \lambda \int_0^{\infty} te^{-\lambda t} dt$$

bl dk lekyu djoð ge ; g n'kz l drsgðfd

$$\tau = 1/\lambda$$

bu ifj. kka dks ge l ðki ea bl izlkj 0; Dr dj l drsgð%

$$T_{1/2} = \frac{\ln 2}{\lambda} = \tau \ln 2 \tag{13.18}$$

, s jðM; k; sDVork rRo ftudh v/ðvk; qfo' o dh vk; q(13.7 vjc o"l dh rgyuk eacgr de gð orðku eð i ðfr eal ðk. kh; ek-k eami yC/ ugha gð rFkfi osiz; kx' kkykvla ea ukfHkdh; vfHkð; kvla ean ðks x, gð VrbV; e , oa lyvksu; e bl h Js kh ea vkrsgð

mngj. k 13.4

mngj. k 13.4 {kf; r gsk jgs ²³⁸₉₂U dh] α&k; oð fy, v/ðvk; q 4.5 x10⁹ o"l gð ²³⁸₉₂U oð 1 g ueus dh , sDVork D; k gð

gy

$$T_{1/2} = 4.5 \times 10^9 \text{ y} = 4.5 \times 10^9 \text{ y} \times 3.16 \times 10^7 \text{ s/y}$$

$$= 1.42 \times 10^{17} \text{ s}$$

fdl h l eLFKfud oð 1 kmol ea vlokakæls l d; k oð cjkj i jek. kqgkrs gð vr% 1g,

$${}^{238}_{92}\text{U} \text{ ea i jek. kq/ka dh l d; k} \frac{1}{238 \cdot 10^{23}} \text{ kmol} \times 6.025 \times 10^{26} \text{ i jek. kq/kmol}$$

$$= 25.3 \times 10^{20} \text{ gð}$$

∴ {k; rk nj R gð}

$$R = \lambda N$$

$$= \frac{0.693}{T_{1/2}} N = \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} \text{ s}^{-1}$$

$$= 1.23 \times 10^4 \text{ s}^{-1}$$

$$= 1.23 \times 10^4 \text{ Bq}$$

mngj. k 13.4

mngj. k 13.5 β&{k; } kjk VrbfV; e dh v/&vk; q 12.5 o"lz gð 25 o"lz ckn 'kq/ka VrbfV; e oð , d ueus dk fdruk v&k vfo?kfvR jgsk\

gy i fjHk"lk oð vuq kj 12.5 o"lz ckn VrbfV; e oð ueus dk ∈ Hkkx cpskA vxys 12.5 o"lz ea bl vk&sk dk fi Oj vk&sk ; kuh ∈ Hkkx cpskA vr% 25 l ky ckn 'kq/ka VrbfV; e oð fdl h ueus dk ∈ vfo?kfvR Hkkx cpskA

mngj. k 13.5

13.6.2 , Yl&{k; }

tc fdl h ukfHkd ea , Yl&{k; } g&sk g&srks, d , Yl&{k; } d. k (, d ghfy; e ukfHkd) ${}^4_2\text{He}$ oð mRl t& } kjk ; g , d fHku ukfHkd ea: i karj&r g&s t&rk g& mngj. k oð fy,) tc ${}^{238}_{92}\text{U}$ ea , Yl&{k; } g&sk g&srks; g ${}^{234}_{90}\text{Th}$ ea: i karj&r g&s t&rk g&s



bl i f& ; k e& ; g n&lk x; k g&sf&d ${}^4_2\text{He}$ ea 2 i k&v&v& , oa 2 U; v&v&v& g&ks oð dkj. k] fo?kfv&t ukfHkd dh n& ; eku l d; k , oa i jek. kq Ø&kl& Ø&'k% 4 , oa 2 de g&s t&rk g& vr% fdl h ukfHkd ${}^A_Z\text{X}$ oð ukfHkd ${}^{A-4}_{Z-2}\text{Y}$ ea: i karj. k d&ks bl i&lkj 0; Dr dj l drsg&μ



t&g& ${}^A_Z\text{X}$ e&y ukfHkd , oa ${}^{A-4}_{Z-2}\text{Y}$ fo?kfv&t ukfHkd g&

${}^{238}_{92}\text{U}$ dk , Yl&{k; } Lor% (fcuk fdl h ck& m&tl& i'kr oð) g&s l drk g& D; k&d {k; &mRi kn& ${}^{234}_{90}\text{Th}$, oa ${}^4_2\text{He}$, dk o&fy n& ; eku e&y ukfHkd ${}^{238}_{92}\text{U}$ oð n& ; eku l s de g& bl i&lkj] {k; &mRi kn& oð fy, o&fy n& ; eku&m&tl& e&y ukfHkd dh n& ; eku&m&tl& l s de g& i kj&Hkd n& ; eku&m&tl& , oa {k; mRi kn& dh o&fy n& ; eku&m&tl& dk vr&j] bl i f& ; k dk g eku v&flok fo?kfv&t m&tl& dg&y&rk g& vr% , Yl&{k; } dk g eku ge bl i&lkj 0; Dr dj l drsg&μ

$$Q = (m_X - m_Y - m_{\text{He}}) c^2 \quad (13.21)$$

; g m&tl& fo?kfv&t ukfHkd ${}^{A-4}_{Z-2}\text{Y}$, oa , Yl&{k; } d. k ${}^4_2\text{He}$ n&sk& ea x&frt &tl& oð : i ea c&v t&rh g& , Yl&{k; } l e&hdj. k (13.14) , oa (13.15) } kjk 0; Dr j&f&M; k& s&DVork oð fu; e dk vuq&kyu d&j&rk g&

mngj .k **13.6** geafuEufyf [kr ijek.kqæ0; eku fn, x, gð %

$${}_{92}^{238}\text{U} = 238.05079 \text{ u} \quad {}_2^4\text{He} = 4.00260 \text{ u}$$

$${}_{90}^{234}\text{Th} = 234.04363 \text{ u} \quad {}_1^1\text{H} = 1.00783 \text{ u}$$

$${}_{91}^{237}\text{Pa} = 237.05121 \text{ u}$$

; gk irhd Pa rRo iKV, fDVfu; e (Z = 91) rRo oð fy, gð

(a) ${}_{92}^{238}\text{U}$ oð α & {k; eamRI ftz mQtiz ifjdfyr dhft, A

(b) n'kkð, fd ${}_{92}^{238}\text{U}$ Lor% iKV/mRI mRI tzu ughadj l drkA

gy

(a) ${}_{92}^{238}\text{U}$ dk , α & {k; l ehdj.k (13.20) oð vuq kj gsrk gð bl if0; k eamRI ftz mQtiz oð fy, l kk gð %

$$Q = (M_{\text{U}} - M_{\text{Th}} - M_{\text{He}}) c^2$$

izu eafn, x, vkvMsmijkDr l kk ea ifrLFKfir djus ij]

$$\begin{aligned} Q &= (238.05079 - 234.04363 - 4.00260) \text{ u} \times c^2 \\ &= (0.00456 \text{ u}) c^2 \\ &= (0.00456 \text{ u}) (931.5 \text{ MeV/u}) \\ &= 4.25 \text{ MeV} \end{aligned}$$

(b) ; fn ${}_{92}^{238}\text{U}$ l s, d iKV/mRI dk Lor% mRI tzu gsrk gð srs {k; & if0; k bl idkj fy [kkp]

$${}_{92}^{238}\text{U} \rightarrow {}_{91}^{237}\text{Pa} + {}_1^1\text{H}$$

; fn ; g if0; k l kko gsrks bl oð fy,]

$$\begin{aligned} &= (M_{\text{U}} - M_{\text{Pa}} - M_{\text{H}}) c^2 \\ &= (238.05079 - 237.05121 - 1.00783) \text{ u} \times c^2 \\ &= (-0.00825 \text{ u}) c^2 \\ &= - (0.00825 \text{ u}) (931.5 \text{ MeV/u}) \\ &= -7.68 \text{ MeV} \end{aligned}$$

; gk if0; k dk 0, D; kkd] 1/2. kRed gð vr% bl dk Lor% {k; r gsrk l kko ugha gð

${}_{92}^{238}\text{U}$ ukfhkd l s, d iKV/mRI mRI ftz djus oð fy, geabl dks 7.68 MeV Åtz inku djuh gsrkA

13.6.3 chVk& {k;

dkbz ukfhkd tks , d byDVmRI ; k iKVtVRI oð mRI tzu }kjk Lor% {k; r gsrk gð mlea chVk& {k; gð dk dgk tkrk gð , β & {k; dh rjg gh ; g Hk , d Lor% if0; k gð sftl dh , d fuf'pr fo?KVu& mQtiz , oa v/Bvk; q gsrh gð vlg , β & {k; dh rjg gh chVk& {k; Hk , d l k [; dh; if0; k gð tks l ehdj.kka (13.14) , oa (13.15) }kjk l pkyr gsrh gð 1/2. kRed chVk (β^-) {k; eð ukfhkd l s, d byDVmRI mRI ftz gsrk gð tð sfd fuEufyf [kr {k; & if0; k eð

$${}_{15}^{32}\text{P} \rightarrow {}_{16}^{32}\text{S} + e^- + \bar{\nu} \quad (T_{1/2} = 14.3 \text{ d}) \quad (13.22)$$

tð k fd ${}_{11}^{22}\text{Na}$ dh fuEufyf [kr {k; & if0; k ean'kkz k x; k gð èkurRed chVk (β^+) {k; eð ukfhkd l s, d iKVtVRI mRI ftz gsrk gð

$${}_{11}^{22}\text{Na} \rightarrow {}_{10}^{22}\text{Ne} + e^+ + \nu \quad (T_{1/2} = 2.6 \text{ y}) \quad (13.23)$$

irhd $\bar{\nu}$, oa v , β^+ / β^- / ν / $\bar{\nu}$, oa U; β^+ / β^- dks 0; Dr djrs gð ; s nksuka gh mnkl hu d.k gð ftudk ; k rls dkbz nð; eku ughaglsk vfkok cgr de nð; eku gsrk gð {k; if0; k ea ; s d.k

ukfHkd l s byDVWU ; k i kvvWU oð l kfk mri ftz gksr gð U; wVks nð; oð l kfk cgr {kh.k vU; kð; fØ; k djrs gð ; gk rd fd osfcuk vo'kðs'kr gq ijh iFoh dksHkndj ikj tk l drs gð ; gh dkj.k gSfd mudk l d pu cgr dfBu gSvks yæs l e; rd mudh mifLFkr dk Kku ugha gk i k; kA

½. kRed chV&{k; ea ukfHkd oð Hkrj , d U; WU] fuEufyf[kr l ehdj.k oð vud kj] , d i kvvWU ea: i krfjr gk tkrk gS

$$n \rightarrow p + e^- + \bar{\nu} \tag{13.24}$$

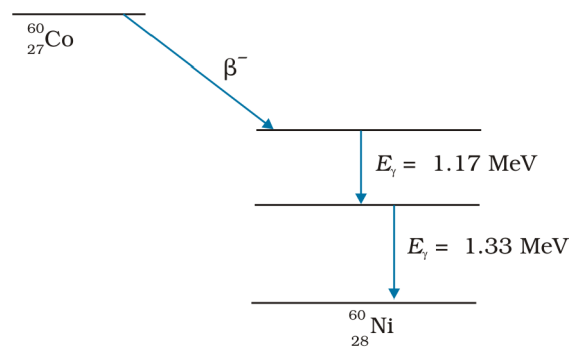
ekurRed chV&{k; ea, d i kvvWU , d U; WU e] fuEufyf[kr l ehdj.k oð vud kj : i krfjr gk gS

$$p \rightarrow n + e^+ + \nu \tag{13.25}$$

; s i fØ; k, j ; g n'kz h gðfd chV&{k; ea ukfHkd dh nð; eku l d ; k A D; ka ugha cnyrh D; kðd bl i fØ; k eabl oð vo; o U; wDyvWUkaeal s , d dk y{k.k l ehdj.k (13.24) ; k (13.25) oð vud kj ifjoerr gk gð

13.6.4 xkek&{k;

ijek. kv/ka oð Åtkz Lrjka dh Hkfr gh ukfHkd ea Hkh Åtkz Lrj gksr gð tc dkbz ukfHkd mülstr volFk ea gk gS rks o] rppðdh; fofdj.k mri ftz dj ; g fuEu Åtkz volFk ea l øfer gk gð D; kðd ukfHkd; volFkvka oð Åtkz Lrjka ea varj nl yk[k byDVWU okV Mev dh dksv dk g] ukfHkd l smri ftz gks okys i kvvWU Hkh Mev Åtkz oð gksr gð vks mudks xkek fdj. ka dgrsgð vfekdkk j sM; ks sDVo U; wDykbM , yH&{k; ; k chV&{k; oð ckn mülstr volFk ea jg tkr gð ; g fo?kvut ukfHkd] , d l øe.k ; k dbzckj dbzøeor l øe. ka oð ckn vülstr volFk xg.k djrs gð vks bl i fØ; k ea, d ; k dbz xkek fdj.k i kvvWU mri ftz djrs gð bl rjg dh i fØ; k dk , d l keW; mnkgj.k ⁶⁰Co ukfHkd gð chV&{k; }kj ⁶⁰Co ukfHkd ⁶⁰Ni oð mülstr ukfHkd eacny tkrk gð bl izdkj cuk ; g mülstr ⁶⁰Ni ukfHkd øfed : i l s 1.17 MeV , oa 1.33 Mev oð nks xkek fdj.k i kvvWU mri ftz djoð vülstr volFk xg.k djrk gð bl i fØ; k dks , d mütiz Lrj vkj k }kj fp-k 13.4 ean'kz k x; k gð



fp-k 13.4 ⁶⁰Co ukfHkd oð chV&{k; eamri ftz &fdj. ka oð mri tzu dks n'kz okyk mütiz Lrj vkj kA

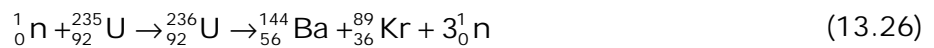
13.7 ukfHkd; Åtkz

fp-k 13.1 ean'kz sx, i fr U; wDy; WU ca'u&Åtkz E_{bn} oð ea A = 30 , oa A = 170 oð chip , d yæk l a kv Hkx gð bl Hkx ea i fr U; wDy; WU ca'u&Åtkz yxHkx vpj (8.0 MeV) gð gyoð ukfHkd] A < 30, okys Hkx , oa Hkjh ukfHkd] A > 170, okys Hkx e] t] k ge igys gh n]k ppð gð i fr U; wDy; WU ca'u&Åtkz 8.0 Mev l s de gð ca'u&Åtkz oð oð bl vfHky{k.k dk vfHki k; gSfd eè; Hkx 30 ≤ A ≤ 170 oð ukfHkd A < 30 vks A > 170 oð ukfHkd dh rgyuk ea vf/d n<rk l sc/s gð de n<rk l sc¼ ukfHkd ka dk tc vf/d n<rk l sc¼ ukfHkd ea rRokj.k (transmutation) gk gS rks Åtkz foedr gk l drh gð

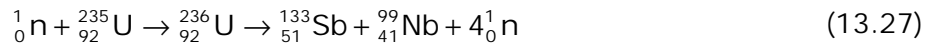
bl h izdkj dh nls ifø; k, j ftuoð fo"k; eageus igys Hkh ppkz dh g\$ fo [kMu , oal y; u gð dks ys, oa i vky; e t\$ s i kjá fjð Átkz l kka ea Átkz jkl k; fud vfHkFØ; k }kjk foedþr glsrh gð ; gk i fr i jek.kqfoedþr gksusokyh Átkz byðVRU okV dh dksV dh glsrh gð t\$ k geus n\$kk fd ukfHkdh; i fØ; kvkaeaedþr Átkz yk [kaxxk (i fr U; fDy; kU dbz Mev) vf/d glsrh gð bl dk vFKz; g gsd æ0; dh l eku ek-k oð fy,] i kjá fjð l kka dh rnyuk eþ ukfHkdh; l kka l s i ktr Átkz nl yk [k xuk vf/d glsrh gð 1 kg dks yk tykus ij 10⁷ J Átkz i ktr glsrh gð tcfð 1 kg ; jfsu; e fo [kMr gksus ij 10¹⁴ J Átkz i ktr glsrh gð

13.7.1 fo [kMu

þMFod }kjk U; WRU dh [kst fd, tkus oð FkMsfnu ckn gh , ufjdlis i oeltz us i k; k fd tc foHkU rRokaij U; WRUka l sigkj fd; k tkrk gS rksu, jfM; k\$ SDVo rRo mRi lu glsrh gð yfdu tc ; jfsu; e ij U; WRUka dk igkj fd; k x; k rks ; jfsu; e dk ukfHkð yxHkx nls l eku [k/ka ea foHkFtr gksx; k vls vR; f/d i jek.k ea Átkz fueþr gð bl izdkj dh vfHkFØ; k dk , d mnkgj.k gS %



fo [kMu ea l nð cfj; e , oafØIVu gh mRi lu ughaglsð , d fHkU ; þe Hkh mRi lu gks l drk g\$ mnkgj.k kfkz %



, d vU; mnkgj.k gS %



fo [kMu i fØ; k eamRi lu [kM ukfHkðka eaU; WRUka dh l f; k vf/d glsrh gð, oa; s vLFk; h glsrh gð ; s jfM; k\$ SDVo glsrh gð vls buearc rd chV&{k; dk Øe pyr k jgrk gð tc rd fd vr ea , d LFk; h [kM i ktr u gks tk, A

; jfsu; e t\$ sukfHkð dh fo [kMu vfHkFØ; k eafueþr Átkz (g-eku) i fr fo [kMr ukfHkð 200 MeV dh dksV dh glsrh gð bl dk vkdyu ge fuEuor djrs gð %

ekuk fd , d ukfHkð dk **A** = 240 gS vls ; g **A** = 120 oð nls [k/ka ea fo [kMr gksk gð rc

A = 240 ukfHkð oð fy, **E_{bn}** yxHkx 7.6 MeV gS (fp=k 13.1 n\$ [k) A

A = 120 okys fo [kMr ukfHkð oð fy, **E_{bn}** yxHkx 8.5 MeV gð

∴ i fr U; fDy; kU ca'u&Átkz dh yfc/ yxHkx 0.9 MeV gð

vr% ca'u&Átkz ea oþy yfc/ 240∅.9 vFlók 216 MeV gð

fo [kMu dh ?kvukvka dh fo?kvu Átkz igys {k; &mRi knka rFk U; WRUka dh xftr Átkz oð : i eal yfxur glsrh gð vr ea ; g vkl ikl oð æ0; dks gLrkrfjr gskdj Á"ek oð : i ea i fjf.kr gks tkrh gð ukfHkdh; fj, DVjka ea ukfHkdh; fo [kMu Átkz l s fo | r mRi knu gksk gð i jek.kqce eafueþr gksusokyh cgr Átkz vfu; fkr ukfHkdh; fo [kMu l s gh mRi lu glsrh gð vxysvutHkx eage oþN foLrkj l s; g ppkz djaksfd ukfHkdh; fj, DVj oð l s dk; z djrk gð

13.7.2 ukfHkdh; fj, DVj

tc ${}_{92}^{235}\text{U}$, d U; WRU oð igkj l s fo [kMr gksk gS rksbl i fØ; k eavfrfjDr U; WRU Hkh fuxter glsrh gð ; s vfrfjDr U; WRU rc fdl h nð js ${}_{92}^{235}\text{U}$ ukfHkð ea fo [kMu i kjkð djus oð fy, mi yCek glsrh gð ; jfsu; e ukfHkð oð fo [kMu ea vls ru 2e U; WRU i fr fo [kMu fueþr glsrh

ijek. kq m0tkz o0 {ksk ea Hkkjr o0 c<rs dne

Hkkjr ea ijek. kq m0tkz dk; D0e dh 'k0/vkr MKW gkeh tgl0chj HkkHk (1909 – 1966) o0 usRo ea yxHkx Lorakrk i kfr o0 l kfk gh dh xba , d i kjaHkd] , srgkfl d miyf0ek igys Hkkjrh; ukfHkdh; fj, DVj (vll jk uked) dh jpuk , oa fuekzk Fk ftl us4 vxLr 1956 l sviuk dk; Z'kq fd; ka bl ea l 0fekr ; y0su; e dks b0ku vls ty dks emd dh rjg bl r0ky fd; k x; k FkA bl o0 ckn n0 jh cMk ?KVuk 1960 ea cuk dukMk b0M; k fj, DVj (CIRUS) FkA 40 MW o0 bl fj, DVj ea i kNfrd ; y0su; e b0ku dh rjg , oa Hkkjh ty emd dh rjg bl r0ky fd; k x; k FkA vll jk , oa l kbj l usey , oa i k; k0xd ukfHkdh; foKku o0 fofHku {kska ea folr0r 'k0ek dks i krl kgr fd; ka dk; D0e o0 igys nks n'kdka dh fof'k"V miyf0ek; ka ea , d Fk VMLc ea Lons kh lyWksu; e l a ak dh jpuk , oa fuekzk ftl us Hkkjr ea b0ku i q l 0 keku rdudh (fj, DVj o0 eDr 'k0k b0ku l smi ; ksh fo[k0/uh; , oamoj ukfHkdh; l kexh dks vyx djuk) dk exz iz kLr fd; ka ckn ea tks vl; fj, DVj 'k0ek o0 fy, 'kq fd, x,] muea 'k0fey g0u , jfyuk i m. k0k (I, II , oa III) 0k0p , oa dkfeuhA dkfeuh nsk dk igyk cMk 'k0ek fj, DVj gSftl ea U-233 dks b0ku dh rjg bl r0ky fd; k x; k g0 ts k uke l sLi"V gS'k0ek&fj, DVj dk i kfkfed m0s ; 'k0Dr tuu ugha g0 oju ukfHkdh; foKku , oardudh o0 fofHku i {ka i j 'k0ek o0 fy, l 00ek inku djuk g0 'k0ek fj, DVj fofHku l eLFkfu0ka o0 mRi knu o0 Hk JSB l 0r g0ftuo0 fofHku {ksk0um | k0} vksk0ek} Nf" k vkfn eami ; k0 g0

dk; D0e dk e0; m0s ; 'kq l s gh ; g jgk gSfd nsk o0 l k0kfd , oa vkrkfd fodkl o0 fy, l jf{k0r , oa fo'ol uh; fo | 0r 'k0Dr inku dh tk, vls ukfHkdh; rdudh o0 l Hk {kska ea vkr0fuHk} cuk tk, A ipkl o0 n'kd o0 'k0/vkrh o'k0e0 Hkkjr ea i jek. od [kfu0ka dks <0e0s dk tks dk; Zg0v0k] ml l s ; g l 00r feysfd ; gk ; y0su; e o0 Hk0kj rts0gr l hfer g0 ij Fk0j; e o0 Hk0kj i ; k0r ek0k ea g0 ml o0 vu0 kj gh gekjs nsk us ukfHkdh; 'k0Dr tuu dh , d rhu pj. ka ea i jh gks okyh ; kstuk viuk; hA igys pj. k ea i kNfrd ; y0su; e dks b0ku o0 : i ea , oa Hkkjh ty dks emd o0 : i ea iz 0r fd; k tkuk g0 fj, DVj o0 vif'k"V dks i q l 0 k0ekr djus ij i klr lyWksu; e&239, n0 jspj. k earhoz fj, DVj ea b0ku dk dke djrk g0 bu fj, DVj ka dks rhoz iztud fj, DVj bl fy, dgrsg0D; k0d buea k0kyk i f0; k dks cuk, j [kus o0 fy, rhoz U; WMLka dk mi ; k0 g0rk gS (vr% emd dh vko' ; drk ugha g0rh) vls ; s'k0Dr tuu o0 vfrfjDr] ftl rjg dk b0ku [k0z djrs g0 ml l svfekd fo[k0/lu'hny inkfka (lyWksu; e) dks tle Hk nrs g0 rhl jk pj. k] tks nh? k0kfyd ; kstuk o0 fgl k0 l s l o0k0ek eg0oi w0z g0 , s rhoz iztud fj, DVj ka o0 bl r0ky ij v0k0fjr gS tks Fk0j; e&232 dks fo[k0/lu'hny ; y0su; e&233 ea cny0s vls fj 0j buo0 fy, fo'k0k : i l s cuk, x, 'k0Dr l a 0ka ea bl r0ky fd, tk, x0

vHk Hkkjr dk; D0e o0 n0 jspj. k l s x0j jgk gS vls Fk0j; e o0 mi ; k0 l 00k rh l jspj. k o0 fy, Hk dkl0k dk; Z gks 00k g0 nsk us [kfu0 vu0 0kku , oamR[kuuA b0ku fuekzk] Hkkjh ty mRi knu] fj, DVj dh jpuk] fuekzk , oa i 0kyu] rFk b0ku i q l 0 keku vkfn] l a' y"V rdudka i j i Hk0o i klr dj fy; k g0 l a hfMr Hkkjh ty fj, DVj (PHWRs) tks nsk ea fofHku LFKuka i j cuk, x, g0 igys pj. k dh i w0z dk l 00r nrs g0 Hkkjr vc viuh vko' ; drk l svfekd Hkkjh ty dk mRi knu dj jgk g0 fj, DVj ka dh jpuk , oa i 0kyu nkska o0 l 00k ea folr0r l jf{k0 iz0k rFk j0M; k0 f0dj. ka l s cplo l 00k i k0k. kd fun0 ka dk l [rh l s ikyu] Hkkjrh; i jek. kq m0tkz dk; D0e dh igpu g0

g0 ; g rF; fd fo[k0/lu ea ftrusU; WML iz k0 ea vkrsg0 ml l svfekd mRi lu g0 ktrsg0 k0kyk vHk0; k dh l k0k0k dks tle nrs g0 ftl ea gj u; k mRi lu gks okyk U; WML , d vls fo[k0/lu dks i j0r djska , ufjdks i 00z us 1939 ea igyh kj bl l k0k0k dk f0pj j [ka k0kyk vHk0; k ; k rls vfu; 0kr , oa vfr rhoz g0 l drh gS (ts k i jek. kq ce ea g0rk gS) ; k fu; 0kr , oafu; fer (ts k ukfHkdh; fj, DVj ea g0rk g0A igyh 00; k fouk'kd0kh g0rh gS t0fd n0 jh i f0; k dks fo | 0r 'k0Dr mRi knu o0 fy, mi ; k0 ea yk; k tk l drk g0



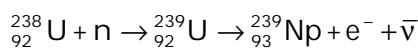


i jarq' kh?k gh ; g [kkt dh xbzfd fdl h ; yjsu; e ukfHkd oð fo [kMu dh i fØ; k eafudys U; WRUka dh Åtkz bruh gsrh gSfd osfdl h vU; ukfHkd eafokMu dh i fØ; k oð dkjd u gkdj ckj fudy tkrsga ; g Hkh ik; k x; k fd rhozU; WRUka dh rgyuk eam U; WRU ea²³⁵₉₂ U eafokMu dls vkjtk djus oð fy, cgr vf/d varufgr ikf; drk gsrh ga

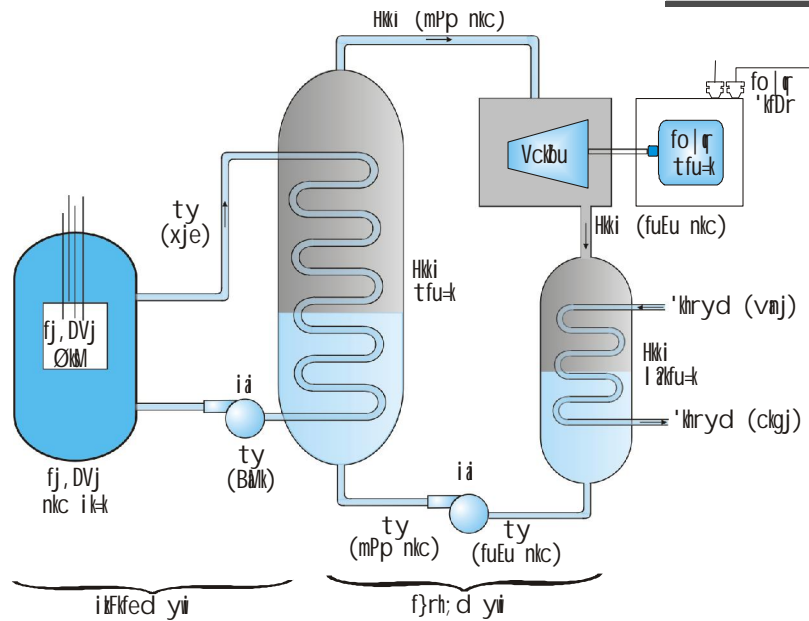
²³⁵₉₂ U oð fo [kMu eamRi knr U; WRU dh vks r Åtkz2 Mev gsrh ga ; sU; WRU tc rd fd budk emu u fd; k tk,] ; yjsu; e ukfHkdka l sfØ; k fd, fcuk gh fj, DVj l scgj fudy tkrsga ; yjsu; e ukfHkdka l sbu rhozU; WRUka oð fy, [kkyk fØ; k (chain reaction) dlsucuk, j [kusea iz ðr fo [kMu/h; inkfz dh cgr vf/d ek-k dh vko' ; drk gsrh ga rhozU; WRUka dlsgyoð U; WRUka oð l kfk i R; kLFk l akêð}kjk efnr fd; k tkrk ga okLro eð pMfod oð iz kskla usn' kiz k fd gkbMkstU oð l kfk i R; kLFk VDdj eaU; WRU yxHkx fLFkj gks tkrsga rFk l eLr Åtkz i kMu }kjk ysyh tkrh ga ; g fLFkr oð h gh gSts k fd fdl h xfreku dko dh xsyh dh vU; fLFkj l eku xsyh oð l kfk vkeu&l keus dh VDdjA vr% fj, DVjka eð rhozU; WRUka dls efnr djuoð fy, fo [kMu/h; ukfHkdka oð l kfk gyoð ukfHkdka¹ftUga voemd (moderator) dgrsga dk iz ksk fd; k tkrk ga ik; % iz ðr gksokys voemd ty] Hkh ty (D₂O) rFk xk OkV ga Hkh ik jek. kvvud a'ku oanz (BARC)] eapz oð vll jk fj, DVj eavoemd oð : i ea ty dk iz ksk gsrk ga 'kDr mRi knu oð fy, iz ðr Hkkjr oð vU; fj, DVjka eavoemd oð : i ea Hkh ty dk mi ; ksk gsrk ga

voemd oð mi ; ksk oð dkj. k] fdl h Lrj ij fudysU; WRUka oð }kjk fo [kMu/ka dh l a; k dk ml oð fi Nys Lrj ij fudysU; WRUka oð }kjk fo [kMu/ka dh l a; k oð l kfk vuq kr] k dk eku , d l svf/d gks l drk ga bl vuq kr dls xqku dkjd (multiplication factor) dgrsga ; g fj, DVj eaU; WRUka dh of¼ nj dseki rk ga k = 1, oð fy, fj, DVj dh i ðfuk Økard dgykrh gSts fLFkj 'kDr mRi knu dh i ðfuk oð fy, , sPnd ga k dk eku , d l svf/d gksus ij fØ; k nj rFk fj, DVj dh 'kDr eapj?kkrka dh (exponentially) Øe ea of¼ gsrh ga k dk eku , d dh l a; k oð vki k l u gksus ij fj, DVj vfrØkard gStk; sk rFk fj, DVj eafoli OkV Hkh gks l drk ga l u-1986 ea; wbu oð psukcy fj, DVj eagvk foLi OkV bl nq'kn rF; dk Lej. k djrk gSfd ukfHkdh; fj, DVj ea dkoz nq'k/uk fdruh fouk' kdkjh gks l drh ga fØ; k nj fu; ak. k oMfe; e ts su; WRU&vo' kskd inkfz l scuh fu; akd NMka (control rods) }kjk fd; k tkrk ga fu; akd NMka oð vfrfjDr fj, DVjka eaj {kd NMka dls Hkh iz ðr fd; k tkrk ga bu j {kd NMka dls vko' ; drk i Meus ij fj, DVj eafufo"V dj k dk k dk eku 'kh?krk l s, d l s de fd; k tk l drk ga

ipjrk l smiyCek ²³⁸₉₂ U l eLFkfud ftl eafokMu ugha gsrk , d U; WRU xg. k djoð lyWksu; e cukr ga bl dh vfHkfØ; k [kkyk bl idkj gS%



lyWksu; e vR; r jSM; ks sDVo gSvks bl ea Hkh em U; WRUka oð i gkj l sfo [kMu gks l drk ga , d fof'kV ukfHkdh; fo l q l a ak tks l a hfMr ty fj, DVj ij vkekfjr gS dh eð; : i js [k fp-k 13.5 ean' kiz h xbz ga bl idkj oð fj, DVj ea ty dls nkskarjg l semd oð : i ea Hkh , oam'ek LFKkukarjd ek; e oð : i ea Hkh mi ; ksk ea yk; k x; k ga i kfkfed yir ea ty fj, DVj ik-k ea ifj l pj. k djrk gSrFk mPp rki , oank (yxHkx 600 K , oa 150 atm) ij] Hki tfu-k (tksfd f}rh; d yir dk vak g) dks mØtkz LFKkukarj r djrk ga Hki tfu-k eaok' iu] mPp nkc ij Hki inku djrk gSts fo l q tfu-k dls pykus oð fy, Vckbu dls ipkyr djrk ga Vckbu l sfudyh de nkc dh Hki dls Bmk fd; k tkrk gSvks ty ea l akfur djoð oki l Hki tfu-k ea Hkst fn; k tkrk ga



fp-k 13.5 ukfHkd; 'kDr l a ak dh l jyhN'r : ijs[WA

ukfHkd; vfHkFØ; kvlaeajkl k; fud vfHkFØ; kvla dh rgyuk eadblzyk[k xqñ Å tkzfoeDr glsh gß vr% l eku 'kDr {kerk oß jkl k; fud fj, DVjka dh rgyuk ea ukfHkd; fj, DVjka eadblzyk[k xqsde bz u dh vko'; drk glsh gß ²³⁵92U dh , d fdykskte ektk i w k-% fo [kAMr gks ij 3 × 10⁴ MW 'kDr mRi lu djrh gß gylkd ukfHkd; vfHkFØ; kvla ea vfr l fØ; jSM; ks SDVo rRo fujarj mRi lu gks jgrsgß vr% fo [kAMr mRi kn rFk i jk; jfsu; e rRokj tS pu lyvksu; e rFk veß l ; e vkfn l sl æfBr jSM; ks SDVo vif'k'Vka dk l æg. k fd l h ukfHkd; fj, DVj iz kkyh oß vifjgk; Zy{k. k gß

vHk rd Å tkz dk mRi knu jkl k; fud vfHkFØ; kvla tS pu dks yk] ydMh] xS vFkok i vRsy; e mRi knaoß ngu }kjk gsk jgk gß bu vfHkFØ; kvlae mRi lu vif'k'V gfjr xg i Hkko (xhu gml bi SDV) oß dkj. k oß'od rki u tS h xalkhj l eL; kvla dks tle nsjgk gß ukfHkd; 'kDr l a ak dh l clscMh l eL; k ; g glsh gSfd vif'k'V inkFkz vR; r jSM; ks SDVo gksrsgß vls iFoh ij fo|eku l Hk thoka oß fy, vR; r [krjukd Hkha fj, DVj ipkyu ,oa jSM; ks SDVo vif'k'Vka dk i q% mi ; kx , oafui vkjk nksuka gh foLr r l g {kk 0; oLFk vka oß fy, vko'; d gß ; sl g {kk 0; oLFk, ; Hkjr h; i jek. kq dk; Døe dh [kl fo'k'Vrk gß jSM; ks SDVo vif'k'Vka dks de l fØ; , oavYi thoh æ0; ka ea i fjoFrZ djus dh l Hkkouk, j < p us oß fy, , d mi ; Dr ; kstuk oß fodkl ij dk; Zy py jgk gß

13.7.3 ukfHkd; l ay; u&rkJka ea Å tkz tuu

fp-k 13.1 ean'kz k x; k çaku&mØtkz oß ; g Hk n'kz k gSfd ; fn nksgyoß ukfHkd feydj , d viškkN'r çMk ukfHkd cuk, j rls mØtkz fueDr glsh gß bl i fØ; k dks ukfHkd; l ay; u dgrsgß bl rjg dh mØtkz foekpd vfHkFØ; kvla oß oßN mnkgj. k uhs fn, x, gß%

$$^1_1\text{H} + ^1_1\text{H} \rightarrow ^2_1\text{H} + e^+ + \nu + 0.42 \text{ MeV} \quad [13.29(a)]$$

$$^2_1\text{H} + ^2_1\text{H} \rightarrow ^3_2\text{He} + n + 3.27 \text{ MeV} \quad [13.29(b)]$$

$$^2_1\text{H} + ^2_1\text{H} \rightarrow ^3_1\text{H} + ^1_1\text{H} + 4.03 \text{ MeV} \quad [13.29(c)]$$



$\text{vffHkf}\emptyset$; k 13.29 (a) eanks i ks/KU feydj , d M; WRU , oa, d i KVTVRU cukrsg δ v δ bl i f \emptyset ; k ea 0.42 MeV m \emptyset t δ z fudyryh g δ vffHkf \emptyset ; k 13.29 (b) eanks M; WRU feydj ghfy; e dk gydk l eLFkfud cukrsg δ vffHkf \emptyset ; k 13.29 (c) eanks M; WRU feydj , d VffV; e , oa , d i ks/KU cukrsg δ bu l Hkh vffHkf \emptyset ; kvka ea ge i krs g δ fd nks δ ekuf' kr d. k feydj , d vi δ kr δ r cMk ukfHkd cukrsg δ ; gk; g Li "V dj nsuk p δ fg, fd bl rjg dh i f \emptyset ; k nks δ ekuf' kr d. k δ o δ chp yxusokys o δ y δ kr δ i frd"l δ k cy o δ dkj. k] vo# $\frac{1}{4}$ gksh g δ tks bu d. k δ dks bruk i kl vkus l s jk δ rs g δ fd ; s vius v δ kd"l δ k cy o δ ifl j ea v δ dj l δ yf; r g δ tk, δ bl o δ y δ kr δ voj δ kek dh m \emptyset p δ z vkos k δ , oa v δ ; k δ ; f \emptyset ; k xr ukfHkd δ dh f δ -T; kvka ij fuHkj d δ rh g δ m δ ngj. k o δ fy,] ; g v δ l kuh l sn' k δ z k tk l drk g δ fd nks i ks/KU ka o δ fy, ; g voj δ kr δ kr δ rk (barrier height) yxHkx 400 keV g δ v δ fed vkos kek δ jh ukfHkd δ o δ fy, voj δ kr δ kr δ rk v δ g Hkh v δ fed g δ schA fdl h i ks/KU x δ ea i ks/KU ka }kj δ d δ y δ kr δ voj δ ks/ d δ s i kj d δ jus o δ fy, i; k δ r δ tk δ 3×10^9 krki ij i k δ r g δ l drh g δ bl rki dk i f δ y δ] l δ kk (3/2) k T = K ea K dk eku 400 keV j [kus ij fd; k tk l drk g δ

m \emptyset t δ z dh mi ; k δ ch ek-k m δ ri lu d δ jus o δ fy, ukfHkd δ ; l δ y; u LF δ y δ &n \emptyset ; ea g δ sk p δ fg, A vko'; drk cl bl ckr dh g δ fd n \emptyset ; dk rki rc rd c<k; k tk, tc rd fd bl o δ d. k ek δ viuh rki h; x δ r o δ dkj. k] o δ y δ kr δ voj δ kek d δ s i kj u dj tk, δ bl i f \emptyset ; k d δ s rki ukfHkd δ ; l δ y; u d δ grs g δ

l w δ o δ \emptyset km dk rki Hkh o δ oy yxHkx 1.5×10^7 k g δ bl fy,] l w δ ea Hkh ; fn l δ y; u f \emptyset ; k d δ s ?kr δ r g δ sk g δ rs; g vko'; d g δ fd bl ea' k δ fe δ g δ sk okys i ks/KU ka dh m \emptyset t δ z v δ g r m \emptyset t δ z l s d δ kl δ h v δ fed g δ

vr% rki ukfHkd δ ; l δ y; u c δ g δ m δ pp rki , oankc ij gh g δ l drk g δ v δ g rki , oankc dh , δ h fLFkr; k o δ oy rkja o δ vrjak ea gh mi y δ ek g δ rkja ea m \emptyset t δ z tuu rki & ukfHkd δ ; l δ y; u o δ ek δ ; e l s gh g δ sk g δ

l w δ ea g δ sk oky h l δ y; u vffHkf \emptyset ; k , d c δ g δ p δ . k i f \emptyset ; k g δ ft l ea g δ kbM δ stu ghfy; e ea cn δ ryh g δ ; gk g δ kbM δ stu b δ ku g δ , oaghfy; e ^jk[k'A i ks/KU & i ks/KU (p - p) p \emptyset ft l o δ }kj ; g ?kr δ r g δ sk g δ fuEufyf [kr vffHkf \emptyset ; kvka o δ l e δ pp; }kj δ 0; Dr fd; k tk l drk g δ

$$\begin{aligned}
& {}^1_1\text{H} + {}^1_1\text{H} \rightarrow {}^2_1\text{H} + e^+ + v + 0.42 \text{ MeV} & \text{(i)} \\
& e^+ + e^- \rightarrow \gamma + \gamma + 1.02 \text{ MeV} & \text{(ii)} \\
& {}^2_1\text{H} + {}^1_1\text{H} \rightarrow {}^3_2\text{He} + \gamma + 5.49 \text{ MeV} & \text{(iii)} \\
& {}^3_2\text{H} + {}^3_2\text{H} \rightarrow {}^4_2\text{He} + {}^1_1\text{H} + {}^1_1\text{H} + 12.86 \text{ MeV} & \text{(iv)} \quad (13.30)
\end{aligned}$$

p δ sk δ h vffHkf \emptyset ; k g δ sk o δ fy, ; g vko'; d g δ fd i gyh rhu vffHkf \emptyset ; k, j nks nks ckj g δ v δ g bl i δ lkj n δ gyo δ ghfy; e ukfHkd feydj l eku; ghfy; e dk , d ukfHkd cuk, δ vxj ge 2(i) + 2(ii) + 2(iii) + (iv) ij fopkj d δ ja r δ s o δ y i Hkko g δ sk]

$$\begin{aligned}
& 4 {}^1_1\text{H} + 2e^- \rightarrow {}^4_2\text{He} + 2v + 6\gamma + 26.7 \text{ MeV} \\
& ; k (4 {}^1_1\text{H} + 4e^-) \rightarrow ({}^4_2\text{He} + 2e^-) + 2v + 6\gamma + 26.7 \text{ MeV} & \text{(13.31)}
\end{aligned}$$

vr% pkj g δ kbM δ stu i jek. kq feydj , d ${}^4_2\text{He}$ i jek. kq cukrsg δ v δ g bl i f \emptyset ; k ea 26.7 MeV m \emptyset t δ z fue δ r g δ sh g δ

l w δ o δ \emptyset km ea g δ kbM δ stu dk ngu bl vffz ea cMs i δ kus ij , d rjg dh dhifexjh g δ D; k δ d ; gk , d rko n δ jsrRo ea cn δ y jgk g δ yxHkx 5×10^9 o'k δ l s ; g py jgk g δ v δ g x. kuk, j n' k δ z h g δ fd l w δ ea bruh g δ kbM δ stu ughag δ fd brusgh o'k δ ard vkxs Hkh ; g pyr δ

jgskA yfdu] yxHlx 5 vjc o"ksa l wZdk ØkM tksml l e; rd e[; r% ghfy; e eacny
 p[plk gksk] Bk/gk gks yxsk] v[; l wZvi us x#Rokd"lkz k cy o[dkj.k l Øfpr gksk 'kq gks
 tk, xhA bl l sØkM dk rki c<+tk, xk v[; bl dkj.k ckgh vkoj.k i Øyusyxsk ftl l sl wZ
 , d yky n[; ea ifjofr[gks tk, xhA

; fn ØkM dk rki 10^8 k rd c<+tk, xk rksfi Qj l sl ay; u o[dkj.k m[tkz tuu gks
 yxsk] ij bl ckj ghfy; e tydj dkc[cuk, xhA t[& t[srkjseav[; fodkl gkrk gS; g
 v[; v[ekd xelgk tkrk g[u; h l ay; u v[HKfØ; k, j, u, rRok dks tle nrh g[fo[arq v[; v[
 vf/d l ay; u v[HKfØ; kvk o[dkj.k c[aku&m[tkz oØ (fp=k 13.1) o['kh"lz ij fLFkr rRo
 l s v[ekd Hkhj rRo fufe[ugha gks l drs Fk

rjka ea m[tkz&tuu rki ukfHkd; l ay; u o[ek[; e l s gkrk g[

ukfHkd; fo[od

, d ; j[; e ukfHkd o[fo[kM u ea yxHlx 0.9235 MeV (≈ 200 MeV) Åtkz fo[pr gksk g[; fn yxHlx
 50 kg $^{235}_{92}\text{U}$ dk iR; d ukfHkd fo[kM r gks tk, rks yxHlx 4×10^{15} J Åtkz mRi lu gkskA ; g Åtkz 20,000
 Vu TNT o[l er[; gStks, d egk foLi Øv o[fy, i ; k[r g[cMh ek-ek eukfHkd; Åtkz dk vfu; k-kr fue[pr
 i jek.kq foLi Øv dgykrk g[6 vxLr 1945 dls; 4/4 ea igyh ckj , d i jek.kq; [Dr dk mi ; kx fd; k x; kA vesj dk
 us tki ku o['kgj fgjks' kek ij , d i jek.kq ce fxjk; kA foLi Øv 20,000 Vu TNT o[l er[; FkA j[; k; s[DVo
 mRi knk[us, d {k.k ea 3,43,000 fuokf l ; k[okys 'kgj o[10 oxZfdykehVj {k[dks u"V dj fn; kA buea 66,000
 ej x,] 69,000 ?k; y gq] 'kgj dh 67% l s vf/d bekj[ar gl & ug l gks xhA

l ay; u v[HKfØ; kvk o[fy, vko' ; d mPp rki fo[kM u ce }kjk mRi lu fd; k tk l drk g[1954 ea
 10 esk Vu TNT dh foLi Øv d {kerk o[l er[; egk foLi Øv dk ijh{k.k fd; k x; kA ; sce ftuea gkbM[stu o[
 l eLFkfuok[M; whfj; e , oa v[HV; e dk l ay; u gkrk g[gkbM[stu ce dgykrk g[, d k ekuk tkrk g[fd brus
 'kDr' kkyh ukfHkd; g[Fk; kj LFkfi r dj fn, x, g[t[segt , d cvu nkus ij dbZckj iFoh l s thou dk l i Qk; k
 dj l drs g[, d sukfHkd; fo[od l su fl i d iFoh dk or[ku thou u"V gks tk, xk] cfYd bl o[j[; k; s[DVo
 vif'k"V vkusokys l e; o[fy, Hkh iFoh ij thou iuius; k[; ugha jgus n[ka l s[k[rd x.kukvk o[vk/kj ij
 t[ks ifjn'; mHkj dj vkrk gSml dh l x[Dr (prediction); g gSfd , d y[ck ukfHkd; 'khr ; x i kj h k gks tk, xk
 D; k[rd j[; k; s[DVo vif'k"V cny dh rjg ok; [mly ear[aks v[; l wZ l siFoh dh v[; vkusokys l Hkh fofdj. kA
 dks vo' k[ks"kr dj ykA

13.7.4 fu; k[r rki ukfHkd; l ay; u

iFoh ij igyh rki ukfHkd; v[HKfØ; k 1 uo[; 1952 dls, fuos/kcd , v[; ea ?kVr g[;]
 tc vesj dk us, d l ay; u ; [Dr ea foLi Øv dj 1 djM+Vu TNT ea foLi Øv o[l er[; m[tkz mRi lu dh
 ^{239}Pu TNT o[foLi Øv l s 2.6×10^{22} MeV m[tkz fue[pr gksk gSA

l ay; u & 'kDr dk , d v[kM] fu; ak.kh; i'kr cukuk cgr gh dfBu dk; Zg[Hkjr l fgr
 n[; k o[vusd n[ka ea bl o[fy, l 'kDr iz kl tkjh g[D; k[rd l ay; u fj, DVj dks Hkfo";
 dk 'kDr & i'kr ekuk tk jgk g[

mnkgj. k 13.7 fuEufyf[kr izuka oð mlkj nhft, %

- (a) D; k ukfHkdh; vfHkfØ; kvka oð lehdj. k (tS k fd Hkx 13.7 ea fn, gð jkl k; fud lehdj. k (mnkgj. k oð fy, $2H_2 + O_2 \rightarrow 2 H_2O$) oð : i ea l arfyrr gð ; fn ughark s fdl : i eanuka vlg lehdj. k l arfyrr gkæð
- (b) ; fn i s/kuka vlg U; wruka dh l æ; kj i R; d ukfHkdh; vfHkfØ; k ea l jf{kr jgrh gð fdl h ukfHkdh; vfHkfØ; k ea fdl izdkj nð; eku] Átlz ea (; k bl dk myVK) cnyrk gð
- (c) l keU; fopkj gsfð oðoy ukfHkdh; fØ; k eagh nð; eku&Átlz, d nð jseacnystk l drs gð tcfð jkl k; fud fØ; k ea ; g dHk ugha gsrk gð ; g dguk vl R; gð l e>kb, A

gy

- (a) fdl h jkl k; fud vfHkfØ; k oð l arfyrr gksadh fLFkr eafð vfHkfØ; k oð lehdj. k oð nuka vlg l Hk rRoka oð i jek. kvka dh l æ; k l eku gsrh gð fdl h jkl k; fud vfHkfØ; k ea i jek. kvka oð emy l a lstu ea ifjorðu ek-ek gsrk gð i jarqfdl h ukfHkdh; vfHkfØ; k ea rRokarj. k Hk gsl drk gð vr% ukfHkdh; vfHkfØ; k ea i R; d rRo oð i jek. kvka dh l æ; k dk l jf{kr gsk vko' ; d ugha gð gylfð] ukfHkdh; vfHkfØ; k ea i s/kuka rFk U; wruka nuka dh l æ; k, j i Fkð : i l sl jf{kr jgrh gð 'oklro eð vr; f/d Átlz oð ifjebny ea ; g dFku Hk l fuf' pr l R; ugha gð oLrq% oðy vkoð rFk oðy ^cðj; ku l æ; k' l jf{kr jgrsgð ge bl fo" k; ij ; gk vlxsvlg fopkj ugha d jækð° ukfHkdh; vfHkfØ; kvka 'tS sfd lehdj. k (13.26)° ea lehdj. k oð nuka vlg i s/kuka dh l æ; k, j rFk U; wruka dh l æ; k, j i Fkð&iFkð : i ea l eku gð
- (b) ge tkursgð fd ukfHkdh dh ca/u&Átlz dk ukfHkdh oð nð; eku ea ½. kRed ; ksnku (nð; eku {kfr) gsrk gð pfd fdl h ukfHkdh; vfHkfØ; k ea i s/kuka rFk U; wruka nuka dh l æ; k, j i jf{kr jgrh gð vr% vfHkfØ; k oð nuka vlg U; wruka rFk i s/kuka dk oðy fojke nð; eku (rest mass) l eku gsrk gð i jarqfdl h ukfHkdh; vfHkfØ; k ea ck; ha vlg oð ukfHkdh dh oðy ca/u&Átlz vfHkfØ; k oð nk; ha vlg oð ukfHkdh dh oðy caku&mðtlz oð l eku gsk vko' ; d ugha gð bu ca/u&Átlz/ædk varj ukfHkdh; vfHkfØ; k ea vo' kð"kr gksokyh vFok fudyusokyh Átlz oð : i ea izdV gsrk gð pfd ca/u&Átlz nð; eku ea ; ksnku nrh gð vr% ge dgrsgðfd fdl h ukfHkdh; vfHkfØ; k eanuka vlg oð oðy nð; eku dk varj Átlz oð : i ea ifjorr gsk tkrh gð (; k bl oð fojhr Átlz oðy æo; eku oð varj oð : i ea ifjorr gsk tkrh gð) A bl : i ea ukfHkdh; vfHkfØ; k nð; eku&Átlz oð vr% : i karj. k dk , d mnkgj. k gð
- (c) nð; eku&Átlz oð vr% : i karj. k dh n"V l j fl ¼karr% , d jkl k; fud vfHkfØ; k ukfHkdh; vfHkfØ; k oð l e : i gð fdl h jkl k; fud vfHkfØ; k ea vo' kð"kr vFok fudyusokyh Átlz vfHkfØ; k oð nuka vlg oð i jek. kvka rFk v. kvka dh jkl k; fud (ukfHkdh; ugha) ca/u Átlz/æoð varj dlsLi"V djrh gð pfd jkl k; fud ca/u&Átlz Hk fdl h i jek. kv vFok v. kv oð oðy nð; eku ea ½. kRed ; ksnku (nð; eku {kfr) dlsn' kð" h gð bl fy, ge fu"ð"lzfudky l drsgðfd fdl h jkl k; fud vfHkfØ; k eanuka vlg oð i jek. kvka rFk v. kvka oð oðy nð; eku dk varj Átlz oð : i ea ifjorr gsk tkrh gð ; k Átlz oðy nð; eku oð varj oð : i ea ifjorr gkðj l ekfo"V gsk tkrh gð gylfð] fdl h jkl k; fud vfHkfØ; k ea l ayXu nð; eku {kfr; ka dk ifjek. k ukfHkdh; fØ; k ea l ayXu nð; eku {kfr; ka dh rgyuk eadbyk[k xqik de gsrk gð l keU; : i ea ; gh ekkj. k gS fd , d k irhr gsrk gð (ts l R; ugha gð) fd fdl h jkl k; fud vfHkfØ; k ea dksZ nð; eku&Átlz dk vr% : i karj. k ugha gsrk

mnkgj. k 13.7

I kjk k

1. iR; d ijek.kq ea , d ukfHkd gsrk gð ukfHkd /ukof' kr gsrk gð ukfHkd dh f=K; k ijek.kq dh f=K; k l s 10⁴ xþk Nks/h gsrh gð ijek.kq dk 99.9% l s vf/d æ0; eku ukfHkd ea l ekfgr gsrk gð
2. ijek.kq/ka oð Lrj ij æ0; eku] ijek.kq æ0; eku bdkb; ka (u) ea eki s tkr s gð i fjHk'kk oð vud kj 1 ijek.kq æ0; eku bdkbz(1u), ¹²C oð , d ijek.kq oð æ0; eku oð 1/1208 Hkkx oð cjkcj gsrh gð
 $1u = 1.660563 \times 10^{-27} \text{ kg}$
3. ukfHkd ea , d fujkof' kr d.k gsrk gsft l su; WNU dgrsgð bl dk æ0; eku yxHkx mrugh gsrk gsft ruk i ks/WU dka
4. fdl h rRo dh ijek.kq l ð; k z ml rRo oð ijekf.od ukfHkd ea i ks/WU dh l ð; k gsrh gð æ0; eku l ð; k A, ijekf.od ukfHkd ea i ks/WU ka, oal; WNU dh ofy l ð; k oð cjkcj gsrh gð $A = Z + N$; gkj N ukfHkd ea fo l eku U; WNU dh l ð; k fufnZV djrk gð , d ukfHkd; iztkfr vFkok , d U; DykbM (nuclide) dks Z_X }kjk 0; Dr djrs gð tgl x ml jkl k; fud iztkfr dk l oðr gð
 l eku ijek.kq l ð; k z, i jarqfofHku U; WNU l ð; k N oð U; DykbM l eLFkufud dgykrs gð osU; DykbM ftuoð fy, æ0; eku l ð; k A dk eku l eku gsl eekfjd rFk osftuoð fy, U; WNU l ð; k N dk eku l eku gsl el; WNU d dgykrs gð
 vf/dk k rRo nls ; k vf/d l eLFkufudka oð feJ.k gsrk gð rRo dk ijek.kq æ0; eku ml oð l eLFkufudka oð æ0; ekuka dk Hkfjr ekè; gsrk gð tgl Hkj l srRi; Z l eLFkufudka dh l kiðk cgyrk l s gð
5. ukfHkd dks xlsykdkj ekudj ml dh , d f=K; k fu/lzjr dh tk l drh gð byDVNU izh.kz iz kskaoð vk/kj ij ukfHkd dh f=K; k Kkr dh tk l drh gð ; g ik; k x; k gS fd ukfHkdka dh f=K; k fuEufyf[kr l wk l s0; Dr gsrh gð
 $R = R_0 A^{1/3}$,
 tgl $R_0 =$, d fu; rkad = 1.2 fm. ; g n'kzk gsfd ukfHkd dk ?kuRo A ij fuHkj ugha djrk vlð ; g 10¹⁷ kg/m³ dh dksV dk gsrk gð
6. ukfHkd oð vmj U; WNU , oa i ks/WU vYi ijkl h icy ukfHkd; cy }kjk c/s gsrk gð ukfHkd; cy U; WNU , oa i ks/WU ea foHkn ugha djrk
7. ukfHkd; nð; eku M ges'kk viusvo; oð oð ofy nð; eku Σm l sde gsrk gð ukfHkd vlð bl oð vo; oð oð nð; ekuka dk vrj nð; eku {kfr dgykrk gð
 $\Delta M = (Z m_p + (A - Z)m_n) - M$
 vkba Vku dk nð; eku mðt l f 1/4 kr $E = m c^2$ bl nð; eku vrj dks mðt l oð : i ea bl izdkj 0; Dr djrk gS%
 $\Delta E_b = \Delta M c^2$
 mðt l ΔE_b ukfHkd dh caku&mðt l dgykrh gð A = 30 l sydj A = 170 nð; eku l ð; k oð ijkl ea ifr U; fDy; WU caku&mðt l dk eku yxHkx fu; r gð ; g yxHkx 8 MeV ifr U; fDy; WU gð
8. ukfHkd; i f0; kvka l s tþlk Åt l z jkl k; fud i f0; kvka dh rgyuk eayxHkx nl yk[k xþk vf/d gsrh gð
9. fdl h ukfHkd; i f0; k dk g-eku gS%
 $g =$ vfire xfrt Åt l z - i kjHkd xfrt Åt l z
 æ0; eku Åt l z l j (k.k oð dkj.k) dg l drs gð fd
 $g =$ (i kjHkd æ0; ekuka dk ; l x - vfire æ0; ekuka dk ; l x) c²
10. jSM; ks fDVork og i f?Kvuk gsft l ea nh xbz iztkfr oð ukfHkd] α ; k β ; k γ fdj.k

- mRI ftZ djoð : i krfjr gis tkrh gð tglk α -fdj. kaghfy; e oð ukfhkd gð β -fdj. ka byðvnu gðrfk γ -fdj. ka α -fdj. kð l shh Nksh rjæns; Zoð fo | q pædh; fofdj. k gð
11. jSM; kS SDVo {k; rk dk fu; e g% $N(t) = N(0) e^{-\lambda t}$
; gk λ {k; kð vfkok fo?kVu fLFkjkd gð fdl h jSM; kskfhkd dh v/&vk; $q(x_{1/2})$ og l e; gSftl eamudh oðy l ð; k N mudh i kjæhkd eku dh vk/h jg tkrh gð vks r vk; q τ og l e; gSftl us N vius i kjæhkd eku dk e^{-1} xqk 'kSk jg tkrk gð
 $T_{1/2} = \frac{\ln 2}{\lambda} = \tau \ln 2$
 12. tc de n<rk l scð/r ukfhkd vf/d n<rk l scð/r ukfhkd eafjofrZ gðrk gSrkS Åtlz foðr gðrk gð fo [kðu ea, d Hkjh ukfhkd nks NkSs [kðu eafohkfr gis tkrk gS mnkj. kfkZ ${}_{92}^{235}\text{U} + {}_0^1\text{n} \rightarrow {}_{51}^{133}\text{Sb} + {}_{41}^{99}\text{Nb} + 4{}_0^1\text{n}$
 13. ; g rF; fd fo [kðu eaftrusl; vnu iz ðr gðrk gð ml l svf/d mRi lu gðrk gð l [kyk vfhkð; k dh l kkkouk inku djrk gð bl i fð; k eamRi lu gðrk okyk i R; sd U; vnu] u, fo [kðu dk i kjæhkd djrk gð ukfhkd; ce foli Oð/ eavfu; ð-kr l [kyk vfhkð; k rsth l sgðrk gð ukfhkd; fj, DVj ea; g fu; ð-kr , oafLFkj nj ij gðrk gð fj, DVj ea U; vnu of ¼ xqkð ð dk eku 1 cuk; sj [k tkrk gð
 14. l ay; u eagyð ukfhkd feydj , d cMk ukfhkd cukrs gð l w Z l fgr l Hk rkjæ ea gðvMst u ukfhkð dk ghfy; e ukfhkð ea l ay; u Åtlz dk l kr gð

Hkkf rd jkf' k	i rtd	foek, j	ektd	fVli . kh
ijek. lq nð; eku bðkbZ		[M]	u	ijek. lq ; k ukfhkd; nð; ekula dls 0; Dr djus oð fy, nð; eku ektdA , d ijek. lq nð; eku bðkbZ ${}^{12}\text{C}$ ijek. lq oð nð; eku oð oð 1/12 oð Hkx oð cjkj gð
fo?kVu ; k {k; fu; rkð	λ	[T ⁻¹]	s ⁻¹	
vèkZ q	$T_{1/2}$	[T]	s	og l e; ftl ea jSM; kS SDVo ueus oð ukfhkð dh l ð; k i kjæhkd l ð; k dh vkiðh jg tkrh gð
jSM; kS SDVo ueus dh , SDVork	R	[T ⁻¹]	Bq	, d jSM; kS SDVo 'i kr dh , SDVork dh eki A

fopkj. kh; fo" k;

1. ukfhkd; æð; dk ?kuRo ukfhkd oð l kb" k ij fuHkZ ughadjrk gð ijek. lqæð; eku ?kuRo bl fu; e dk ikyu ughadjrkA
2. byðvnu izh. kðu }kj kkr dh xbZ ukfhkd dh f=kt; k dk eku , yHk d. k izh. kðu oð vk/kj ij kkr dh xbZ f=kt; k l soðN fhku i k; k x; k gð , d k bl fy, gð D; kð] byðvnu

- izdh. kú ukfHkd oð vkošk forj.k l s i Hkkfor gsk gStcfd , YHkk d.k vlg ml tS s vl; d.k ukfHkd; æ0; l s i Hkkfor gsksg
3. vkbVku }kjk æ0; eku , oa Åtíz dh l erY; rk $E = mc^2$ inf' k' fd, tkusoð ckn vc ge æ0; eku l j {k.k , oa Åtíz l j {k.k oð i Fkd fu; eka dh ckr ugha djr } oju æ0; eku & Åtíz l j {k.k oð , d , dh N' r fu; e dh ckr djrs gð i N' fr ea; g fu; e olr r% i Hkkoh gS r Fk bl dk fo' ol uh; i æk.k ukfHkd; Hkk r dh ea ik; k tkrk gð æ0; eku , oa Åtíz dh l erY; rk oð fu; e] ukfHkd; Åtíz , oaml oð ' kDr l k r oð : i eami ; kx dk vk/ kj gð bl fu; e dk mi ; kx djoð fdl h ukfHkd; i f0; k ({k; vFlok vFk0; k) oð g- elu dls i kj ð Hkd , oa v' ire æ0; eku oð in l æa0; Dr fd; k tk l drk gð
 4. (ifr U; mDy; kU) ca' u & Åtíz oð dh i N' fr ; g n' k' z h gS fd Å" ek { k i h ukfHkd; vFk0; k; j l hko gð t s n k s gyoð ukfHkd l æoð l ay; u l s; k , d Hkjh ukfHkd oð eke; fed æ0; eku okys n k ukfHkd l æoð fo [k l u ea n s k h tk l drh gð
 5. l ay; u oð fy, gyoð ukfHkd l æa i ; k' r i kj ð Hkd Åtíz gskh p kfg, r f d o s o y k h f o h k o vojls' dls i kj dj l oð A ; gh dkj . k gS fd l ay; u oð fy, vR; ð p rki dh vko' ; drk gsk h gð
 6. ; | fi (ifr U; mDy; kU) ca' u & Åtíz oð l r r gS vlg bl ea/ hj & / hjs gh i f j o r u vkrk gS i j a r q bl ea ⁴He, ¹⁶O vkn U; ð y k b M k a oð fy, f' k [kj gsksg ; g i j e k . k q dh r j g gh ukfHkd ea Hk ' l s y l j p u k dh fo | e k u r k dk i æk . k e k u k t k r k gð
 7. è; ku n a f d b y ð V M U & i k M t V M U , d d . k & i f r d . k ; ð e gð buoð æ0; eku , d l eku gð buoð vkošk l æoð i j e k . k l eku i j a r q f o i j h r i N' fr oð gsksg (; g i k; k x; k gS fd t c , d b y ð V M U , o a , d i k M t V M U , d l k f k v k r s gð r l s , d & n u j s dk f o y k i u (annihilation) dj n r s gð vlg g- f d j . k i O S / M U l æoð : i e a Åtíz i n k u d j r s gð
 8. ð- {k; (b y ð V M U m R l t ũ) e a b y ð V M U oð l k f k m R l f t z g k s o k y k d . k , ð h & U; ð v u l s (v) gð bl oð f o i j h r ð- {k; (i k M t V M U m R l t ũ) e a U; ð v u l s (v) m R l È t r g s k gð U; ð v u l s , o a , ð h & U; ð v u l s d k ; ð e d . k & i f r d . k ; ð e g s k gð i N' fr e a i R; s d d . k d k , d i f r d . k g s k gð r c , ð h & i k s / M U t k s i k s / M U d k i f r d . k gð D; k g s k p k f g , \
 9. , d e ð r U; W M U v L F k; h g s k g s (n → p + e - + v) A i j a r q bl h r j g l s e ð r i k s / M U d k {k; l h k o u g h a gð , d k g k s d k d k j . k ; g gS fd i k s / M U d k æ0; eku U; W M U oð æ0; eku dh r g y k e a F k k / k d e g s k gð
 10. i k; % , Y H k k ; k c h v k m R l t ũ oð c k n x l e k m R l t ũ g s k gð x l e k i O S / M U m R l È t r d j oð d k b z u k f H k d m i h f i r (m P p r j) v o L F k l s f u E u r j v o L F k e a y k s / r k gð , Y H k k v F k o k c h v k m R l t ũ oð i ' p k r d k b z u k f H k d m i h f i r v o L F k e a j g l d r k gð , d g h u k f H k d l s (t S s f d f p = k 13.4 e a n ' k z s x , ⁶⁰Ni oð i z d j . k e x x l e k f d j . k a d k Ø e o k j m R l t ũ bl c k r d k L i " V i æk . k gS fd u k f H k d l æ a H k i j e k . k q l a d h g h r j g f o f o D r Åtíz L r j g s ksg
 11. j ð M; k s ð V o r k u k f H k d oð v L F k; R o d k l a p u gð g y oð u k f H k d l æ a L F k; R o oð fy, U; W M U s , o a i k s / M U l æoð l a ; k d k v u i j r y x H x 1:1 g s k p k f g , A H k j h u k f H k d l æ oð L F k; R o oð fy, ; g v u i j r 3:2 g s k p k f g , A (i k s / M U l æoð e e ; y x u o k y s i f r d " l z k oð i H k o oð f u j l u oð fy, v f e k d U; W M U l æoð v l o ' ; d r k g s k h) b u L F k; R o v u i j k r l æ d s u j [k u s o k y s u k f H k d v L F k; h g s k gð b u u k f H k d l æ oð U; W M U v F k o k i k s / M U l æoð v f / d r k g s k gð o k l r o e j (l H h r R o l æ oð) K k r l e L F k f u d l æ oð e k y x H x 10% g h L F k; h gð v l ; u k f H k d N' f - t e : i l s i z k s ' k y k e a c u k ; s t k r s gð (; s L F k; h u k f H k d ; i z k f r ; l a i j α , p , d , n v F k o k v l ; d . k a oð i z k r } k j k c u k ; s t k r s gð) A v L F k; h l e L F k f u d f o ' o e a i n k f l æ oð [l x s y h ; i s k . k a e a H h v o y k d r f d , t k r s gð

vH; kl

vH; kl oð i t u gy djustu eafuufyf [kr vkrMæ vki oð fy, mi ; lsh fl ¼ glæks:

$$e = 1.6 \times 10^{-19} \text{ C} \quad N = 6.023 \times 10^{23} \text{ ifr elsy}$$

$$1/(4\pi\epsilon_0) = 9 \times 10^9 \text{ N m}^2/\text{C}^2 \quad k = 1.381 \times 10^{-23} \text{ J } ^\circ\text{K}^{-1}$$

$$1 \text{ MeV} = 1.6 \times 10^{-13} \text{ J} \quad 1 \text{ u} = 931.5 \text{ MeV}/c^2$$

$$1 \text{ year} = 3.154 \times 10^7 \text{ s}$$

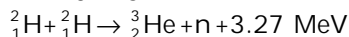
$$m_{\text{H}} = 1.007825 \text{ u} \quad m_{\text{n}} = 1.008665 \text{ u}$$

$$m({}^4_2\text{He}) = 4.002603 \text{ u} \quad m_{\text{e}} = 0.000548 \text{ u}$$

- 13.1** (a) yhfFk; e oð nlsLFkk; h l eLFkkfudka ${}^6_3\text{Li}$, ${}^7_3\text{Li}$ dh cgyrk dk ifr'kr Øe'k% 7.5, ${}^92.5$ gð bu l eLFkkfudka oð æ0; eku Øe'k% 6.01512 u, ${}^7.01600$ u gð yhfFk; e dk ijek.kqæ0; eku Kkr dhft, A
- (b) clskjkl oð nlsLFkk; h l eLFkkfud ${}^{10}_5\text{B}$, ${}^{11}_5\text{B}$ gð muoð æ0; eku Øe'k% 10.01294 u, ${}^11.00931$ u, oackjkl dk ijek.kqHkj 10.811 u gð ${}^{10}_5\text{B}$, ${}^{11}_5\text{B}$ dh cgyrk Kkr dhft, A
- 13.2** fu; kl oð rhu LFkk; h l eLFkkfudka dh cgyrk Øe'k% 90.51%, 0.27%, ${}^9.22$ gð bu l eLFkkfudka oð ijek.kqnð; eku Øe'k% 19.99 u, 20.99 u, ${}^21.99$ u gð fu; kl dk vkr ijek.kqnð; eku Kkr dhft, A
- 13.3** ukbVktu ukfHkd (${}^{14}_7\text{N}$) dh cakumtæz Mev eakkr dhft, $m_{\text{N}} = 14.00307 \text{ u}$
- 13.4** fuufyf [kr vkrMæ oð vkrkj ij ${}^{56}_{26}\text{Fe}$, ${}^{209}_{83}\text{Bi}$ ukfHkd dh cakumtæz Mev eakkr dhft, A $m({}^{56}_{26}\text{Fe}) = 55.934939 \text{ u}$ $m({}^{209}_{83}\text{Bi}) = 208.980388 \text{ u}$
- 13.5** , d fn, x, fl Doð dk nð; eku 3.0 g gð ml mætkæ dh x.kuk dhft, tksbl fl Doð oð l Hk u; wruka, oai ts/ruka dks, d&nð jsl svyx djustu fy, vko'; d gð l jyrk oð fy, eku yhft, fd fl Ddk iwræ% ${}^{63}_{29}\text{Cu}$ ijek.kqka dk cuk gð (${}^{63}_{29}\text{Cu}$ dk nð; eku = 62.92960 u)A
- 13.6** fuufyf [kr oð fy, ukfHkd; l ehdj.k fyf [k, %
- (i) ${}^{226}_{88}\text{Ra}$ dk α -{k; (ii) ${}^{242}_{94}\text{Pu}$ dk α -{k;
- (iii) ${}^{32}_{15}\text{P}$ dk β^- -{k; (iv) ${}^{210}_{83}\text{Bi}$ dk β^- -{k;
- (v) ${}^{11}_6\text{C}$ dk β^+ -{k; (vi) ${}^{97}_{43}\text{Tc}$ dk β^+ -{k;
- (vii) ${}^{120}_{54}\text{Xe}$ dk byðvru vfhæxg.k
- 13.7** , d jsm; ks sDVo l eLFkkfud dh v/kz q r o"æ gð fdrus l e; oð ckn bl dh , sDVorkj i kjæHkd , sDVork dh (a) 3.125% rFkk (b) 1% jg tk, xhA
- 13.8** thfor dkcú; ðr nð; dh l kekl; , sDVorkj ifr xte dkcú oð fy, 15 {k; ifr feuv gð ; g , sDVorkj LFkk; h l eLFkkfud ${}^{14}_6\text{C}$ oð l kfk&l kfk vyi ek-kk eafol eku jsm; ks sDVo ${}^{12}_6\text{C}$ oð clj.k gsh gð tho dh er; qgksus ij ok; æMy oð l kfk bl dh vl; kð; fØ; k (tks mi jkðr l rfy, sDVork dksuk, j [krh gð) l ekir gsktrh gð rFkk bl dh , sDVork de gksih 'kq gsktrh gð ${}^{14}_6\text{C}$ dh Kkr vkræ q (5730 o"æ) vkr uemus dh eki h xbz, sDVork oð vkrkj ij bl dh l fludv vk; qdh x.kuk dh tk l drh gð ; gh igkrRo fokku eai z ðr gksus okyh ${}^{14}_6\text{C}$ dkyfuekj.k (dating) i ¼fr dk fl ¼kr gð ; g ekudj fd eksgutksMks l sikr fdl h uemus dh , sDVork 9 {k; ifr feuv ifr xte dkcú gð fl ækq&vH l H; rk dh l fludv vk; qdk vkdyu dhft, A

- 13.9** 8.0 mCi l fØ; rk dk jfM; ks fDVo i kr i kr djus oð fy, $^{60}_{27}\text{Co}$ dh fdruh ekHk dh vko'; drk gksx\ $^{60}_{27}\text{Co}$ dh vekz q5.3 o"lz gð
- 13.10** $^{90}_{38}\text{Sr}$ dh vekz q28 o"lz gð bl l eLFkfud oð 15 mg dh fo?kvu nj D; k gð
- 13.11** Lo. lz oð l eLFkfud $^{197}_{79}\text{Au}$, oajtr oð l eLFkfud $^{107}_{47}\text{Ag}$ dh ukfHkd; f-kt; k oð vuq kr dk l fludv eku Kkr dhft, A
- 13.12** (a) $^{226}_{88}\text{Ra}$, oð (b) $^{220}_{86}\text{Rn}$ ukfHkd oð α -{k; eamRI ftz α -d. ka dk Q -eku, oaxfrt Åtzl Kkr dhft, A
fn; k g% $m(^{226}_{88}\text{Ra}) = 226.02540 \text{ u}$, $m(^{222}_{86}\text{Rn}) = 222.01750 \text{ u}$,
 $m(^{222}_{86}\text{Rn}) = 220.01137 \text{ u}$, $m(^{216}_{84}\text{Po}) = 216.00189 \text{ u}$.
- 13.13** jfM; k; ðykM ^{11}C dk {k; fuEufyf[kr l ehdj.k oð vuq kj gsrk gð
 $^{11}_6\text{C} \rightarrow ^{11}_5\text{B} + e^+ + \nu$; $T_{1/2} = 20.3 \text{ min}$
mRI ftz i kvTVk dh vfedre mØtz 0.960 MeV gð nð; ekuka oð fuEufyf[kr eku fn, x, gð
 $m(^{11}_6\text{C}) = 11.011434 \text{ u}$ rFk $m(^{11}_5\text{B}) = 11.009305 \text{ u}$,
 Q -eku dh x. kuk dhft, oamRI ftz i kvTVk dh vfedre mØtz oð eku l sbl dh ryuk dhft, A
- 13.14** $^{23}_{10}\text{Ne}$ dk ukfHkd β^- mRI tzu oð l kfk {kf; r gsrk gð bl β^- -{k; oð fy, l ehdj.k fyf[k, vj mRI ftz byðvMka dh vfedre xfrt mØtz Kkr dhft, A $m(^{23}_{10}\text{Ne}) = 22.994466 \text{ u}$
u; $m(^{23}_{11}\text{Na}) = 22.989770 \text{ u}$,
- 13.15** fd l h ukfHkd; vfhkfØ; k $A + b \rightarrow C + d$ dk Q -eku fuEufyf[kr l ehdj.k }kj i fjHkf"kr gsrk gð
 $Q = [m_A + m_b - m_C - m_d]c^2$
tgk fn, x, nð; eku ukfHkd; fojke nð; eku (rest mass) gð fn, x, vkdMka oð vlekj ij crtb, fd fuEufyf[kr vfhkfØ; k, j mØ'ek{ki h gð; k mØ'ek' kskva
(i) $^1_1\text{H} + ^3_1\text{H} \rightarrow ^2_1\text{H} + ^2_1\text{H}$
(ii) $^{12}_6\text{C} + ^{12}_6\text{C} \rightarrow ^{20}_{10}\text{Ne} + ^4_2\text{He}$
fn, x, i jek.k nð; eku bl i d kj gð %
 $m(^2_1\text{H}) = 2.014102 \text{ u}$
 $m(^3_1\text{H}) = 3.016049 \text{ u}$
 $m(^{12}_6\text{C}) = 12.000000 \text{ u}$
 $m(^{20}_{10}\text{Ne}) = 19.992439 \text{ u}$
- 13.16** ekuk fd ge $^{56}_{26}\text{Fe}$ ukfHkd oð nsl eku vo; oka $^{28}_{13}\text{Al}$ eafol kMu ij foplj dja D; k Åtzl dh n"V l s; g fo kMu l kko gð bl i Øe dk Q -eku Kkr djoð viuk roð l Lrç dja
fn; k g% $m(^{56}_{26}\text{Fe}) = 55.93494 \text{ u}$, oð $m(^{28}_{13}\text{Al}) = 27.98191 \text{ u}$
- 13.17** $^{239}_{94}\text{Pu}$ oð fo kMu xqk cgr oð $^{235}_{92}\text{U}$ l sfeyr & tyrs gð ifr fo kMu foed r vk r mØtz 180 MeV gð; fn 1 kg 'kq' $^{239}_{94}\text{Pu}$ oð l Hk ijek.k fo kMu r gsrk fdruh Mev mØtz foed r gksx\
- 13.18** fd l h 1000 MW fo kMu fj, DVj oð vkeks beku dk 5.00 o"lz ea 0; ; gkstrk gð i kj k eabl eafdrk $^{235}_{92}\text{U}$ fK\ eku yft, fd fj, DVj 80% l e; dk; jr jgrk gð bl dh l a w lz mØtz $^{235}_{92}\text{U}$ oð fo kMu l sgh mRI lu gþz gð rFk $^{235}_{92}\text{U}$ u; ðykM oðoy fo kMu i fØ; k ea gh 0; ; gsrk gð

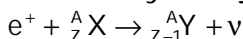
13.19 2.0 kg M ; M f; e oð l y ; u l s, d 100 okV dk fo l r y f d f r u h n j i z l k f ' k r j [k t k l d r k g s l y ; u v f h k f Ø; k f u E u o r y h t k l d r h g s



13.20 nls M ; M nls oð v k e u & l k e u s d h V D d j oð f y, oð y k e v o j k s' d h m o p k b z k k r d h f t, A (l oð r & oð y k e v o j k s' d h Å p t b z d k e k u b u M ; M oð c h p y x u s o k y s m l oð y k e i f r d " l z k c y oð c j k c j g l r k g s t k s, d & n i j s d k s l i oð e a j [k s t k u s i j m u oð c h p v k j k i r g l r k g s ; g e k u l d r s g s f d M ; M 2.0 fm i h k k o h f - t ; k o k y s n < x l s y s g s)

13.21 l e h d j . k $R = R_0 A^{1/3}$ oð v k / k j i j n' k b, f d u k f h k d h; æ o; d k ? k u r o y x h k x v p j g s (v f h k f A i j f u h k j u g h a d j r k g s) A ; g k R_0 , d f u; r k a d g s, o a A u k f h k d d h æ o; e k u l d ; k g s

13.22 f d l h u k f h k d l s β^+ (i m t v n u) m r l t z d h, d v l; i f r; l s k h i f Ø; k g s f t l s b y Ø v n u i f j x g . k (C a p t u r e) d g r s g s (b l e a i j e k . k q d h v l a r f j d d { k } t s s f d k & d { k } l s u k f h k d, d b y Ø v n u i f j x g h r d j y r k g s v l s, d U; Ø v u k s v m r l f t t d j r k g s) A



n' k b, f d ; f n β^+ m r l t z m o t i z f o p k j l s v u e r g s r k s b y Ø v n u i f j x g . k h h v l o'; d : i l s v u e r g s i j r q b l d k f o y k e v u e r u g h a g s

vfrfjDr vH; kl

13.23 v k o r z l k j . l h e a e x u h f ' k; e d k v l s r i j e k . k q n o; e k u 24.312 u f n; k x; k g s ; g v l s r e k u l i f o h i j b l oð l e l f h k f u d k a d h l k i s k c g y r k oð v l e k k j i j f n; k x; k g s e x u h f ' k; e oð r h u k a l e l f h k f u d r f k m u oð n o; e k u b l i z l k j g s μ ${}^{24}_{12}\text{Mg}$ (23.98504 u), ${}^{25}_{12}\text{Mg}$ (24.98584 u), o a ${}^{26}_{12}\text{Mg}$ (25.98259 u) A i f i f r e a i k l r e x u h f ' k; e e a ${}^{24}_{12}\text{Mg}$ d h (æ o; e k u oð v u d k j) c g y r k 78.99% g s v l; n s k a l e l f h k f u d k a d h c g y r k d k i f j d y u d h f t, A

13.24 U; M i f k d d j . k m o t i z (S e p a r a t i o n e n e r g y), i f j h k k oð v u d k j o g m o t i z g s t k s f d l h u k f h k d l s, d U; M d k s f u d k y u s oð f y, v l o'; d g l r h g s u h p s f n, x, v l o d m l a d k b l r e k y d j oð ${}^{40}_{20}\text{Ca}$, o a ${}^{27}_{13}\text{Al}$ u k f h k d k a d h U; M i f k d d j . k m o t i z k k r d h f t, A

$$m({}^{40}_{20}\text{Ca}) = 39.962591 \text{ u}$$

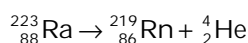
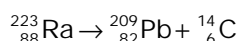
$$m({}^{41}_{20}\text{Ca}) = 40.962278 \text{ u}$$

$$m({}^{26}_{13}\text{Al}) = 25.986895 \text{ u}$$

$$m({}^{27}_{13}\text{Al}) = 26.981541 \text{ u}$$

13.25 f d l h i k r e a i Ø m l i Ø s l oð n l s j s M; l s U; Ø y k b M f u f g r g s ${}^{32}_{15}\text{P}$ ($T_{1/2} = 14.3 \text{ d}$), o a ${}^{33}_{15}\text{P}$ ($T_{1/2} = 25.3 \text{ d}$) A i k j b l k e a ${}^{33}_{15}\text{P}$ l s 10% {k; i k l r g l r k g s b l l s 90% {k; i k l r d j u s oð f y, f d r u s l e; i r h { k d j u h g l s k h }

13.26 oð n f o f ' k v i f j f l f r; k e j, d u k f h k d] æ & d . k l s v f e k d n o; e k u o k y k, d d . k m r l f t t d j oð {k; r g l r k g s f u e u y f [k r {k; & i f Ø; k v l a i j f o p k j d h f t, %



b u n s k a {k; i f Ø; k v l a oð f y, g & e k u d h x . k u k d h f t, v l s n' k b, f d n s k a i f Ø; k; j m o t i z d h n' v l s l h k o g s

13.27 r h o z U; M k j k ${}^{238}_{92}\text{U}$ oð f o [k b u i j f o p k j d h f t, A f d l h f o [k b u i f Ø; k e a i k f k e d v a k k a (P r i m a r y f r a g m e n t s) oð c h v k & {k; oð i' p k r d k b z U; M m r l f t r u g h a g l r k r f k

$^{140}_{58}\text{Ce}$ rFk $^{99}_{44}\text{Ru}$ väre mRikn ikr gks gä fo [kMu ifØ; k oö fy, **g** oö eku dk ifjdyu dhft, A vko'; d vkdMæbl izdkj g8%

$m(^{238}_{92}\text{U}) = 238.05079 \text{ u}$

$m(^{140}_{58}\text{Ce}) = 139.90543 \text{ u}$

$m(^{99}_{44}\text{Ru}) = 98.90594 \text{ u}$

13.28 D-T vfhkfo; k (M; Vhfj; e&VhfV; e l y; u) $^2_1\text{H} + ^3_1\text{H} \rightarrow ^4_2\text{He} + n$ ij fopkj dhft, A

(a) uhpfn, x, vkdMæoö vkekj ij vfhkfo; k esfoeØr mØtkz dk eku MeV eaKkr dhft, A

$m(^2_1\text{H}) = 2.014102 \text{ u}$

$m(^3_1\text{H}) = 3.016049 \text{ u}$

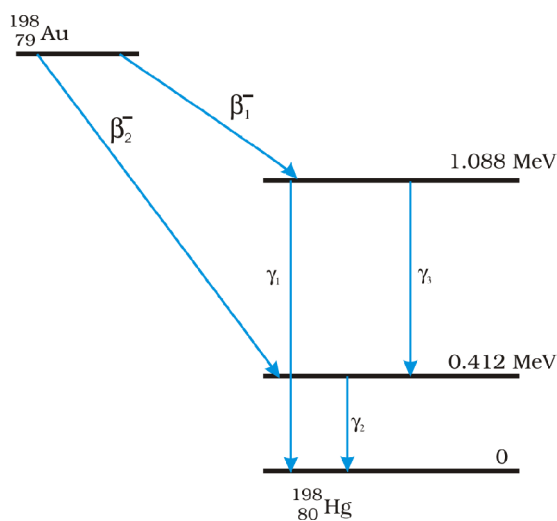
(b) M; Vhfj; e , oaVhfV; e nkska dh f-kT; k yxHkx 1.5 fm eku yhfT, A bl vfhkfo; k eö nkska ukfHkdka oö eè; oöyke ifrd"lk k l s i k j i kus oö fy, fdruh xfrt mØtkz dh vko'; drk gS vfhkfo; k i kjalk djus oö fy, xS ka (D rFk T xS g) dksfdl rki rd Åf"er fd; k tkuk pkfg, \

(l oö r % fd l h l y; u fØ; k oö fy, vko'; d xfrt mØtkz = l y; u fØ; k ea l yXu d. ka dh vS r rki h; xfrt mØtkz = 2 (3kT/2); k % ckV"keku fu; rkd rFk T = i je rki)

13.29 uhpfnh xbz {k; & ; l s t uk eö g& {k; ka dh fofdj. k vkofÜk; k , oaβ-d. ka dh vfekdre xfrt mØtkz; Kkr dhft, A fn; k gS%

$m(^{198}\text{Au}) = 197.968233 \text{ u}$

$m(^{198}\text{Hg}) = 197.966760 \text{ u}$



fp-k 13.6

- 13.30** Í 7.00 vH; rj ea (a) 1 kg gkbMkstu oð l y; u oð l e; foedr Átk/ dk í fdyu dhft, A (b) fo [kMu fj, DVj ea 1.0 kg ^{235}U oð fo [kMu ea foedr Átk/ dk í fdyu dhft, A (c) rFkk (b) izuka ea foedr Átk/ka dh rgyuk dhft, A
- 13.31** eku yhft, fd Hkkjr dk y{; 2020 rd 200,000 MW fo | r 'kfDr tuu dk gð bl dk 10% ukfHkdh; 'kfDr l a awwa l siklr gksuk gð ekuk fd fj, DVj dh vkð r mi; kx n{krk (m'ek dks fo | r ea í fjofr r djus dh {kerk) 25% gð 2020 oð var rd gekjs ns k dks í r o'iz fdrus fo [kMu; ; jfsu; e dh vko'; drk gkskh ^{235}U í fr fo [kMu mRl ft r mQt k 200 MeV gð

