

vè; k; 12

ijek. kq

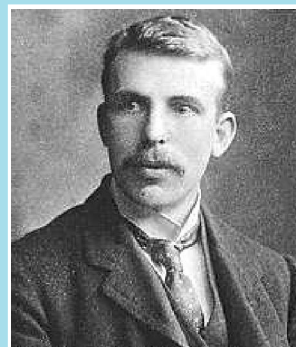


12.1 Hkfrfiedk

mlluhl oha 'krkCnh rd inkFKZ dh ijek.oh; ifjdYi uk oð l eFKZ ea dklkCh l k{; , df=kr gks x, FlA l u-1897 ea fcfV'k Hkfrdfokkuh tkl sQ ts VkkE l u (1856 – 1940) us xS ka ds fo|q fol tZ iz kxka }kjk Kkr fd; k fd fofHkuu rRoka oð ijek.kq/ka ea mi fLFkr ½.kkRed vkof'kr l æKVd (byðVVMU) l Hkh ijek.kq/ka oð fy, i wkZ; k l eku gð rFKfi i] ijek.kqLo; a ea oS|q : i l smnl hu gks s gð bl fy,] byðVVMU oð ½.k vkof'k dks fu"i Hkfrfor djus ds fy, ijek.kq ea /ukRed vkof'k Hkh vo'; gksuk pkrfg, A yfdu ijek.kq ea /ukRed vkof'k rFKk byðVVMU dh 0; oLFkk D; k gS. nuh js 'kCnka e] ijek.kq dh l jipuk D; k gS.

l u-1898 ea ts ts VkkE l u us ijek.kq dk igyk ekMy iZrkfor fd; ka bl ekMy oð vuq kj] ijek.kq dk /u vkof'k ijek.kq ea i wkZ; k , dl eku : i l sforfjr gS rFKk ½.k vkof'kr byðVVMU bl ea Bhd ml h izdkj var%LFkkfir gð tS sfdl h rjcut eachtA bl ekMy dks fp=ke; : i ea l ye i qMx ekMy dgk x; ka rFKfi ijek.kq ds fo" k; ea ckn ds vè; ; uka us tS k fd bl vè; k; ea of. kZ gS ; g n' kZ; k fd ijek.kq ea byðVVMU ka rFKk /u vkof'ka dk forj. k bl iZrkfor ekMy l scgq fHkuu gð

ge tkurs gð fd l ækur inkFKZ (Bkl rFKk æo) rFKk l ?ku xS a l Hkh rki ka i j oS|q ppa; dh; fofdj. k mRl ftZ djrs gð ft l ea vusl rjxnS; ksdk l arr forj. k fo|eku gksrk gS; | fi mudh rhork; ; fHkuu gksrk gð ; g l e>k x; k fd ; g fofdj. k ijek.kq/ka rFKk v. kq/ka ds nky ula ds dkj . k gksrk gS tS i R; sd ijek.kq vFkok v. kq dk vius l ehi oð ijek.kq/ka; k v. kq/ka oð l kfk gksus okyh



vušV jnji Q&MZ (1871-1937)

vax's'k H&K&rdfoKluh ftUglaus j&M; kš fDVo fofdj.kka ij vxz.kh dk; Zfd; KA mUglaus , YH&K&], oachV&k&fdj.kkadh [k&st d&A i&fV&ed l k&Vh o& l f&k dk; Zdj mUglaus j&M; kš fDVork dk vk/fud fl ¼&ar i&L&rq fd; KA mUglaus F&K&š; e l s fudyus okys fofdj.kka dk v&; u fd; k ftl o& ifj.kkeLo: i fuf"Ø; xš F&K&š&u dh [k&st g&ž t&š j&M&W dk l eL&F&K&fud g&š i rys&kk&rq o& od&š&ej , YH&K&fdj.kka o& izdh.k& l smUglaus ij&kf.od ukf&H&kd dh [k&st dh v&š ij&ek.kq dk x&g&h; ek&W&ly i&L&rq fd; KA mUglaus ukf&H&kd o& l fludV l kb" k dk vu&ku H&h y&x&k; KA

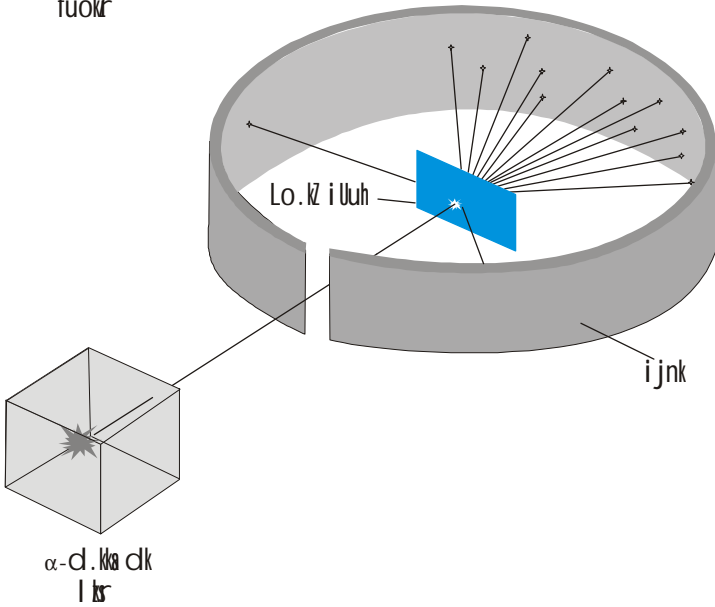
vU; k; fØ; k l s fu; f&hr g&rk g&š bl o& foijhr Tokyk ea x&el dh x&b&ž foj&fyr x&š ka }&j&k m&Rl ft&ž i&zk'k v&F&ok fd l h r&ki n&hlr ufy&dk ea fo l q mU&š&tr x&š] t&š sfuv&W&W l kb&u v&F&ok i&kj&n&o&k" i& i&zk'k ea o&š&oy fuf' pr fofoDr r&j&xn&š; Z&g&rh g&š buo&š Li&šV&e ea pedhyh j&š&k&v&ka dh , d k&š&kyk fn [k&b&ž n&rh g&š , š h x&š ka ea i&jek.kq/ka o&š& e&e; varjky vf/d g&rk g&š vr&š& m&Rl ft&ž fofdj.k] i&jek.kq/ka v&F&ok v.kq/ka o&š& chp vU; k; fØ; kv&ka o&š& ifj.kkeLo: i ugh&š cfY&d 0; f"V&x&r i&jek.kq/ka ds&dkj.k ekuk tk l drk g&š ml&u&hl o&ha 'kr&k&cnh o&š& i&kj&h&k ea gh ; g L&F&K&fir g&š x&; k F&k fd i&R; š&l rRo l sm&Rl ft&ž fofdj.k dk , d v&f&H&kyk {k&f.k&d Li&šV&e g&rk g&š m&n&kgj.k o&š& fy,] g&kb&M&st&u Li&šV&e l n&š j&š&k&v&ka dk , d l e&P&p; g&rk g&š ftl ea j&š&k&v&ka o&š& chp dh v&k&š&f&kd f&L&F&K&fir; k&š fuf' pr g&rh g&š bl r&F; us&fdl h i&jek.kq dh v&kr&f&jd l &j&puk v&š&š bl l s m&Rl ft&ž fofdj.k o&š& Li&šV&e ds& chp ?&f&u" B l &ca' dh v&š&š l &š&ar fd; KA l u-1885 ea t&ku t&dc& c&ej (1825 – 1898) us i&jek.o&h; g&kb&M&st&u l sm&Rl ft&ž j&š&k&v&ka o&š& l e&g& dh v&k&f&š&k; ka o&š& fy, , d l j&y v&ku&h&f&od l &š& i&kl&r fd; KA p&f&id g&kb&M&st&u , d l j&yre k&kr rRo g&š ge bl o&š& Li&šV&e dk bl v&e; k; ea fo l r&kj l s v&e; ; u dj&ka

t&š ts v&W&š l u o&š& , d H&ar i&v&ž' k&š' N&š& k vušV jnji Q&MZ (1871-1937), o&š&N j&š&M; k&š fDVo rRo&ka l sm&Rl ft&ž , YH&K&d.k&ka (α-d.k&š) ij , d iz&š& djuse&0; Lr F&ka i&jek.kq dh l &j&puk dk v&lo&š&k& djuse&š& fy, mUglaus l u-1906 ea i&jek.kq/ka }&j&k , YH&K&d.k&ka ds& izdh.k&š& l s l &š&ar r , d Dy&k&f&l dh iz&š& i&L&rk&for fd; KA ; g iz&š& o&š&N l e; i' p&kr l u-1911 ea g&š& x&kb&x&j (1882 – 1945) r&F&k vušV ek&l Mu (1889 – 1970, t&š 20 o"kh&ž, N&š& k&š r&F&k ftUglaus v&H&h Lukrd dh m&lf&/ H&h x&g&.k ugh& dh F&h) us fd; KA vu&š&N&š 12.2 ea bl dh fo&L&rkj l s 0; k [; k dh x&b&ž g&š bl ds& ifj.kkeLo dh 0; k [; k us i&jek.kq o&š& jnji Q&MZ ds& x&g&h; ek&W&ly d&š& t&le fn; k (ftl s i&jek.kq dk ukf&H&kd&h; ek&W&ly H&h dg&k t&kr& g&š&A bl o&š& vu&š& k&j] fd l h i&jek.kq dk o&š& /uk&š& k r&F&k vf/d&ka&k &e&0; eku , d l &š&e v&k; ru ea l &š&ar g&rk g&š ftl s ukf&H&kd dg&rs g&š v&š&š bl o&š& p&kj&ka v&š&š by&š&V&R&W ml h i&zk&j ifj&š&ek dj&rs g&š t&š l w&ž o&š& p&kj&ka v&š&š x&g& ifj&š&ek dj&rs g&š

ijek.kq o&š& ftl or&ž&ku : i d&š&ge t&kurs g&š& jnji Q&MZ dk ukf&H&kd&h; ek&W&ly ml fn'k& ea , d c&M&k& dne F&KA r&F&K&fi bl o&š& }&j&k ; g 0; k [; k ugh&ad&k tk l dh fd i&jek.kq o&š&oy fofoDr (discrete) r&j&xn&š; Z&dk i&zk'k g&h D; ka m&Rl &tr& dj&rk g&š g&kb&M&st&u t&š& k , d l j&y i&jek.kq ftl ea , d by&š&V&R&W r&F&k , d i&š&v&W&W g&rk g&š fo'k&š&k r&j&xn&š; Z&dk , d t&f&vy Li&šV&e o&š& l s m&Rl ft&ž dj&rk g&š i&jek.kq o&š& Dy&k&f&l dh fp&=k& e&š& by&š&V&R&W ukf&H&kd o&š& p&kj&ka v&š&š B&hd , š s&gh ifj&š&ek dj&rk g&š t&š& s&f&d l w&ž ds&p&kj&ka v&š&š x&g& ifj&š&ek dj&rs g&š r&F&K&fi] ge n&š& l&ks&f&d bl ek&W&ly d&š& l&oh&dkj dj&us ea o&š&N x&h&k&j d&f&B&uk&š; k&š g&š

12.2 , YH&K& d.k izdh.k&š& r&F&k i&jek.kq dk jnji Q&MZ ukf&H&kd&h; ek&W&ly l u-1911 ea jnji Q&MZ o&š& l &š&ko ij , p- x&kb&x&j r&F&k b&ž ek&l Mu us o&š&N iz&š& fd, A muo&š& }&j&k

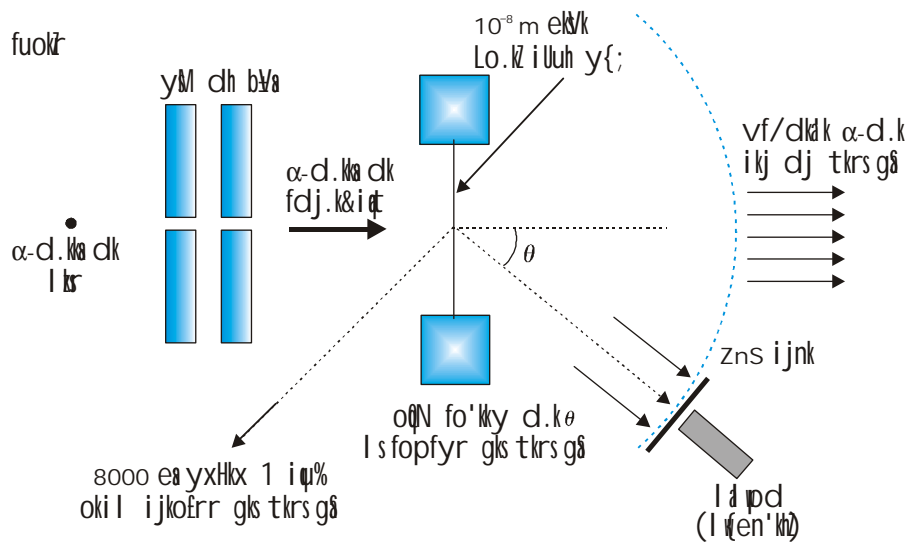
fuokzr



fp= 12.1 xkxj&ekl Mu izdh. kzu iz ksa l a wZ midj. k , d fuokzr d{k eaj [kk x; k gB (bl fp= ea ; g d{k ughan' kZ k x; k gB)

fd, x, , d iz kx eaj sM; k sDVo l kr $^{214}_{83}\text{Bi}$ l s mRl ftZ 5.5 MeV AtkZ okys α-d. kka oB , d i q dks irys Lo. kz i Uuh ij fn"V dj k; k x; k j tS k fd fp= 12.1 ea n' kZ k x; k gB fp= 12.2 ea bl iz kx oB 0; ofLFkr fp= dks n' kZ k x; k gB j sM; k sDVo l kr $^{214}_{83}\text{Bi}$ l s mRl ftZ α-d. kka oB , d irys fdj. k&i q dks yM dh bV ka dseè; l s x q k j dj l j f [kr fd; k x; ka bl fdj. k&i q dk $2.1 \times 10^{-7} \text{m}$ e k s/h Lo. kz i Uuh ij vk? kr dj k; k x; ka iz dhf. kZ α-d. kka dk fo{ki eki us oB fy, , d ?w khZ l a p d dk iz kx fd; k x; k ft l ea, d t d l Y i Q k M dk i j n k , o a , d l w en' khZ FkA iz dhf. kZ , s t k & d. k i j n s l s V d j k d j p e d h y s Y y s k v F k o k i z i q j m R i l u d j r s g B ; s Y y s k l w en' khZ } k j n s [k s t k l d r s g a r F k k i z dhf. kZ d. kka dh l q ; k oB forj. k dk iz dh. kzu dks oB i o y u oB : i ea vè ; ; u f d ; k t k l d r k g B

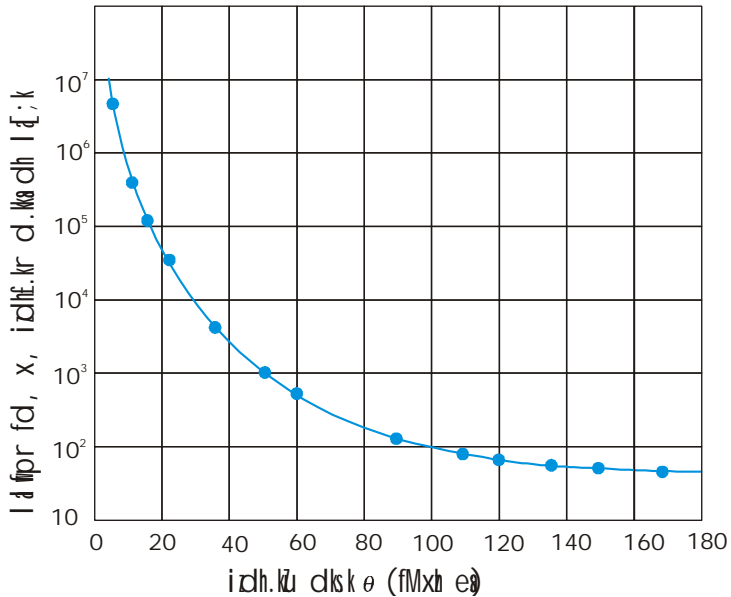
fuokzr



fp= 12.2 xkxj&ekl Mu iz kx dk 0; oLFKRRed fu: i. ka

fp= 12.3 eafdl h fn, l e; k r j k y e a f o f H k u d l s k a i j i z dhf. kZ o q y , s t k & d. kka dh l q ; k dk i k : f i d v k y s [k n' k Z k x; k g B bl fp= e a f n [k k , x, t n q i z k x e a i k t r v k d M k a d l s f u : f i r d j r s g B v l s l r r o B l s 4 k i r d i n o k z e k u g s t k s b l d Y i u k i j v k / k j r g s f d i j e k . k q e a , d l w e l ? k u r F k / u k o s ' k r u k f H k d g B c g r l s , s t k & d. k Lo. kz i Uuh d l s i k j d j t k r s g B bl dk v F i z g s m u e a l a k e u u g h a g l s k a v k i f r r , s t k & d. kka e a l s o B o y 0.14% (y x H k x) dk 1° oB d l s k l s v f / d i z dh. kzu g l s k g s r F k k 8000 , s t k & d. kka e a l s y x H k x 1 d. k 90° l s v f / d f o {k i r g l s k g B j n j i Q k M Z u s r o d f d ; k f d , s t k & d. kka d l s f o i j h r f n' k k

ea fo{lsir djus oð fy,] bu ij cgr vf/d ifrd"lk k cy yxuk pfg, A bruk vf/d cy rHkh i ktr gsl drk gS; fn ijek.kqdk vf/dlk æ0; eku rFk bl dk /u&vkošk bl oð oðe ij n<rk i nðl l oðæar gk rc vnj vkrk gqk , yHk&d.k /u vkošk dksHksfcuk bl oð vR; r l ehi vk l drk gS rFk bl izkj oð l exo oð ifj.kelo: i vfekd fo{lsi gkskA bl l s ukfHkd; ijek.kq dh ifjdYiuk dh if"V gksh gA ; gh dkj.k gS fd jnji OðMZ dksukfHkd dh [kst dk Js fn; k tkrk gA jnji OðMZ oð ijek.kq oð ukfHkd; ekmy eð ijek.kq dk oðy /ukošk rFk bl dk vf/dlk æ0; eku ijek.kq oð cgr Nksl svk; ru ea l oðæar gsk gS ft l s ukfHkd dgrs gA rFk byDVNU bl l s oðN nji gksr gA byDVNU ukfHkd oð pkja vlsj d{kk ea pDdj yxkrs gA Bhd , d s gh tS s l w Z oð pkja vlsj xg pDdj yxkrs gA jnji OðMZ oð iz kxka us l qk; k fd ukfHkd dk l kb" k yxHkx 10^{-15} m l s 10^{-14} m gS l drk gA xfrt fl ¼kr oð vud kj ijek.kqdk l kb" k 10^{-10} m eku tkrk gS tksfd ukfHkd oð l kb" k dh višk yxHkx 10,000 l s 100,000 xqk cMk gS (d{kk 11 dh Hksrdh i kb; i krd dk vè; k; 11, vuPNn 11.6 nS{A bl izkj) ukfHkd l s byDVNU ukfHkd oð l kb" k dh višk yxHkx 10,000 l s 100,000 xqk nji fn [kbs nskA bl izkj) ijek.kq oð Hkrj dk vf/dlk Hkx [kyh gA ijek.kq oð Hkrj dk vf/drj Hkx [kyh gks oð dkj.k ; g l e>uk vki ku gS fd vf/drj , yHk&d.k iryh /krq dh iluh l sfcuk fo{lsir gq ckj D; ka fudy tkrsgA rFkfi) tc dkbz, yHk&d.k ukfHkd oð l ehi vkrk gS rksogk ij fo|eku icy fo|q cy bl scM&dsk l s izhf. krdj nsk gA ijek.kq oð byDVNU vR; r gyoð gks oð dkj.k , yHk&d.k. ka ij i ; krd i Hko ugha Mky i krA



fp= 12.3 fp= 12.1 rFk 12.2 ea xkxj&ekl Mu }kj iz qd iz kx 0; oLFk }kj i ktr fcmj fd l h Lo.k&iluh oð fy, , yHk&d.k izh.ku vqdMs gA Bkl oð l ¼krd i mZupku gS tks bl dYiuk ij vk/kfjr gS fd ijek.kq ea, d l [e] l ?u rFk /ukošk'kr ukfHkd gA

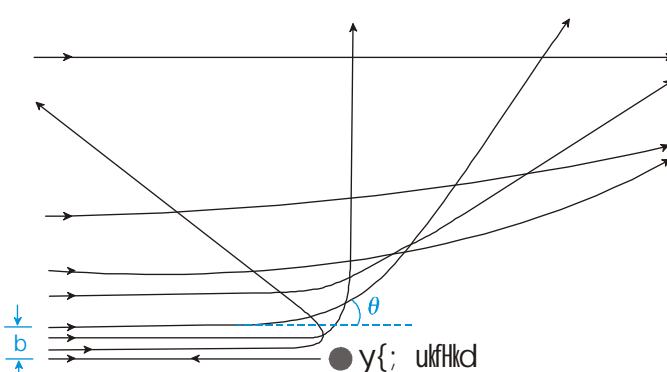
fp= 12.3 ea inf' krd izh.ku vqdMka dk fo'ySk. k jnji OðMZ oð ijek.kq oð ukfHkd; ekmy }kj fd; k tk l drk gA Lo.k iluh oð cgr iryh gks oð dkj.k ; g dYiuk dh tk l drh gS fd bl iluh dsk ij djs l e; α -d.k , d l svf/d ckj izhf. krd ughagkA vr% fd l h , d ukfHkd l s izhf. krd , yHk&d.k oð i z k i f k dk vfHkdyu dklh gA , yHk&d.k ghfy; e ijek.kq oð ukfHkd gA bl fy, bu ij nls bdkb] 2e, /ukošk gS vlsj æ0; eku ghfy; e ijek.kq oð æ0; eku oð cjkj gA Lo.k oð ukfHkd dk vkošk **Ze** gS ; gk **Z** ijek.kq dk ijek.kq Øekd gS tks Lo.k oð fy, 79 gA pfd Lo.k&ukfHkd α -d.k oð ukfHkd l s 50 xqk Hkj gS vr% ; g dYiuk djuk roðl ær gS fd izh.ku iðe oð l e; Lo.k&ukfHkd fLFkj jgrk gA bu vfHk/kj.kvka oð vk/kj ij , yHk&d.k vlsj /ukošk'kr ukfHkd oð eè; fLFkj oð q ifrd"lk k cy oð oðy&f; e rFk U; wu oð xfr oð f}rh; fu; e }kj , yHk&d.k oð i z k i f k dk vfHkdyu fd; k tk l drk gA bl cy dk ijek.k bl izkj 0; Dr fd; k tkrk gS %

$$F = \frac{1}{4\pi\epsilon_0} \frac{(2e)(Ze)}{r^2} \tag{12.1}$$

tgk r, Ylkk&d.k dh ukfhkd l snjh g& vkijsi r cy], Ylkk&d.k vlg ukfhkd dlsfeykusokyh j&kk o& vuq'n'k g&, Ylkk&d.k ij vkijsi r cy dk ifjek.k, oafn'kk], Ylkk&d.k o& ukfhkd dh vlg vfhkxeu djusokysrFkk ml l snjh tkus o& l kfk yxkrkj ifjofr'z g&sh jgrh g&

12.2.1 , Ylkk&d.k i&ksi & i Fk

, Ylkk&d.k }kjk vuq'f [kr i&ksi i Fk] l &ke& o& l &ke& i kpy] b ij fuHkj djrk g& l &ke& i kpy , Ylkk&d.k o& i kja&hk d osx l fn'k dh ukfhkd o& o&e l svfhky&ch; njih g& (fp=k 12.4) A fn, x, , Ylkk&d.k ka o& i&e ds l &ke& i kpy b dk forj.k bl i&zkj g&sd i&e fofhkuu fn'kkvka



fp=k 12.4 fdl h Hkjh ukfhkd o& o&e yk&e {lek ea, Ylkk&d.k dk i&ksi i Fk l &ke& i kpy b vlg i&zh.ku dlsk o& vrj fp=k ea n'kk, x, g&

ea fHkuu&fHkuu i kf; drkva l s i&zhf. k& g&rk g& (fp=k 12.4) A (fdl h i&e ea l Hkh d. ka dh yxHkx l eku xfrt &tkz g&sh g&); g n&kk x; k g&sd ukfhkd o& l ehi d&bz, Ylkk&d.k (de l &ke& i kpy) vf/d i&zhf. k& g&rk g& i R; {k l &ke& dh fLFkr ea l &ke& i kpy U; ure g&srFkk, Ylkk&d.k i hNs dh vlg ifrf {kr g&rk g& (theta = pi) A l &ke& i kpy o& vf/d eku o& fy,] , Ylkk&d.k yxHkx vfopfyr jgrk g&srFkk fo {ki cgr de g&rk g& (theta = 0) A

; g rF; fd vki frr d. ka ea l so&oy, d Nk&v Hkx gh Vdjk& oki l yk&rk g&; g l fpr djrk g& fd i R; {k l &ke& dh fLFkr ea vkus okys, Ylkk&d.k ka dh l&e; k cgr de g& bl l s kkr g&rk g&sd ukfhkd dk &e; eku cgr Nk&svk; ru ea l o&f&er g& bl i&zkj

jnji o&MZ i&zh.ku ukfhkd o& l kb''k dh mPpl hek kkr djus dk, d 'kDr' kkyh l k/u g&

mnkgj. k 12.1

mnkgj. k 12.1 i jek. kqo& jnji o&MZ o& ukfhkd; ekmy ej ukfhkd (f=kT; k yxHkx 10⁻¹⁵ m) l wZ o& l n'k g& ft l o& ifjr% by&DV& viusd {k (f=kT; k ≈ 10⁻¹⁰ m) ea, l s ifj&ek djrk g&st& s iFoh l wZ o& pkja vlg ifj&ek djrh g& ; fn l k& ifjokj dh foek, i ml h vuq kr ea g&sha t&sf dl h i jek. kqea g&sh g& rls D; k iFoh viuh okLrfod fLFkr dh vi&kk l wZ o& i kl g&sh; k njj g&sh \ iFoh o& d {k dh f=kT; k yxHkx 1.5 × 10¹¹ m g& l wZ dh f=kT; k 7 × 10⁸ m ekuh x&z g&

gy by&DV& o& d {k dh f=kT; k rFkk ukfhkd dh f=kT; k dk vuq kr g& (10⁻¹⁰ m)/(10⁻¹⁵ m) = 10⁵, vFkr by&DV& o& d {k dh f=kT; k] ukfhkd dh f=kT; k l s 10⁵ x&pk vf/d g& ; fn l wZ o& pkja vlg iFoh o& d {k dh f=kT; k l wZ dh f=kT; k l s 10⁵ x&pk vf/d g& rls iFoh o& d {k dh f=kT; k g&sh 10⁵ × 7 × 10⁸ m = 7 × 10¹³ mA ; g iFoh dh okLrfod d {k; f=kT; k l s 100 x&pk vf/d g& vr% bl fLFkr ea iFoh l wZ l scgr vf/d njj g&sh A bl l s; g Hkh kkr g&rk g&sd i jek. kqea g&js l k& ifjokj dh vi&kk cgr vf/d Hkx [kkyh LFku g&

mnkgj.k 12.2 xkxj&ekl Mu iz; s; ea 7.7 Mev o& fdl h , yHk&d.k dh Lo.k&ukfHkd l s{k.k Hkj o& fy, fojkeoLFk ea vkus l sigys rFk fn'kk ifrykeu l siwz lehire njih D;k g&

gy ; gk&ed; ; ekj.kk ; g gsf& izh.ku i&e dh l elr vofek eafdl h rak t& s, yHk&d.k vlg Lo.k&ukfHkd dh o&y ; k&id m&tkz l jf{kr jgrh g& , yHk&d.k vlg ukfHkd dh vU; k& f& ; k l siwz rak dh ikj&Hkd ; k&id m&tkz E_i d.k o& {k.f.kd : i l sfojkeoLFk ea vkus i j ml dh ; k&id m&tkz E_f o& cjkcj g& ikj&Hkd m&tkz E_i vlxkeh , yHk&d.k dh xfrt m&tkz K o& Bh& cjkcj g& v&ire m&tkz E_f rak dh fo|r fLFkrt m&tkz U gh g& fLFkrt m&tkz U dk lehdj.k (12.1) l si fdyu fd;k tk l drk g&

eku yHft, fd , yHk&d.k o& o&nz vlg Lo.k&ukfHkd o& o&nz o& chp njih d g& tc α d.k vi usfojkeu fcnqij fLFkr g& rc m&tkz l j{k.k o& fu; eku& kj] $E_i = E_f$ dks bl izkj 0; Dr fd;k tk l drk g&

$$K = \frac{1}{4\pi\epsilon_0} \frac{(2e)(Ze)}{d} = \frac{2Ze^2}{4\pi\epsilon_0 d}$$

vr% lehire njih d g&sch

$$d = \frac{2Ze^2}{4\pi\epsilon_0 K}$$

iko&fr& l s;ka o& , yHk&d.k.ka ea ik&z tkus okyh vf/dre xfrt \hat{A} tkz 7.7 Mev vFkok 1.2×10^{-12} J g& D; k&id $1/4\pi\epsilon_0 = 9.0 \times 10^9$ N m²/C² bl fy, $e = 1.6 \times 10^{-19}$ C, o& l fFk] gea i klr g&sch

$$d = \frac{(2)(9.0 \times 10^9 \text{ Nm}^2/\text{C}^2)(1.6 \times 10^{-19} \text{ C})^2 Z}{1.2 \times 10^{-12} \text{ J}}$$

$$= 3.84 \times 10^{-16} \text{ Z m}$$

i Uuh o& inkf&z Lo.kz dk ijek.kq &ek& z = 79, bl fy,

$$d(\text{Au}) = 3.0 \times 10^{-14} \text{ m} = 30 \text{ fm} \quad (1 \text{ fm (vFk&z-i Qehz)} = 10^{-15} \text{ m})$$

vr% Lo.kz ukfHkd dh f&kt; k 3.0 $\times 10^{-14}$ m l sde g& ; g i f{kr i j.k&e l scgr vf/d esy ugha [kkrh g&SD; k&id Lo.kz ukfHkd dh okLrfod f&kt; k 6 fm g& bl fol xfr dk dkj.k ; g gsf& lehire i gpus dh njih , yHk&d.k rFk Lo.k&ukfHkd dh f&kt; kv&ao& ; s; l s&kl&h vf/d g& bl izkj , yHk&d.k Lo.k&ukfHkd dksokLro ea Nq fcuk gh vi uh xfr dh fn'kk foijhr dj ysk g&

12.2.2 by&DV&u&d{k& , j

ijek.kq dk jnji o&nz ukfHkdh; ek&ny ftl ea Dykfl dh /kj.kk, j l f&efyr g& ijek.kq dks , d fo|r; mnk hu x&sys o& : i eafp&f&r djrk g& ftl o& o&nz i j cgr Nk&v& Hk&jh rFk /u vkos'kr ukfHkd g& t&sviuh&viuh xfr'khy fLFkj d{k&v&ka&?k&ers by&DV&u&l sf?kj& g&rk g& i f&j&ek djrsg& by&DV&u& rFk ukfHkd o& chp fLFkjos& r v&d"l&k cy F_e by&DV&u& dks vi us d{k& eacuk, j [kus o& fy, vko'; d v&f&ko&eh cy (F_c) i nku djrk g& vr% g&kb&st&u ijek.kq ea xfr'khy fLFkj d{k& o& fy,

$$\mathbf{F}_e = \mathbf{F}_c$$

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2} \tag{12.2}$$

jnji o&nz izh.ku iz; s; o& vupkj
<http://www.outreach.phy.com.ac.uk/compan/nucleus/nucleus-exp.html>

mnkgj.k 12.2



vr% d{kk&f=kT; k rFkk byDVNM&ox ea l ca/ glsk

$$r = \frac{e^2}{4\pi\epsilon_0 mv^2} \tag{12.3}$$

gkbMrstu oð i jek. kq ea byDVNM dh xfrrt Åtkz(x) rFkk fLFkjof r fLFkrrt Åtkz(u) glsk

$$K = \frac{1}{2}mv^2 = \frac{e^2}{8\pi\epsilon_0 r} \text{ rFkk } U = -\frac{e^2}{4\pi\epsilon_0 r}$$

(U ea ½. WRed fpÉ l fpr djrk gSfd fLFkjof r cy -r fn'kk eag) vr% gkbMrstu i jek. kq ea byDVNM dh ofy Åtkz[E]

$$E = K + U = \frac{e^2}{8\pi\epsilon_0 r} - \frac{e^2}{4\pi\epsilon_0 r} = -\frac{e^2}{8\pi\epsilon_0 r} \tag{12.4}$$

byDVNM dh ofy Åtkz ½. WRed gð ; g rF; n'kkzrk gS fd byDVNM ukfHkd l s ifjc¼ gð ; fn E /ukRed glsk rks byDVNM ukfHkd oð pjka vjg ca d{k ea ugha ?merkA

mnkgj. k 12.3

mnkgj. k 12.3 iz lsk jkjk ; g ik; k x; k fd gkbMrstu i jek. kq dks , d i kVNM rFkk , d byDVNM ea i Fkd djus oð fy, 13.6 eV Åtkz dh vko' ; drk gð gkbMrstu i jek. kq ea d{kh; &f=kT; k rFkk byDVNM dk ox ifjdfyr dhft, A

gy gkbMrstu i jek. kq ea byDVNM dh ofy Åtkz gS -13.6 eV = -13.6 × 1.6 × 10⁻¹⁹ J = -2.2 × 10⁻¹⁸ J vr% l ehdj. k (12.4) l s gea i klr glsk

$$-\frac{e^2}{8\pi\epsilon_0 r} = -2.2 \times 10^{-18} \text{ J}$$

bl l s d{kh; &f=kT; k i klr glsk %

$$r = -\frac{e^2}{8\pi\epsilon_0 E} = -\frac{(9 \times 10^9 \text{ N m}^2/\text{C}^2)(1.6 \times 10^{-19} \text{ C})^2}{(2)(-2.2 \times 10^{-18} \text{ J})} = 5.3 \times 10^{-11} \text{ m}$$

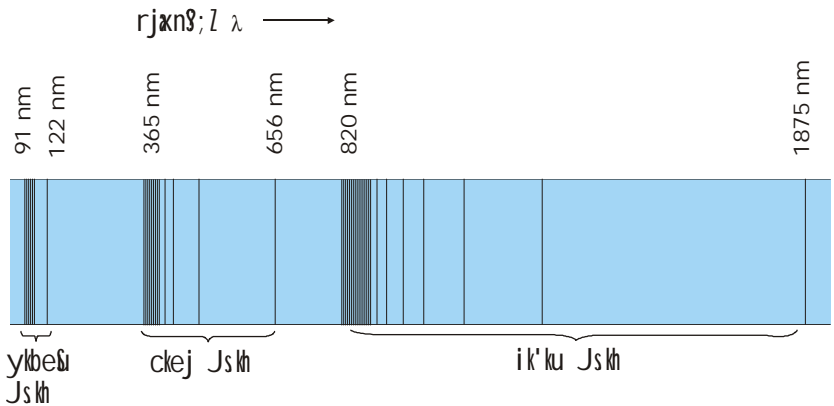
ifjØe. k djrs byDVNM dk ox l ehdj. k (12.3) l sm = 9.1 × 10⁻³¹ kg ydij ifjdfyr dj l drsgð

$$v = \frac{e}{\sqrt{4f v_0 m r}} = 2.2 \times 10^6 \text{ m/s}$$

12.3 i jek. oh; Li DVe

vu@Nn 12.1 ea mYy[k fd, vuq kj] iR; d rRo vfHkyk{kf. kd Li DVe&fodj. k mRI Ètr djrk gð tc dkbz i jek. oh; xS vFkok ok'i fuEu nkc ij] ik; % bl l s fo| r /kj k iokgr djoð] mRI Ètr dh tkrh gS rks mRI ftz fofdj. k l s Li DVe i klr glsk gS ft l ea oqN fo' k'V rjans; Zgh glsk gð bl izdj oð Li DVe dks mRI tZ jS[kd Li DVe dgrsg rFkk bl eadkyh

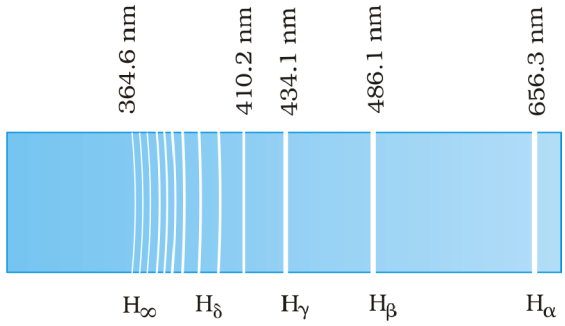
i"BMWe ij nhr j[kk, j gkrh g[fp=k 12.5 ea ije.koh; gkbMkstu }kjk mRI Etr LiDV'e n'kz k x; k g[vr%fdl h inkFKZ o[mRI t[j[kd LiDV'e dk v[; ;u] x[dh igpku djus o[fy, 'ioxji v' o[: i eadk; Zdj l drk g[tc 'or idk'k fdl h x[l sgkdj x[tkrk gsrFkk ge LiDV'kehVj }kjk ikjxr idk'k dk fo'y'sk.k djrs g[rks LiDV'e ea o[PN vnhr j[kk, j fn[kkbZnrh g[; svnhr j[kk, j ifj' k[4r% : i lsmu rjxn[; k[o[rnuq ih gkrh g[tks ml x[o[mRI t[j[kd LiDV'e ea ikbz tkrh g[; g ml x[o[inkFKZ dk vo'k[sk.k LiDV'e dgykrk g[



fp=k 12.5 gkbMkstu o[LiDV'e ea mRI t[j[kk, j

12.3.1 LiDV'eh Jskh

ge ; g vk'kk dj l drsg[fd fdl h rRo fo'k[sk l smRI Etr idk'k dh vkof[uk; k[o[PN fu; fer i'vuzn'kz x[HA gkbMkstu , d l jyre ije.k.kqgsVl[bl fy, bl dk LiDV'e l jyre gkrk g[rFkfi] igyh n'v eagea i[skr LiDV'e dh LiDV'eh j[kkv[ka eadl h [e ; k l eferk dk v[kHkl ugha gkrk y[du gkbMkstu LiDV'e o[o[PN fo'k[sk l e[pp; k[o[Hkrj j[kkv[ka o[chp dh njh fu; fer : i l s?kVrh tkrh g[(fp=k 12.5) A bl ea l s i r; d l e[pp; dks LiDV'eh Jskh dgrsg[l u-1885 ea LohMu o[, d Lohy v[; ki d tku t[dc ckej (1825 - 1898) usgkbMkstu LiDV'e o[n'; Hkkx eabl idkj dh igyh Jskh dks n[KA bl Jskh dks ckej Jskh dgrsg[(fp=k 12.6) A yky j[dh l o[Z/d rjxn[; j[656.3 nm okyh j[kk dks H α ; 486.1 nm rjxn[; Z dh uhyh&gj h vxyh j[kk dks H β ; 434.1 nm rjxn[; Z dh c[kuh j[dh rhl jh j[kk dks H γ bR; kfn }kjk 0; Dr fd; k tkrk g[t[s & t[s rjxn[; Z?kVrh tkrh g[j[kk, j l ehi gkrh irhr gkrh g[rFk mudh rhork de g[tkrh g[ckej usbu j[kkv[ka dh i[skr rjxn[; k[o[fy, , d l jy vkuf[kfod (empirical) l k[klr fd; k %



fp=k 12.6 gkbMkstu o[mRI t[LiDV'e ea ckej Jskh

$$\frac{1}{\lambda} = R \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \tag{12.5}$$

tgk λ rjxn[; Z rFk R , d fu; r[ad gsft l sfjMcx[fu; r[ad dgrsg[; gk n o[i w[ked eku 3, 4, 5 bR; kfn g[l drsg[R dk eku $1.097 \times 10^7 \text{ m}^{-1}$ g[bl l ehdj.k dks ckej l k dgrsg[

l ehdj.k (12.5) ea $n = 3$ ekudj j[kk H α dh rjxn[; Z i ktr dj l drsg[

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2} \right) \text{ m}^{-1}$$

$$= 1.522 \times 10^6 \text{ m}^{-1}$$

$$v_{\text{Fk}} \lambda = 656.3 \text{ nm}$$

$n = 4$ j[kusij ge j[kk H_{β} dh rjxnS; ZrFk bl h idkj n oð foFkku eku j[kdj vU; j[kk/vk dh rjxnS; Zi klr dj l drsgð $n = \infty$ ydj rjxnS; $Z\lambda = 364.6 \text{ nm}$ ij] Js kh dh l hek i klr dh tkrh gð ; g ckej Js kh dh y?kpe rjxnS; Zgð bl l hek oð vlxS dkkZ Li "V j[kk fn [kkZ ugha nrh] oðoy em l k lrr Li ðV'e fn [kkZ nrk gð

gkbMkst u oð fy, Li ðV'e dh vU; Jf.k; k; ykbeð i k'ku] cðV i ðV dh Hkh [kst gls pðh gð ftlgamu oð 'kkedrkv/ka oð uke l sgh tkuk tkrk gð blugafuEu l #ka }kjk fu: fir fd; k tkrk gð %

ykbeð Js kh %

$$\frac{1}{\lambda} = R \left(\frac{1}{1^2} - \frac{1}{n^2} \right) \quad n = 2, 3, 4, \dots \quad (12.6)$$

i k'ku Js kh %

$$\frac{1}{\lambda} = R \left(\frac{1}{3^2} - \frac{1}{n^2} \right) \quad n = 4, 5, 6, \dots \quad (12.7)$$

cðV Js kh %

$$\frac{1}{\lambda} = R \left(\frac{1}{4^2} - \frac{1}{n^2} \right) \quad n = 5, 6, 7, \dots \quad (12.8)$$

i ðV Js kh %

$$\frac{1}{\lambda} = R \left(\frac{1}{5^2} - \frac{1}{n^2} \right) \quad n = 6, 7, 8, \dots \quad (12.9)$$

ykbeð Js kh ea mRI ðtr Li ðV'e j[kk; ij kckuh {k k ea vlg i k'ku , oa cðV Jf.k; ka ea Li ðV'e j[kk; Li ðV'e oð vojDr {k k ea i klr gkrh gð

l cðk $c = v\lambda$ vFkok $\frac{1}{\lambda} = \frac{v}{c}$ dk mi ; kx djoð ckej Js kh oð fy, l #k (12.5) dks idk'k dh vkofuk oð inka eabl λ_c idkj Hkh fy[kk tk l drk gð

$$v = Rc \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \quad (12.10)$$

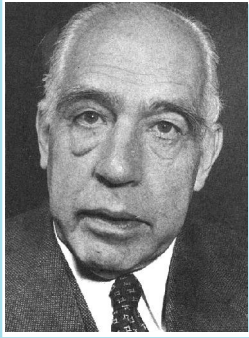
l ehdj.k (12.5 -12.9) oð l jy l #ka l soðoy oðN rùoka (gkbMkst u) , dèk vk; fur ghfy; e vlg f}r% vk; fur yhfFk; e) oð Li ðV'eka dks gh fu: fir fd; k tk l drk gð

l ehdj.k (12.5) - (12.9) mi ; kxh gðD; kfd ; sgkbMkst u i jek. kq/ka }kjk mRI ðtr vFkok vo'kk'kr dh tkusokyh rjxnS; k oð ckj sea crykrh gð rFkfi ; sifj. kke oðoy vkuþkfod gð rFk bl dk dkkZ dkj. k ugha crykrfd gkbMkst u oð Li ðV'e ea oðoy oðN vkofuk; k; gh D; ka i f}kr dh tkrh gð

12.4 gkbMkst u i jek. kq dk ckj ekMly

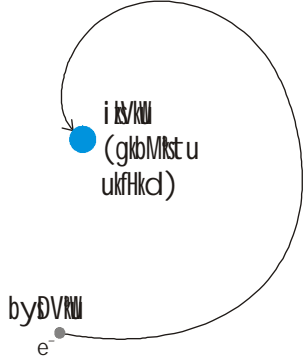
i jek. kq oð jnji oðMZ }kjk i Lrkfor ekMly ea ; g eku fy; k x; k gðfd i jek. kq oð oðnz ea ukfHkd gkrk gð rFk i fjðek djrs byðVMU fLFkj gð Bhd oð sgh tS k l kS i fjokj ea gkrk gð ft l dk vuþj. k djoð bl ekMly dks fodl r fd; k x; ka rFkfi] nksuka fLFkr; ka ea oðN eny/Hkr varj

gá xgh; rak x#Roh; cy oð dj.k.k cy/k gš tçfd ukfHkd&byÐVRU rak ea vkof'kr d.k gksuod dj.k.kj cy oð oðyK&fu; e }kjk vU; kš; fØ; k gksh gá ge tkursgáfd oðkkdkj i Fk ea?kerh dkbZ oLrqyxkrkj Roj.k ea gksh gš vlg bl Roj.k dh iðfrr vfHkoðnh gá Dykfl dh oš rppædh; fl ¼kr oð vuð kj dkbZ Rofjr vkof'kr d.k oš rppædh; rjakraoð : i ea fofdj.k mRI Ètr djrk gá vr% Rofjr byÐVRU dh Átkz fujarj ?KVuh pfg, A byÐVRU vñj dh vlg l ei y i Fk ij pysk rFk vrr% ukfHkd ea fxj tk, xk (fp= 12.7) A vr% , š k ijek.kq LFk; h ugha gk l drka bl oð vfrfjDrj Dykfl dh oš rppædh; fl ¼kr oð vuð kj ifjØeh byÐVRUka }kjk mRI Ètr oš rppædh; rjakra dh vkofuk ifjØe.k&vkofuk oð cjkj gksh gá tc byÐVRU l ei y i Fk ij vñj ukfHkd dh vlg vkrs gá rksmuoð dks kh; os vlg bl izdkj mudh vkofuk; k fujarj ifjoferr gkshA i QyLo: i mRI Ètr izdk'k dh vkofuk Hkh fujarj ifjoferr gksh pfg, A vr% bluga, d l arr Li ÐVè mRI ftz djuk pfg, tks okro ea i škr jš[kd Li ÐVè oð foijhr gá Li "Vr; k jnji oš dk ekmy oðoy rLohj dk , d igyw fn[kykrk gšft l dk vFkz gšfd Dykfl dh fopkj ijek.kq l j puk dh 0; k[; k djus oð fy, i ; k r ugha gá



uhYl gšfjd MfoM çkj (1885 - 1962)

uhYl gšfjd MfoM çkj (1885 - 1962)
 Mšekoð oð HkšrdfoKkuh ftUglaus Dokve fopkjaoð vk/kj ij gkbMstu ijek.kq oð Li ÐVè dh 0; k[; k dha ukfHkd oð no&çm ekmy oð vk/kj ij mUglaus ukfHkd; fo[kamu dk , d fl ¼kr iLrç fd; ka çkj us Dokve& kš-kdh dh l adYiukRed l eL; kvka dks fo'kškdj l i j drk oð fl ¼kr dh iLrçr }kjk Li "V djusea ; ksnku fd; ka



fp= 12.7 ijek.kq dk dkbZ Rofjr byÐVRU Átkz Bkl djoð l ei y i Fk ij ukfHkd dh vlg vñj vk tk, xkA

mngkj . k 12.4 Dykfl dh oš rppædh; fl ¼kr oð vuð kj gkbMstu ijek.kq ea i ts/KU oð pkja vlg ifjØkeh byÐVRU }kjk mRI Ètr izdk'k dh i k j a Hkd vkofuk ifjdfor dhft, A gy mngkj . k 12.3 ls ge tkurs gá fd gkbMstu ijek.kq ea i ts/KU oð pkja vlg 5.3×10^{-11} m dh f=ft; k dh d{kk ea ifjØkeh byÐVRU dk os 2.2×10^{-6} m/s gá vr% i ts/KU oð pkja vlg ifjØkeh byÐVRU dh vkofuk gš%

$$v = \frac{v}{2\pi r} = \frac{2.2 \times 10^{-6} \text{ m s}^{-1}}{2\pi(5.3 \times 10^{-11} \text{ m})}$$

$$\approx 6.6 \times 10^{15} \text{ Hz}$$

Dykfl dh oš rppædh; fl ¼kr oð vuð kj ge tkursgáfd ifjØkeh byÐVRUka }kjk mRI Ètr oš rppædh; rjakra dh vkofuk bl dh ukfHkd oð pkja vlg ifjØe.k vkofuk oð cjkj gá vr% mRI Ètr izdk'k dh i k j a Hkd vkofuk 6.6×10^{15} Hz gkshA

mngkj . k 12.4

uhYl clj (1885 – 1962) usjnji Q&M/O oð ekMy ea u; h fodkl 'khy Dokve ifjdYi uk oð fopkjka dks tkM/ej oðN : i karj fd; ka uhYl clj us1912 ead bz eghukard jnji Q&M/O dh iz, kx' kkyk eavè; ; u fd; k Fkk rFkk og jnji Q&M/O oð ukfHkd; ekMy dh oYrk oð ckjse a i jh rjg vk' oLr FkA mijkDr nfoekk ea my>s clj us 1913 ea fu" d" l'z fudkyk fd ; | fi oS rppædh; fl ¼kar] ogr Lrjh; i fj?Kvukvka dks 0; k[; k djusea l {ke gSrFkfi bl fl ¼kar dks i jek. kqLrj oð i Øeka ea iz ðr ughafd; k tk l drkA ; g Li"V gksx; k fd i jek. kqL j puk vlg bl dk i jek. oh; LiðVè l s l æk l e > us oð fy, Dykfl dh ; ka=kdh vlg oS rppædRo oð LFkfi r fl ¼kar ka l s vkeny fopyu dh vko'; drk gkskA clj us Dykfl dh , oa i kjæHkd Dokve l æYi ukvka dks l a ðr djoð rhu vfHkxghrka oð : i ea vi uk fl ¼kar i Lrj fd; ka ; s vfHkxghr gð%

- (i) clj dk igyk vfHkxghr Fkk fd fdl h i jek. kq ead kbz byðVrnu fuf' pr LFk; h d {k vka ea fofdj. k môtiz mri ètr fd, fcuk ifjØe. k dj l drk gð ; g oS rppædh; fl ¼kar oð vupkuka oð foi jhr gð bl vfHkxghr oð vuð kj i R; d i jek. kq dh oðN fuf' pr LFk; h volFk; ; gðft l ea; g jg l drk gsvlg i R; d l blko volFk eafufgr oðy môtiz fuf' pr gksh gð bu l blkkfor volFk vka dks i jek. kq dh flFkj volFk; ; dgrsgð
- (ii) clj dk nù jk vfHkxghr bu LFk; h d {k vka dks i fjHkkr"kr djrk gð bl vfHkxghr oð vuð kj byðVrnu ukfHkd oð pkjka vlg oðoy mu d {k vka ea gh ifjØe. k djrk gsfuoð fy, dks kh; l øx dk eku $h/2\pi$ dk i wkkel xqkt gksh gð tgi h lykæd fu; rkað (= 6.6×10^{-34} J s) A vr% ifjØek djrsqg byðVrnu dk dks kh; l øx (L) DokvR gð vFkr

$$L = nh/2\pi \tag{12.11}$$

(iii) clj oð rhl js vfHkxghr ea i jek. kq fl ¼kar ea lykæd rFkk vka Vku }kjk fodfl r i kjæHkd Dokve ifjdYi ukvka dks l ekfo"V fd; k x; ka bl oð vuð kj dksz byðVrnu vi usfo' lsk : i l smfYyf [kr vfofdj. kh d {k l s nù jh fuEu môtiz okyh d {k ea l Øe. k dj l drk gð tc ; g , d k djrk gSrks , d i oS/Vnu mri ètr gksh gsfth dh môtiz i kjæHkd , oa väre volFk vka dh môtiz oð vrj oð cjkj gksh gð mri ètr i oS/Vnu dh vkofuk fuEu 0; ad }kjk nh tkrh gð%

$$h\nu = E_i - E_f \tag{12.12}$$

tgi E_i , oa E_f i kjæHkd vlg väre volFk vka dh Åtlz; gð $E_i > E_f$ A l ehdj. k (12.4) ea gkbMst u i jek. kq oð fy, fofHku Åtlz flFkr; ka dh Åtlz; kkr djus dk 0; ad fn; k x; k gð yfdu bl l ehdj. k ea byðVrnu d {k dh f=kT; k r dh vko'; drk gð r dk eku ifjdfyr djus oð fy, byðVrnu oð dks kh; l øx l s l æa/r clj oð nù js vfHkxghr & Dokvehdj. k ifrca' dk iz, kx djrs gð dks kh; l øx L gksh gð

$$L = mvr$$

Dokvehdj. k dk clj oð nù js vfHkxghr [l ehdj. k (12.11)] oð vuð kj dks kh; l øx oð vuðer eku $h/2\pi$ oð i wkkel xqkt gksh gð

$$L_n = mv_n r_n = \frac{nh}{2\pi} \tag{12.13}$$

tgi n , d i wkkel gð r_n l blkkfor d {k n^{th} dh f=kT; k gSrFk v_n , n^{th} d {k ea xfreku byðVrnu dh pky gð vuðer d {k vka dks n oð eku oð vuð kj] 1, 2, 3 ..., }kjk Øekædr fd; k x; k gð ftluga d {k dh e[; Dokve l æ; k dgrsgð

I ehdj.k (12.3) l s v_n rFkk r_n oñ chp l ca' gS

$$v_n = \frac{e}{\sqrt{4\pi\epsilon_0 m r_n}}$$

bl s l ehdj.k (12.13) oñ l kfk l a kstr djus ij gea v_n rFkk r_n oñ fy, fuEu 0; ad iklr glsr gñ

$$v_n = \frac{1}{n} \frac{e^2}{4\pi\epsilon_0} \frac{1}{(h/2\pi)} \quad (12.14)$$

rFkk

$$r_n = \left(\frac{n^2}{m}\right) \left(\frac{h}{2\pi}\right)^2 \frac{4\pi\epsilon_0}{e^2} \quad (12.15)$$

I ehdj.k (12.14) n'kkzk gSfd n^{th} d{kk ea byDVMM dh d{kh; & pky} xqkd n l s de gls tkrh gñ l ehdj.k (12.15) dk mi; ks djoñ vjre d{kk ($n = 1$) dk l kb"k fuEu izkj iklr fd; k tk l drk gñ

$$r_1 = \frac{h^2 \epsilon_0}{\pi m e^2}$$

bl s cki f=kT; k dgrs gñ vñ l oñ a_0 }kjk fu: fir djrs gñ bl izkj

$$a_0 = \frac{h^2 \epsilon_0}{\pi m e^2} \quad (12.16)$$

h , m , ϵ_0 rFkk e oñ eku ifrLFkkfir djus ij $a_0 = 5.29 \times 10^{-11}$ m iklr glsr gñ l ehdj.k (12.15) l s; g Hkh nçkk tk l drk gSfd d{kk dh f=kT; k vka ea n^2 oñ l kfk of¼ glsrh gñ fdl h gkbMstus i jek.kq dh LFkk; h volFK ea byDVMM dh ofy Åtkz l ehdj.k (12.4) ea d{kh; f=kT; k dk eku ifrLFkkfir djus ij iklr dh tk l drh gñ; Fkk

$$E_n = - \left(\frac{e^2}{8\pi\epsilon_0} \right) \left(\frac{m}{n^2} \right) \left(\frac{2\pi}{h} \right)^2 \left(\frac{e^2}{4\pi\epsilon_0} \right)$$

$$\text{vFkok } E_n = - \frac{me^4}{8n^2\epsilon_0^2 h^2} \quad (12.17)$$

I ehdj.k (12.17) ea fu; rkkka oñ eku j[kus ij gea iklr glsrk

$$E_n = - \frac{2.18 \times 10^{-18}}{n^2} \text{ J} \quad (12.18)$$

i jek.oh; Åtkz; ik; % tñ oñ LFkkus ij byDVMM okV (eV) ea 0; Dr dh tkrh gñ D; kfd 1 eV = 1.6×10^{-19} JA l ehdj.k (12.18) dls iq% bl izkj fy[kk tk l drk gS

$$E_n = - \frac{13.6}{n^2} \text{ eV} \quad (12.19)$$

fdl h d{kk ea xfreku byDVMM dh ofy Åtkz oñ 0; ad ea ½. WRed fpÉ bl ckr dk |ksd gSfd byDVMM i jek.kq oñ ukfHkd l svk¼ gñ vr% gkbMstus i jek.kq l s byDVMM dls ukfHkd l s (; k gkbMstus i jek.kq ea i kMM l) vur njih rd foyx djus oñ fy, Åtkz dh vko'; drk glsrh

I ehdj.k (12.17) – (12.19) dh 0; ði fúk bl dYiuk ij vk/kfjr gSfd byDVNU dh d{kk, i oÜkh; gS ; | fi 0; ðe oxlcy oð v/hu d{kk, i keW; r% nh?kzÜkh; gsrh gA (I Hkh xg I wZ oð 0; ðe oxlx#Roh; cy oð v/hu nh?kzÜkh; d{kkvka eafxreku gA) rFkfi teZ HKSrdfoKkuh vukBYM I keji SYM (1868 – 1951) us; g n' kZ, k Fk fd ; fn oÜkh; d{kk oð ifrcz' dksf' kFky dj fn; k tk, rc Hkh ; sI ehdj.k nh?kzÜkh; d{kkvka ij Hkh I eku : i I sykxwgsrh gA

ijek.kq ea byDVNU dh fLFkr % d{kk cuke vkÜcVy

HKSrdh oð vè; ; u eafdl h u fdl h Lrj ij gekjk ifjp; ijek.kq oð ckg ekWY I sdjk; k tkrk gA Dokve ; k-kdh rFk fo'ksk : i I s ijek.kq dh I jpuK dh 0; k[; k djusea bl ekWY dk fo'ksk LFku gA Rofjr d.k oð fujarj Åtk&fodfjr djusoð Dykfl dh fl ¼kr oð foi jhr] ckg }kjk fuf' pr Åtk&d{kk dk Økardkjh fopkj , d mi yfc/ gA ckg usfuf' pr d{kkvka ea ifjØkeh byDVNUka oð dkskh; I oð oð Dokvehdj.k oð fopkj dks Hkh i Lrj fd; kA bl izdkj ijek.kq dh I jpuK dk ; g , d I eh&Dykfl dh fp=k.k FkA

vc] Dokve ; k-kdh oð fodkl oð I kFk gea ijek.kq dh I jpuK dh vf/d vPNh I e> gA 'ksMxj rjx I ehdj.k oð gykous ijek.kq oð I kFk i kFk oð vkd"iz k cy oð dkj.k vk¼ byDVNUka dks rjx oð I n' k fu/kfjr fd; kA

ckg ekWY eafdl h byDVNU dk d{kk ukfHkd oð pkjka vkg byDVNU dh xfr dk oÜkh; i Fk gA i jarq Dokve ; k-kdh oð vuq kj] ge fdl h ijek.kq ea byDVNU dh xfr dks fdl h fuf' pr i Fk oð I kFk I ¼ ugha dj I dra ge oðoy ukfHkd oð pkjka vkg fnoLFku oð fdl h fuf' pr Hkh ea byDVNU oð feyus dh ikf; drk oð ckg ea ckr dj I drsgA ; g ikf; drk , dy&byDVNU rjx i ðyu ftl s d{kd (vkÜcVy) dgrsgA I svuekfur dh tk I drh gA ; g i ðyu oðoy byDVNU oð funk d ij fuHkj djrk gA

vr% ; g vko' ; d gSfd ge bu nks ekWYka ea I ve varja dks I e>a %

- 1 ckg ekWY oðoy , d byDVNU ijek.kqvk; u oð fy, oS gS bl ekWY ea i R; d d{kk oð fy, Åtk&dk , d fu; r eku gsrk gS tiseç; Dokve I ç; k n ij fuHkj djrk gA vc gea Kkr gSfd fdl h byDVNU dh fLFkj volFk I s I ¼ Åtk&, d byDVNU ijek.kqvk; u ea oðoy n ij fuHkj gA cgh byDVNU & ijek.kqvk; u oð fy, ; g I R; ugha gA
- 1 gkbMst u tS ijek.kqvk; u oð fy, i klr 'ksMxj rjx I ehdj.k dk gy ftl s rjx i ðyu dgrsgA ukfHkd oð pkjka vkg foFku {sika eafdl h byDVNU dh i kf; drk dks Kkr djusoð fy, I jpuK inku djrk gA bl vkÜcVy dh ckg ekWY ea byDVNU oð fy, ifjHkf"kr d{kk I s dkbZ I eku rjx ugha gA

mnkgj.k 12.5

mnkgj.k 12.5 10 kg dk dkbZ mi xg 8000 km f=kT; k dh , d d{kk ea i Foh dk , d pDdj i R; d 2 h ea yxkrk gA ; g ekursgq fd ckg dk dkskh; I oð dk vfHkxghr] ml h izdkj mi xg ij ykxwgsrk gSftl izdkj fd ; g gkbMst u oð ijek.kq eafdl h byDVNU oð fy, ekW; gS mi xg dh d{kk dh Dokve I ç; k Kkr dhft, A

gy
I ehdj.k (12.13) I s ge i krs gA
 $m v_n r_n = nh/2\pi$

; gk $m = 10 \text{ kg}$ rFk $r_n = 8 \times 10^6 \text{ mA}$?kersgq mi xg dk vlorZ dky T , 2 h gß vFKZ-
 $T = 7200 \text{ sA}$

vr% oX $v_n = 2\pi r_n / T$

mi xg dh d{kk dh Dokve I \dot{q} ; k

$n = (2\pi r_n)^2 \times m / (T \times h).$

ekula dks i frLFKfir djus ij]

$n = (2\pi \times 8 \times 10^6 \text{ m})^2 \times 10 / (7200 \text{ s} \times 6.64 \times 10^{-34} \text{ J s})$
 $= 5.3 \times 10^{45}$

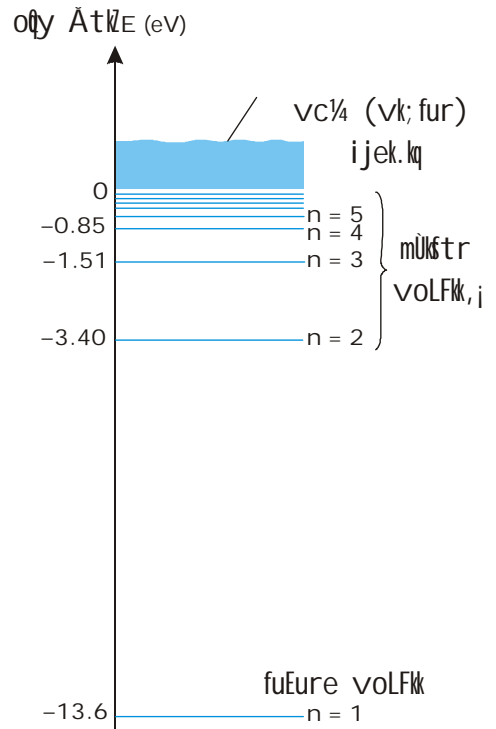
è; ku nft, fd mi xg dh xfr oß fy, Dokve I \dot{q} ; k vr; r vf/d gß oLro eabruh vfeld
 Dokve I \dot{q} ; k oß fy, Dokvehdj.k i frca'aoß ifj. ke Dykfl dh Hksrdh oß ifj. keaoß I ehi gß

12.4.1 ÁtkLrj

ijek.kq dh mÓtkl ml Ie; U; ure (vfeldre ½. WRed eku) gsrh gß tc ml dk byðVNU ukfhkd dh fudvre d{kk (vFKZ- $n = 1$) ea ifjØe.k djrk gß $n = 2, 3 \dots$ oß fy,] mÓtkl E oß fuji{kk eku de gsrh tkrsgß vr% cká d{kk dh vlg tkusij d{kkvæamÓtkl vfeld gsrh tkrh gß ijek.kq dh U; ure volFk eaftl sfuEure volFk dgrsgß byðVNU dh mÓtkl U; ure gsrh gß rFk byðVNU U; ure f-kT; k (ckj f-kT; k a_n) dh d{kk ea ifjØe.k djrk gß bl volFk dh mÓtkl ($n = 1$), $E_1 = -13.6 \text{ eV}$ gß vr% gkbMstU ijek.kq dh fuEure volFk I sbyðVNU dks eðr djkus oß fy, vko'; d U; ure mÓtkl 13.6 eV gß bl sgkbMstU ijek.kq dh vk; uu mÓtkl Hkh dgrsgß ckj oß ekmy oß vkekj ij ikr eku vk; uu mÓtkl oß ik; kfxd ekula smúke vuq irk j [krk gß

dejs oß rki ij] vf/dkák gkbMstU ijek.kq viuh fuEure volFk ea jgrsgß tc dks ijek.kq byðVNU I ákèotß siðela}kjk mÓtkl ikr djrk gß rc og vLFk; h : i ls bruh mÓtkl vftz dj l drk gß tks byðVNU dks mPp d{kkvæard igpkus oß fy, i; klr gsrh gß rc og ijek.kq mÚkstr volFk ea dgykrk gß I ehdj.k (12.19) I s $n = 2$ oß fy, - Átkl E_2 , -3.40 eV gß bl dk vFKZ; g gprk fd gkbMstU ijek.kq ea fdl h byðVNU dks bl dh igyh mÚkstr volFk ea mÚkstr djus oß fy, vko'; d Átkl $E_2 - E_1 = -3.40 \text{ eV} - (-13.6) \text{ eV} = 10.2 \text{ eV}$ gsrhA bl h iðkj] $E_3 = -1.53 \text{ eV}$ rFk $E_3 - E_1 = 12.09 \text{ eV}$ vFKZ-} gkbMstU ijek.kq dks bl dh fuEure volFk I s ($n = 1$) ni jh mÚkstr volFk ($n = 3$), rd mÚkstr djus oß fy, 12.09 eV Átkl dh vko'; drk gsrh gß ; g Øe bl h iðkj vlxs pyrk jgrk gß bu mÚkstr volFk vka I s byðVNU fi Oj viuh fuEu Átkl volFk ea oki I fxj l drk gß bl ifjØ; k ea og , d iðk/vkú mri ètr djrk gß bl iðkj] gkbMstU ijek.kq dh mÚkstr volFk cckus ij (vFKZ- n oß cckus ij) mÚkstr ijek.kq I s byðVNU dks Lorak djus oß fy, vko'; d U; ure Átkl ?kvrh gß

I ehdj.k (12.19) I svfhkd fyr gkbMstU ijek.kq dh LFk; h volFk vka dk Átkl Lrj vkj{kk* fp-k (12.8) ean'kz k x; k gß eq; Dokve I \dot{q} ; k n



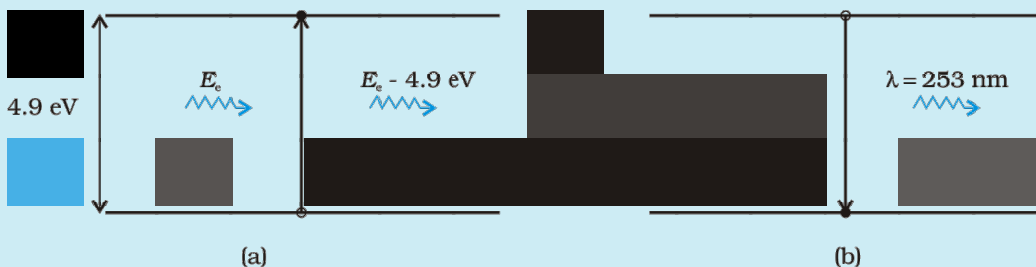
fp-k 12.8 gkbMstU ijek.kq oß fy, ÁtkLrj vkj{kk dejs oß rki ij gkbMstU ijek.kq ea byðVNU viuk vf/dkák Ie; fuEure volFk ea 0; rhr djrk gß gkbMstU ijek.kq dks vk; fur djus oß fy, fdl h byðVNU dks fuEure volFk I s 13.6 eV Átkl vo'; miyc/ djuk pkfg, A (fkr t j{kk, i vuðr Átkl volFk vka dh mi flfkr dks n'kz-h gß)

* fdl h byðVNU dh $E = 0 \text{ eV}$ I svf/d oðN Hkh oßy Átkl gsl drh gß , d h n'kvka ea byðVNU Lorak gsrk gß bl iðkj $E = 0 \text{ eV}$ I s Áij fp-k 12-8 ean'kz, vuq kj Átkl volFk vka dk , d I krR; gß

LFkk; h volFKkva dks Átkz oð vjkjsh. ðe eavídr djrk gð bl fp=k eamPpre Átkz volFKk l ehj.k (12.19) ean = ∞ oð l ær gsrFKk bl dh Átkz oð ev gð ; g ijek.kq dh og Átkz gStc ukfhkd l sbyðVRU ijh rjg nji dj fn; k x; k gS(r = ∞) vjg og fojke eagg è; ku nhft, fd mÚkstr volFKkva dh Átkz; n oð c < us ij fdl iðlkj ikl & ikl vk trk gð

íðd & gvZk iz kx

fdl h ijek.kq eafofodr Átkz Lrjla oð vflrko dh l h/h íq"V l u-1914 ea tE l íðd rFKk xlrko gvZk jkjk dh xba mlugkus ikjs oð ok'i oð LiðVè dk vè; ; uj ok'i l sfofHklu xfrt Átkz/ka oð byðVRU xqkjj dj fd; ka byðVRU dh Átkz ífoerr djus oð fy, mu ij ífjortz rhork oð fo l r {kek yxk, x, A byðVRUka us ikjs oð ijek.kq/ka l s l ækèðfd; k rFKk ikjs oð ijek.kq/ka dks viuh Átkz varfjr dj nhA ; g rHk l blko gsl drk gStc byðVRU dh Átkz ikjs oð ml Átkz Lrj ftl eabyðVRU gkrFKk bl l s Ápsfdl h fjDr Átkz Lrj (fp=k nS[k,) oð chp Átkz varj l svf/d gkð mnkjg.k oð fy,) ikjs oð fdl h f?kjsgg Átkz Lrj rFKk [kyh Átkz Lrj ea 4.9 ev dk Átkz varj gð ; fn dkbz byðVRU ftl dh Átkz 4.9 ev ; k bl l svf/d gð ikjs l s xqkjr gsrks ikjs oð ijek.kq dk dkbz byðVRU Vdjkusokys byðVRU l s Átkz vo'kk"kr dj l drk gsrFKk ÁpsLrj ij mÚkstr gsl drk gS [fp=k(a)]A Vdjkusokys byðVRU dh xfrt Átkz bruh gh ek=kk l s de gsl tk, xhA



mÚkstr byðVRU ckn eafodj.k mri ðtr djoð fuEure volFKk ij okil vk tk, xk [fp=k(b)]A mri ðtr fofdj.k dh rjxnS; Z gskh %

$$\lambda = \frac{hc}{E} = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{4.9 \times 1.6 \times 10^{-19}} = 253 \text{ nm}$$

l h/sekiu jkjk íðd rFKk gvZk usnS[kk fd ikjs oð mri tZ LiðVè eabl rjxnS; Zoð l ær , d jS[kk gð clj oð ijek.kq eafofodr Átkz Lrjla oð emy fopkjkrFKk iðVRU mri tZ oð iðe dh ik; kSxd íq"V oð fy, íðd rFKk gvZk dks 1925 ea ukcsy ij ldkj l s l ekkfur fd; k x; ka

12.5 gkbMkstu ijek.kq dk ykbu LiðVè

clj oð ekmy oð rih; vflhxghr oð vuðkj] tc dkbz ijek.kq mPp Átkz lFKkr ftl dh Dokve l ð; k n_i gð l sfuEu Átkz lFKkr ftl dh Dokve l ð; k n_j gð (n_j < n_i) eal ðe.k djrk gð rc mÚkz oð bl varj dks vkofúk v_f dk , d iðVRU ogu djrk gð rkfd

$$h\nu_{if} = E_{n_f} - E_{n_i} \tag{12.20}$$

E_{n_f} vls E_{n_i} oð fy, l ehdj.k (12.16) dk iz lxx djus ij

$$h\nu_{if} = \frac{me^4}{8\epsilon_0^2 h^2} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \tag{12.21}$$

$$v_{flok} v_{if} = \frac{me^4}{8\epsilon_0^2 h^3} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \tag{12.22}$$

l ehdj.k (12.21) gkbMkst u ijek.kq oð Li ðVè oð fy, fjMcxZ dk l xk gð bl l æk ea ;fn ge $n_f = 2$ vls $n_i = 3, 4, 5, \dots$ ifrLFKfir djsrsgð rks ;g l æk ckej Js kh oð fy, l ehdj.k (12.10) oð l n'k ifjofrðr gls tkrk gð bl l sge fjMcxZ fu; rkd R dk eku kkr dj l drsgð tks bl izlkj gð%

$$R = \frac{me^4}{8\epsilon_0^2 h^3 c} \tag{12.23}$$

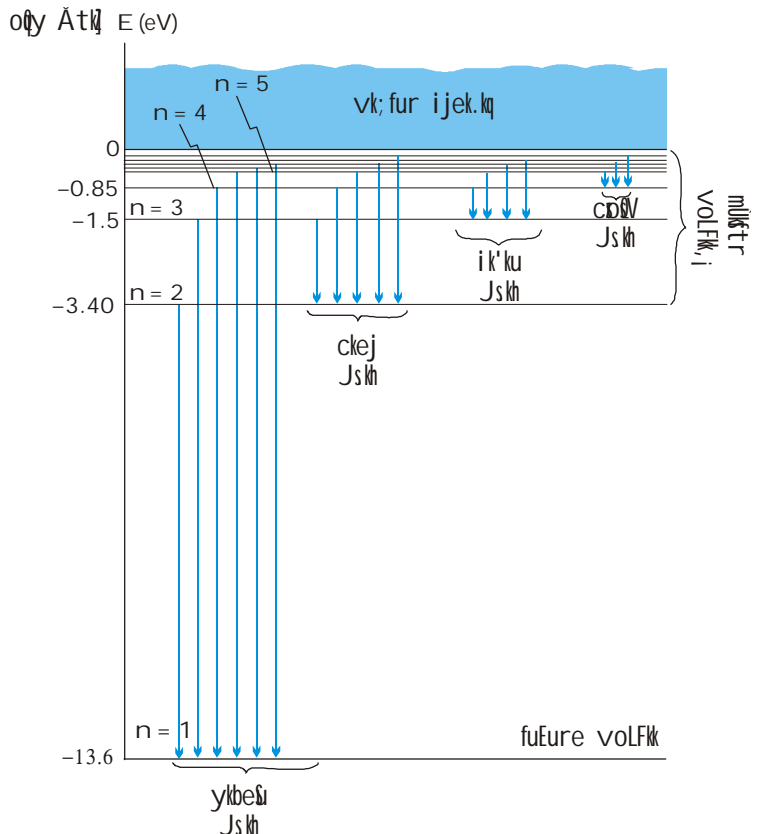
l ehdj.k (12.23) ea fofHku fu; rkdka oð eku ifrLFKfir djus ij] ge ikrsgðfd

$$R = 1.03 \times 10^7 \text{ m}^{-1}$$

;g eku vkuklfrod ckej l xk l s ikr eku ($1.097 \times 10^7 \text{ m}^{-1}$) oð vfr fudV gð l s kfrd ,oa ikr kfxd eku oð bl l kætL; us cksj&ekMy dh Li "V ,oa iHkko'kkyh l a f"V dh gð

pfid n_f vls n_i nkska i wked gð vr% bl l s rgr ifj.kke ikr gsrk gsfid ijek.oh; Lrjka oð eè; l ðe.kka eð fofHku fofodr vkoflk; ka oð izlk'k mri ðtr gksrsgð gkbMkst u Li ðVè ea ckej l xk $n_f = 2$ vls $n_i = 3, 4, 5$ vkfn oð rnuq ih gð cksj&ekMy ea vL; jçkkvka dh mi fLFKfr dls Hkh crk; k x; k Fk tks $n_f = 1$ vls $n_i = 2, 3$ vkfn $n_f = 3$ vls $n_i = 4, 5, \dots$ bR; kfn rFk l ðe.kka oð rnuq ih gls l drh gð bu Jf.k; ka dh igpku okLro ea Li ðVè dks id 'kæk oð l e; gþZftUgaykbeð] ckej] i k'ku] cððV rFk i fV Jf.k; ka oð uke l stkuk tkrk gð bu Jf.k; ka oð rnuq ih byðVnuð l ðe.k fp-k (12.9) ea n'kkz, x, gð

tc byðVnuð mPp Åtkz fLFKfr l sfuEu Åtkz fLFKfr ea vkrsgð rks i Qs/kku mri ðtr gksrsgð rFk ijek.oh; Li ðVè dh vusd jçkk, j mri l u gsrh gð bu Li ðVè h jçkkvka dls mri tzu jçkk, j dgrs gð yfdu tc dksz ijek.kq i Qs/kku dls vo'kks"kr djrk gð ftl dh Bhd ogh Åtkz gð tks fd l h byðVnuð dls fuEu Åtkz fLFKfr l s mPp Åtkz



fp-k 12.9 ykbu Li ðVè Åtkz Lrjka oð chp l ðe.kka oð dkj.k mri l u gsrk gð 431

fLFkr ea l Øe.k oð fy, vko'; d gkrh gð rksbl i Øe dks vo' ksk.k dgrsgð vr% ; fn l rr ifjl j dh vkofúk; ka oð i Qs/KW fdl h fojfyx xð l sxdkjusoð i 'pkr fdl h Li ðVhVj l sfo' yf'kr fd, tkrsgð rksl rr Li ðVh ea vnhlr Li ðVh vo' ksk'kr jð kvkadh Js kh fn [kbz nrsh gð vnhlr jðkk; mu vkofúk; ka dksfuðV djrh gð tks xð oð i jek. kvka }kjk vo' ksk'kr dh xbl gð

gkbMstus i jek. kvð Li ðVh dk ckj ekWY }kjk fn; k x; k Li "Vhdj.k , d ifrHkk' kkyh egku mi yfC/ Fkk ftl us vk/tud Dokve fl ¼kr dh ixfr dks vr; f/d i kll kfgr fd; ka l u-1922 ea ckj dks Hkkrdh ea ukxy i jLdkj l s l Eekfur fd; k x; ka

mnkgj. k 12.6

mnkgj. k 12.6 fjMczl wk dk mi ; kx djoð gkbMstus Li ðVh dh ykbeð Js kh ea i Fke pj j Li ðVh jð kvkadh rjxnð; l dks ifjdfyr dhft, A gy fjMczl wk bl idkj 0; Dr fd; k tkrk gð%

$$hc/\lambda_{if} = \frac{me^4}{8\epsilon_0^2 h^2} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

ykbeð Js kh dh i Fke pj jð kvkadh rjxnð; l $n_i = 2, 3, 4, 5$ l $n_f = 1$ oð l Øe.k oð rnuq i h gkrh gð ge tkursgð fd

$$\frac{me^4}{8\epsilon_0^2 h^2} = 13.6 \text{ eV} = 21.76 \times 10^{-19} \text{ J}$$

vr%

$$\lambda_{if} = \frac{hc}{21.76 \times 10^{-19} \left(\frac{1}{1} - \frac{1}{n_i^2} \right)} \text{ m}$$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^8 \times n_i^2}{21.76 \times 10^{-19} \times (n_i^2 - 1)} \text{ m} = \frac{0.9134 n_i^2}{(n_i^2 - 1)} \times 10^{-7} \text{ m}$$

$$= 913.4 \frac{n_i^2}{(n_i^2 - 1)} \text{ \AA}$$

bl l oðk ea $n_i = 2, 3, 4, 5$ ifrLFkrir djust j geð pjka oð nr rjxnð; l i klr gkrh gð tksbl idkj gð% $\lambda_{21} = 1218 \text{ \AA}$, $\lambda_{31} = 1028 \text{ \AA}$, $\lambda_{41} = 974.3 \text{ \AA}$ rFkk $\lambda_{51} = 951.4 \text{ \AA}$

12.6 ckj oð Dokv/ehdj.k oð f}rh; vfHkxghr dk ns ckWYh }kjk Li "Vhdj.k

ckj }kjk i Lrr i jek. kvð ekWY oð l Hkh vfHkxghrka ea l kkor% nu jk vfHkxghr l cl svfekd my>u i ðk djustokk Fkk bl oð dFku oð vuq kj ukfHkd oð pjka vls i fjØek djrsbyðVWU dk dks kh; l oð Dokv r gð (vfkr $L_n = nh/2\pi$; $n = 1, 2, 3 \dots$) A dks kh; l oð oð oðoy ogh eku D; ka gkrsgð tks $h/2\pi$ oð i wkkel xqkt gð ckj }kjk viuk ekWY i Lrr djust oð nl o"l i 'pkr l u-1923 ea , d i oðk hl h Hkkrd oð kfud yðl ns ckWYh usbl l eL; k dk gy < k

geus vè; k; 11 ea ns ckWYh dh ifjdyiuk dk vè; ; u fd; k Fkk ftl oð vuq kj] nð; d.k tð sbyðVWU Hkh rjx tð sy{k.k inf'kr djrs gð l h-ts Mfol u rFkk , y-, p- teð }kjk

1927 eai k; k&sd rlg ij byÐVRNUkadh rj& i Ðfr dk l R; ki u fd; k x; kA yqI ns c&lyh us roÐ fd; k fd byÐVRNU dks clj }kjk i Lrkfor bl dh o&kkkj d{kk eþ , d d.k&rj& o& : i eans[kk tkuk plfg, A Mlg h ea xeu djrh rj&ka o& l n' k] d.k rj&a Hkh vuqknh voLFk vk&ea vi&keh rj&am Ri uu dj l drh g& d{kk 11 o& fy, Hk&rdh dh i k& ; i &rd o& v& ; k; 15 l sge tkurs g&fd fdl h rfur Mlg h dks foFHku LFkka i j d" k k djo& ml eafoFHku rj&n& ; k&dk sm Ri uu fd; k tk l drk g& rFkfi] o&oy ogh rj&n& ; Zfo |eku jg ikh g&ftuo& fl j& i j fu"im gl&sg& rFk tks Mlg h ea vi&keh rj& cukh g& bl dk vFkz g&fd fdl h Mlg h eþ vi&keh rj&a rHkh cu&h tc rj& }kjk Mlg h ea, d v&g tkusearFk oki l vkusear; dh x&zo&f y njh] , d rj&n& ; i n&s rj&n& ; i vFkok d k&Z Hkh i wk&ed l & ; k dh rj&n& ; Zo& cjkj g& v& ; rj&n& ; k&dh rj&ka ea i j kor&u o& i 'pkr vki l ea 0; frdj .k gl&rk g&srFk muo& vk; ke 'k?krk l s' k& ; g&sk tkrs g& r_n f=kT; k dh nth dh d{kk ea i fj&ok djrsfdl h byÐVRNU }kjk d{kk dh ifjf/ ear; dh x&zo&f y njh $2\pi r_n$ gl&sh& vr%

$$2\pi r_n = n\lambda, \quad n = 1, 2, 3... \quad (12.24)$$

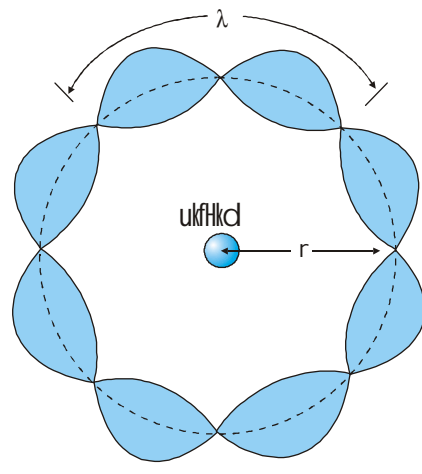
fp=k 12.10 eafdl h o&kkkj d{kk ij ftl o& fy, n = 4 g& , d vi&keh d.k rj& n' k& ; h x&zo&g& bl i&dkj $2\pi r_n = 4\lambda$, tgk λ nth d{kk ea i fj&ok djrs g& byÐVRNU dh n&ch&lyh rj&n& ; Z g& v& ; k; 11 l j ge tkurs g& $= h/p$, tgk p byÐVRNU o& l o& dk ifjek.k g& ; fn byÐVRNU dh pky i&dk'k dh pky l scg& de g& r&s l o& mv_n gl&sh& bl i&dkj $\lambda = h/mv_n$ gl&sh& l ehdj .k (12.24) l sgea i k&r gl&sh& %

$$2\pi r_n = n h/mv_n \quad \text{vFkok} \quad m v_n r_n = nh/2\pi$$

; g clj }kjk i Lrkfor byÐVRNU o& dks kh; l o& dk Dok&e ifrca' g& l ehdj .k (12.13)ª A vuqknh 12.5 ea geus n&kk g&fd ; g l ehdj .k g&kbM&st u i j ek .k q ea Å t&z Lrj&a rFk fofoDr d{kkv&ka dh 0; k[; k djus dk v&ek&j g& bl i&dkj ns c&lyh dh ifjdYi uk] i fj&ok byÐVRNU o& dks kh; l o& o& Dok&e ehdj .k dh clj }kjk i Lrkfor f}rh; v&fHk&g&hr o& fy, 0; k[; k i Lr& djrh g& byÐVRNU dh Dok&vr d{kk, i rFk Å t&z l Fk&r; k] byÐVRNU dh rj& i Ðfr o& dkj .k g& v&g& o&oy vuqknh vi&keh rj&a gh vofLFkr jg l drh g&

clj&ek&ly ftl eafpj ifr"Br i &ki i Fk fp=k .k (ukfHkd o& p&j&ka v&g& x&g&l n' k d{kk, i) l f&efyr g& g&kbM&stul e i j ek .k q /k& (, dy byÐVRNU) o& e& ; y{k .k& e& ; : i l smRl f&tr vFkok oj .k&red vo' k&s"kr fofdj .k&adh vkof&uk; k&adh mfpr Hkfo"; ok .k& djrk g& rFk&fi bl ek&ly dh o&N l hek, i g& buea l s o&N g& %

(i) clj&ek&ly g&kbM&stul e i j ek .k q /k& o& fy, gh mi ; Ðr g& f}&byÐVRNU i j ek .k q t& s ghfy; e o& fy, Hkh bl sfolr&k&jr ugh&fd; k tk l dr&a g&kbM&stul e* i j ek .k q /k& o& fy, clj ek&ly dks, d l svf/d byÐVRNU okys i j ek .k q /k& o& fo' y&sk .k o& fy, i z k& djuso& i z Ru fd, x,] i j&ar&dk&z l i Qyrk i k&r ugh&g&h& dfBuk&z ; g g&fd i R; &d byÐVRNU o&oy &ek&os'kr ukfHkd l s gh ugh& i j&ar&q n& j s l Hkh byÐVRNU&ka l s Hkh v&u; k& ; f& ; k djrk g&



fp=k 12.10 o&kkkj d{kk ea, d vi&keh rj& n' k& ; h x&zo&g& tgk ij d{kk dh ifjf/ ear&pkj ns c&lyh rj&n& ; Z v&krh g&

* g&kbM&stul e i j ek .k q o& i j ek .k q g&ftuea / u vk&sk +ze ; Ðr ukfHkd v&g& , dy byÐVRNU gl&rk g& tgk&z i &v& l & ; k g& g&kbM&stul e i j ek .k q , d/k vk; fur ghfy; e] f}r% vk; fur y&f&f&k; e bR; k&n g&kbM&stul e i j ek .k q /k& o& m&n&g&j .k g& bu i j ek .k q /k& ea vf/d t&fy byÐVRNU&byÐVRNU v&u; k& ; f& ; k, i ugh& i k&z tk&rh&

clj ekMly oð l a i . k ea by ðVRU rFk /ukoð' kr ukfHkd oð chp fo | r cy l fEefyr gð buea by ðVRUka oð eè; fo | r cy 'kfe y ugha gð tks fd cg&by ðVRU i jek.kq/ka ea vko'; d : i l s i z V g l r k g ð

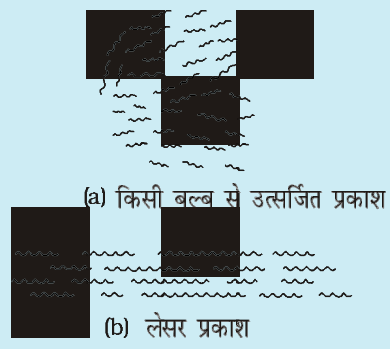
(ii) ; | fi clj & ekMly gkbMstule i jek.kq/ka }kjk mRI Ètr izk'k dh vkofÙk; ka dh l gh Hkfo"; ok.kh djrk gð fi Oj Hkh ; g Li ðVÈ ea vkofÙk; ka dh vki f{kd rhorkvka dh 0; k[; k ughadj i krkA gkbMst u oð mRI tzu Li ðVÈ ea oðN n' ; vkofÙk; ka dh rhork {kh.k g l r h gð tcf d nu jh vkofÙk; ka dh rhork icy g l r h gð , ð k D; ka g l r k gð i k; k f x d i g k . k n' k z s g ð f d o ð N l Ø . e . k nu j k a dh vi f k k v f / d Lohdk; Zgð clj & ekMly fofHku l Ø . e . ka dh fofok rhorkvka dh 0; k[; k djus ea vl eFkz gð

clj & ekMly i jek.kq dk ifj"oðr fp-k i z r r djrk gð rFk bl dk t f V y i jek.kq/ka oð fy, 0; ki dh d j . k ugha f d ; k tk l drkA t f V y i jek.kq/ka oð fy, geaDokve ; k k dh ij vk/krj , d u, eyHkr fl ¼kr dk mi ; kx djuk g l r k t k s i jek.kq l j p u k dk v f / d i w k z f p - k i z r r djrk gð

yd j izk'k

fdl h HkhM&HkhM+okys ck"kkj ; k j s y o s l y v i o k z dh d Y i u k dh f t , t g k c g r l s e u t ; , d } k j l s i z s k d j o ð l H k h f n ' k v k a e a t k j g s g ð m u o ð d n e v f u ; f e r g ð r F k m u o ð c h p e a d k b z d y k l a z ' u g h a g ð n u j h v l j c g r c M h l a ; k e a l s u d k a d l s l q ; o f l F k r e k p z d j r s g q l k s p , A m u l H k h o ð d n e , d & n u j s l s f e y r s g ð ; g k b l f p - k d l s n f [k , A

l k e u ; l k r t s s e k e c u k h ; k f d l h c Y c l s m R I È t r r F k y d j l s m R I È t r i z k ' k e a ; g h v r j g ð i f j o . k z ' k c n y d j j (L A S E R) l s r k r i ; Z g s % f o f d j . k o ð m i h r m R I t z u } k j k i z k ' k i o / u (L i g h t A m p l i f i c a t i o n b y S t i m u l a t e d E m i s s i o n o f R a d i a t i o n) A 1 9 6 0 e a b l o ð f o d k l o ð l k f k g h] b l u s f o k k u v l j i k s k f x d h o ð l H k h { k s k a e a i o s k d j f y ; k a v k t d y H k s r d h j l k ; u ' k l - k j t h o f o k k u j v k ; f o k k u j ' k y ; f o f d r i k j b a t h f u ; j h v k f n e a b l o ð v u q z k x g l s j g s g ð o ð N y d j f u E u { k e r k o ð g l r s g ð f t u d h { k e r k 0 . 5 m W g l r h g ð b l g a i ð l y y d j d g r s g ð t k s l o r d d h H k h r d k ; Z d j r s g ð v k t d y f o f H k u { k e r k v k a o ð y d j m i y c / g ð f t u d k m i ; k x v k [k t s s u k t p l v a k a v F k o k v l e k ' k ; d h x a f k o ð ' k y ; d e z o ð f y , g l r k g ð v a r r % o ð N , ð s y d j H k h g ð t k s b l i k r d l s H k h d k v v F k o k o y M d j l d r s g ð



fdl h l k r l s i z k ' k j r j a k a o ð i ð o v o ð : i e a m R I È t r g l r k g ð f d l h l k e u ; l k r l s v k u s o k y k i z k ' k v u e d r j a k a d k f e j . k g l r k g ð f o f H k u r j a k a e a d k b z d y k l a z ' H k h u g h a g l r k A b l f y , j , ð k i z k ' k j ; f n f d l h } k j d l s H k h x d j r k g s r k s v r ; r r s t h l s f o l r k f j r g l r k g s r F k i e t d k l k b " k n j h o ð l k f k r s " k l s c < f k g ð y d j i z k ' k e a i r ; d i ð o v d k r j a n s ; z i k ; % l e k u g l r k g ð r j a k o ð i ð o v d h v l r y a c k b z H k h c g r v f / d g l r h g ð b l d k v F k z g s f d y a s l e ; v a r j k y o ð f y , v P N k d y k l g l a z ' g l r k g ð b l o ð i f j . k e l o : i y d j i e t d k v i l j . k H k j i j d e g l s t k r k g ð ; f n f d l h l k r e a z v i j e k . k q g ð v l j i r ; d i j e k . k q z r h o r k d k i z k ' k m R I È t r d j j g k g ð r c f d l h l k e u ; l k r } k j k m R I l u o f y r h o r k z v r o ð v u o e k u i k r h g l r h g ð t c f d y d j l k r e a ; g z v r 2 o ð v u o e k u i k r h g ð ; g e k u r s g q f d z v d k l k h v f e k d g ð g e n f k l d r s g ð f d l k e u ; l k r d h v i f k k y d j l s i z k ' k v r ; r r h o z g l s l d r k g ð t c v i l s y k s f e ' k u o ð v a r f j { k ; k h p n e k i j x , r i s m u g l a u s m l o ð i " B i j i f o h d h f n ' k k d h v l j , d n i z k j [k k a r c i f o h i j o k k f u d k a u s , d r h o z y d j i e t b l d h v l j H k s t k f t l s p n e k i j j [k s n i z k } k j k i j k o f r r d j k d j i f o h i j o k i l x g . k f d ; k x ; k a i j k o f r r y d j i e t d k l k b " k r F k v k u & t k u s e a y x s l a w k l e ; d k s e k i k x ; k a b l l s v r ; r ; F k f k z r r k l s (a) y d j i e t d k v r ; r d e v i l j . k r F k (b) i f o h l s p n e k d h n j h] k k r g ð a

I kjk k

1. ijek.kq oŷ feyk dj oŷ q mnkl hu gŷrk gŷvŷŷ bl fy, ijek.kq eŷ ekukoŷ k vŷŷ 1/2. kkoŷk dh ek-kk, j l eku gŷrŷ gŷ
2. Vŷkŷl u&ekŷŷy ea ijek.kq ekukoŷ kŷ dk xŷŷy; eŷk gŷft l ea byŷVŷŷŷ vŷŷ LFkŷf r gŷrŷ gŷ
3. jnji Oŷŷ&ekŷŷy ea ijek.kq dk l oŷkŷed nŷ; eku vŷŷ bl dk oŷŷy ekukoŷ k, d l ŷŷe ukŷHkd ea l oŷŷer gŷrk gŷ (iz ir% ijek.kq oŷ l kb" k dk nl g"kkjokŷ Hkkx) rFk byŷVŷŷŷ bl oŷ pŷjŷa vŷŷ iŷŷŷek djrs gŷ
4. ijek.kq dh l jŷpuk dh 0; k[; k djus ea jnji Oŷŷ& oŷ ukŷHkd; ekŷŷy ea nŷs eŷ; dŷBukb; kŷ gŷŷ(a) bl oŷ vudŷ kj ijek.kq vŷLFkŷ gŷD; kŷd ukŷHkd oŷ pŷjŷa vŷŷ ?kŷers gŷ Rofjr byŷVŷŷŷk dŷk l eŷy iFk ij ukŷHkd dh vŷŷ vŷj vk tkuk pŷŷg, A ; g inŷFŷ oŷ LFkŷ; Ro dk [kŷu djrk gŷ (b) ; g fofHku rRoŷ oŷ ijek.kq/ka oŷ vŷHkyk{kŷ.kd ykbu LiŷVŷe dh 0; k[; k ugha dj l drk
5. iR; d rRo oŷ ijek.kq LFkŷ; h gŷrŷ gŷ vŷŷ vŷHkyk{kŷ.kd LiŷVŷe mRl eŷr djrs gŷ LiŷVŷe eafoyx l eŷr j jŷŷkŷka dk l eŷp; gŷrk gŷft l jŷŷ[ky LiŷVŷe dgrŷ gŷ ; g ijek.kq l jŷpuk oŷ fo" k; eami ; kŷŷ l jŷpuk, j nrk gŷ
6. ijek.oh; gkbŷŷŷŷu vudŷ Jŷŷk ; ŷr jŷŷ[ky LiŷVŷe mRl eŷr djrk gŷ fdl h Jŷŷk ea fdl h jŷŷk dh vkofŷk dŷnŷ inŷa oŷ vŷj oŷ : i ea 0; Dr fd; k tk l drk gŷ

$$ykbeŷ Jŷŷk : v = Rc \left(\frac{1}{1^2} - \frac{1}{n^2} \right); n = 2, 3, 4, \dots$$

$$ckej Jŷŷk : v = Rc \left(\frac{1}{2^2} - \frac{1}{n^2} \right); n = 3, 4, 5, \dots$$

$$ik'ku Jŷŷk : v = Rc \left(\frac{1}{3^2} - \frac{1}{n^2} \right); n = 4, 5, 6, \dots$$

$$cŷŷŷ Jŷŷk : v = Rc \left(\frac{1}{4^2} - \frac{1}{n^2} \right); n = 5, 6, 7, \dots$$

$$iŷŷ Jŷŷk : v = Rc \left(\frac{1}{5^2} - \frac{1}{n^2} \right); n = 6, 7, 8, \dots$$

7. ijek.kq/ka }jŷk mRl eŷr jŷŷ[ky LiŷVŷe rFk ijek.kq/ka oŷ LFkŷ; Ro dh 0; k[; k djus oŷ fy, uŷŷl ckŷ us gkbŷŷŷŷu l e ijek.kq/ka (, dy byŷVŷŷŷ) oŷ fy, , d ekŷŷy iŷrŷfor fd; kŷ mŷgŷŷŷŷu vŷHkxŷghr iŷrŷ fd, rFk Dokŷe ; kŷ-kdh dh uŷŷ j [kŷ% (a) fdl h gkbŷŷŷŷu ijek.kq ea dŷŷ byŷVŷŷŷ fcuŷ fofdj.k mŷtkŷ oŷ mRl tŷ oŷ fuf'pr dŷŷkŷka (ftlŷa LFkŷ; h dŷŷk dgrŷ gŷ) ea iŷŷŷe.k djrs gŷ (b) LFkŷ; h dŷŷk oŷ gŷft uŷŷ fy, dŷŷk; l oŷx $h/2\pi$ dk dŷŷ iŷŷkŷel xqkt gŷrk gŷ (ckŷ dk Dokŷehŷŷr iŷrŷ) A vŷŷŷŷ $L = nh/2\pi$, tŷŷk n, d iŷŷkŷel gŷft l s Dokŷe l ŷ; k dgrŷ gŷ (c) rhl jŷŷvŷHkxŷghr oŷ vudŷ kj dŷŷ byŷVŷŷŷ viuh, d fofufnŷV vŷodj.kh dŷŷk l s vŷ; fuŷr j mŷtkŷ dh dŷŷk ea l ŷŷe.k dj l drk gŷ, d k djus ea, d iŷŷŷŷŷ mRl eŷr gŷrk gŷft l dh mŷtkŷ iŷŷŷHkd vŷŷ vŷŷe voLFkŷka dh ŷtkŷka oŷ vŷj oŷ ckŷŷk gŷrŷ gŷ mRl eŷr iŷŷŷŷŷ dh vkofŷk (v) fuEu l eŷk }jŷk nh xŷŷgŷ%

$$h\nu = E_i - E_f$$

dŷŷ ijek.kq mŷtkŷ oŷ fofdj.k dŷŷvo' kŷŷŷŷ djrk gŷft l sog ijek.kq mRl eŷr djrk gŷ bl fLFkŷr ea byŷVŷŷŷ n l s mŷp eku dh dŷŷk ea vŷŷŷŷ gŷrk gŷ

$$E_i + h\nu = E_f$$

8. dls kh; I dx oð Dokvehdj.k ifrcv' oð ifj.kelo: i] byðvnu ukfhkd dh ifjðek oðoy for' k'V f-kT; kvla dh d{kvla eagh djrk gð gkbMstu i jek.kq oð fy, bl dk eku gð

$$r_n = \left(\frac{n^2}{m}\right) \left(\frac{h}{2\pi}\right)^2 \frac{4\pi\epsilon_0}{e^2}$$

oðy Átz Hkh Dokvr gð

$$E_n = \frac{me^4}{8n^2\epsilon_0^2h^2}$$

$$= -13.6 \text{ eV}/n^2$$

rc] n = 1 voLFkkj fuEure voLFkk dgykrh gð gkbMstu i jek.kq eafuEure voLFkk Átz dk eku -13.6 eV gð n oð cmæku (n > 1) mÚkstr voLFkkvle oð l ær gð i jek.kq bu mÚkstr voLFkkvle eð nÚ js i jek.kq/ka; k byðvnu ka l sl ækêð}kjk vFkok mfpr vkofúk oð i oðvnu dls vo' k'kr djoð i gprð gð

9. n sçmlyh dh ifjdYiuk] fd byðvnu dh rjærnð; $\lambda = h/mv$ gkrh gð us rjæ&d.k oð }ðh l ær' dk mi; kx djoð clj dh Dokvr d{kvla dh 0; k[; k dhA d{kk; i oÚkkckj vixkeh rjæka oð l ær gðftudh d{kk dh ifj/ rjærnð; kæ oð i wZxqktka oð cjkj gð
10. clj ekmy gkbMstule i jek.kq/ka (, dy byðvnu) oð fy, gh mi; ðr gð bl s f}&byðvnu i jek.kq tð sghfy; e oð fy, Hkh folrkfjr ughafð; k tk l drkA ; g ekmy gkbMstule i jek.kq/ka dh vkofúk; ka dh vki s{kcd rhorkvle dh Hkh 0; k[; k ugha dj i krka

fopkj.kh; fo"k;

1. Vkel u ekmy vlg jnji oðvz ekmy nkska gh vLFkk; h rak cukrs gð vke l u ekmy fLFkj oð r : i l s vLFkk; h gð tcd jnji oðvz ekmy d{kh; byðvnu ka oð oð r pædh; fofdj.k oð dkj.k vLFkk; h gkrk gð
2. clj us dls kh; I dx (f)rh; vfhxghr) dk gh Dokvehdj.k D; kofd; k] fd l h vlg jk' k dk D; ka ugha è; ku nafð n rFkk dls kh; I dx dh foek , d gh gkrh gð vlg oÚkkckj d{kvla oð fy, dls kh; I dx , d cgr i kl fxd jk' k gð vr% f}rh; vfhxghr Lokhfod gh gð
3. gkbMstu i jek.kq ea clj ekmy ea d{kh; fp=k.k] vfuf' prr fl ¼kr oð l kfk vl ær FkA ; g vkequd Dokve ; kæ-dh }kjk i frLFkfi r dj fn; k x; k Fk ft l ea clj dh d{kk, i os {sk gð tgl byðvnu oð ik, tkus dh i kf; drk cgr vfeld gsl drh gð
4. l g ifjokj dh fLFkr l sfHku] tgl xg&xg oð chp xæRokd"lz k cy] l wZvlg i R; d xg oð chp xæRokd"lz k cy (D; kæd l wZdk nð; eku fd l h Hkh xg oð nð; eku l scgr vf/d gð dh vi s{k cgr de gð byðvnu & byðvnu dh vl; kð; fð; k oð dkj.k oð r cy dk i jek.k byðvnu ukfhkd oð r cy oð r; gð D; kæd vkoš rFkk nðj; k i fjek.k ea l eku dksV dh gð ; gh dkj.k gsfð xg l n' k byðvnu dh eku; rk oky clj ekmy cg&byðvnu i jek.kq/ka oð fy, mi; ðr ugha gð
5. oðN for' k'V d{ka dh ifjdYiuk djoð ftuea byðvnu fofdfjr ugha djr} clj us Dokve fl ¼kr dh uho j [kha clj oð ekmy ea oðoy , d Dokve l æ; k n l fEefyr gð u; k fl ¼kr ft l s Dokve ; kæ-dh dgrsgð clj oð vfhxghr dh i q'V djrk gð rFkfi

Dokve ; kãkdh (vf/d 0; ki d : i l seku;) eã dkbzfo'ksk ÅtãzLrj l nã , d gh Dokve volFkk oã l ær ughaglrã mnkgj.k oã fy, l dkbzvolFkk plj Dokve l ã; kvka (n, l, m, rFlk s) l s vfHkyl{lf.kr g§ yfdu 'kq/ oãykã foHko oã fy, (gkbMst u ijek.kq dh Hããr) Åtãz oãoy n ij fuHkj djrh gã

6. l k/lj.k Dykfl dh vi{kkvka oã ifrony] clj ekMy eafdl h byðVnu oã vi uh d{kk ea ifjØe.k dh vkofuk dk Li ðVeh j§kk dh vkofuk l sãkãz l æãk ughagã Li ðVeh j§kk dh vkofuk h nekjk foHkfr nls d{kh; môtãvka dk varj gsrk gã cMk Dokve l ã; kvka (n l sn - 1 rd] n cgr cMk yusij) oã eè; l Øe.kãeankukã oã eku l eku gsrks gã tã k fd vi{kr gã
7. clj dk lãhDykfl dh ekMy tks oãN rls Dykfl dh Hããrdh oã igyã/kã ij rFlk oãN vkeãud Hããrdh oã igyã/kã ij vk/kfjr g§ l jyre gkbMst ul e ijek.kq/kã dk Hkh l gh fp-k.k ugha djrkã l gh fp-k oãLro ea Dokve ; kãkdh l sãkãr gsrk gStãscj ekMy l svud eyHkr : i kã eafHku gã fi Oj ; fn clj ekMy iãkz : i l s Bhd ugha Srks ge bl oã clj ea pfr D; kã gsrk gã rFlki clj ekMy dks mi ; lãch cukus okys oãN clj.k gã%
 - (i) ; g ekMy oãoy rhu vfHkxghrã ij vk/kfjr gsyfdu fi Oj Hkh gkbMst u Li ðVeh dh yxHkx l Hkh fo'kskrkvka dh 0; k[; k djrk gã
 - (ii) geus Dykfl dh Hããrdh dh ftu l dYiukvka dks l h[kk gSmudk bl ekMy ea l ekoãk gã
 - (iii) ekMy n'ãkãk gSfd oãN Hkfo"; okf.k; kãdh vk'kk eã fdl iãkã fdl h l sããrd HããrdfoKkuh dñj dhHkãdHkh oãN l n'k l eL; kvka dh v{kj'kk mi{kk dj nãh plfg, A ; fn fl ¼ãr ; k ekMy dh Hkfo"; ok.kh iz, lã l sey [kãrh gSrks oãkãfud dks mi{kr dh xbz l eL; kvka dh 0; k[; k djus dk iz Ru djuk plfg, A

vH; kl

- 12.1** iR; d dFku oã vr eafn, x, l ðãrã eã l s l gh fodYi dk p; u dhft, %
- (a) Vãã l u ekMy ea ijek.kq dk l kb"kl jnji oãMz ekMy ea ijek.koh; l kb"kl l s..... gsrk gã
(vi{kkãr dklãh vfeãd] fHku ughã vi{kkãr dklãh de)
 - (b) eafuEure volFkk eã byðVnu l Fkk; h l kE; eã gsrk gã tãfd eã byðVnu] l nã uã/ cy vubko djrgã
 - (c) ij vk/kfjr fdl h Dykfl dh ijek.kq dk u"V gsrk fuf'pr gã
(Vãã l u ekMy] jnji oãMz ekMy)
 - (d) fdl h ijek.kq oã nã; eku dk eã yxHkx l rr forj.k gsrk gSyfdu eã vr; r vl eku nã; eku forj.k gsrk gã
(Vãã l u ekMy] jnji oãMz ekMy)
 - (e) eã ijek.kq oã /ukof'kr Hkx dk nã; eku l okããd gsrk gã
(jnji oãMz ekMy] nããã ekMykã)
- 12.2** eku yhft, fd Lo.kz i l u h oã l Fku ij Bkl gkbMst u dh iryh 'khv dk mi ; lã dj oã vki dks, YHkã&d.k iãdh. kã iz, lã nãgãkus dk vol j iãr gsrk gã (gkbMst u 14 k l suhps rki ij Bkl gsrk tãrh gã) vki fdl ifj.kã dh vi{kk djrgã

- 12.3** i'ku Js kh eafo|eku Li DVeh js khvka dh y?kpe rjxnS; Z D; k gS
- 12.4** 2.3 ev mOtKz varj fdl h ijek. kqea nsmOtKz Lrjka dks i Fkd dj nsk gS mRl Etr fofdj. k dh vkofuk D; k glxh ; fn ijek. kqea byDVNU mPp Lrj l sfuEu Lrj ea l Øe. k djrk gS
- 12.5** gkbMstu ijek. kq dh fuEure volFkk eamOtKz -13.6 ev gS bl volFkk ea byDVNU dh xfrt vjg fLFkfrt mOtKz; j D; k glxh
- 12.6** fuEure volFkk eafo|eku , d gkbMstu ijek. kq, d i OskvU dks vo'kks"kr djrk gS tks bl s $n = 4$ Lrj rd mUkstr dj nsk gS i OskvU dh rjxnS; ZrFkk vkofuk Kkr dhft, A
- 12.7** (a) clj ekWY dk mi; lx djoE fdl h gkbMstu ijek. kq ea $n = 1, 2$, rFkk 3 Lrjka ij byDVNU dh pky ifjdfyr dhft, A (b) buea l siR; d Lrj oE fy, d {kh; vof/ ifjdfyr dhft, A
- 12.8** gkbMstu ijek. kq ea varjre byDVNU d {kk dh f-kT; k 5.3×10^{-11} m gS d {kk $n = 2$ vjg $n = 3$ dh f-kT; k; j D; k gS
- 12.9** dejsOE rki ij xS h; gkbMstu ij fdl h 12.5 ev dh byDVNU i q dh ceckjh dh xba fdu rjxnS; kadh Js kh mRl Etr glxh
- 12.10** clj ekWY oE vuq kj l wZ oE pkjka vjg 1.5×10^{11} m f-kT; k dh d {kk e j 3×10^4 m/s oE d {kh; ox l si fJØek djrh i Foh dh vfHkyk {kr. kd Dokke l q; k Kkr dhft, (i Foh dk nO; eku = 6.0×10^{24} kg)A

vfrfjDr vH; kl

- 12.11** fuEufyf [kr izuka oE mUkj nhft, tks vki dks VNE l u ekWY vjg jnji OAZ ekWY ea varj l e>us grq vPNh rjg l sl gk; d gS
- (a) D; k VNE l u ekWY ea irys Lo. k iz Uuh l s iz dhf. kr α & d. ka dk i nOZupkur vjg r fo {ki. k dks k jnji OAZ ekWY }kjk i nOZupkur eku l svR; r de j yxHx l eku vFkok vR; fekd cMk gS
- (b) VNE l u ekWY }kjk i nOZupkur i 'p iz dh. ku dh i kf; drk (vFkr α & d. ka dk 90° l scMs dks ka i j iz dh. ku) jnji OAZ ekWY }kjk i nOZupkur eku l svR; r de j yxHx l eku vFkok vR; fekd gS
- (c) vU; dkj dka dks fu; r j [krs gq] iz lx }kjk ; g ik; k x; k gSfd de ekWkz t oE fy,] eE; e dks ka i j iz dhf. kr α & d. ka dh l q; k t oE vuqekuq kfrd gS t ij ; g js [kd fuHkjrk D; k l ODr nsh gS
- (d) fdl ekWY ea α & d. ka oE iryh i Uuh l s iz dh. ku oE i 'pkr vjg r iz dh. ku dks k oE ifjdyu grq cgq dh. ku dh mi s {kk djuk i wkz; k xyr gS
- 12.12** gkbMstu ijek. kq ea byDVNU , oa i k vU oE eE; xqRokd "k k oE ykE & vkd "k k l s yxHx 10^{-40} oE xqkd l s de gS bl rF; dks n [kusdk , d oE fYi d mik; ; g gSfd ; fn byDVNU , oa i k vU xqRokd "k k }kjk vlc ¼ glark fdl h gkbMstu ijek. kq ea i Fke clj d {kk dh f-kT; k dk vuqku yxkb, A vki euljatd mUkj ik, xA
- 12.13** tc dkbz gkbMstu ijek. kq Lrj n l s Lrj $(n - 1)$ ij 0; qkstr glsk gS rks mRl Etr fofdj. k dh vkofuk grqO; atd i klr dhft, A n oE vfekd eku grq n' kO, fd ; g vkofuk byDVNU dh d {kk ea i fJØe. k dh Dykfl dh vkofuk oE cjkj gS
- 12.14** Dykfl dh : i eafdl h ijek. kq ea byDVNU ukfHkd oE pkjka vjg fdl h Hkh d {kk eagls l drk

gđ rc iz ih ijeK.oh; l kb"K fdlls fuekđjr gkrk gđ ijeK.kq vius iz ih l kb"K dh viđk nl g"kkj xpk cMk D; ka ugha gđ bl izu us cđj dks vius ifl ¼ ijeK.kq ekMly] tks vki us ikB; iđrd ea i<k gđ rd igpus ls igys cgr my>u ea Mkyk FKA viuh [kđt l s iđz ml gkas D; k fd; k gskđ] bl dk vuđj.k djus ođ fy, ge ey fu; rkađa dh iđfr ođ l kfk fuEu xfrfođ/ djođ nđ ka fd D; k gea yckbz dh foek okyh dks jkf'k i ktr gkrh gđ ftl dk l kb"K yxHlx ijeK.kq ođ Kkr l kb"K (~ 10⁻¹⁰m) ođ cđkj gđ

- (a) ey fu; rkađa **e**, **m_e**, vđđ **c** l syckbz dh foek okyh jkf'k dh jpuk dhft, A ml dk l đ; kRed eku Hkh fuekđjr dhft, A
- (b) vki ik, xsfđ (a) ea i ktr yckbz ijeK.oh; foekvka ođ ifjek.k dh dksV l s dklkch Nkđh gđ bl ođ vfrfjDr bl ea **c** l feefyr gđ ijq ijeK.kq/ka dh mđtz vfeđrj vuki đ{kđh; {sk (non-relativistic domain) ea gđ tgđ **c** dh dksV vi đ{kr Hkđedk ughađ bl h rođ us cđj dks **c** dk ifjR; kx dj l gh ijeK.oh; l kb"K dks i ktr djus ođ fy, ^ođN vđ; * nđkus ođ fy, ifjR fd; ka bl l e; lykađ fu; rkađ **h** dk dgha vđđ igysgh vkfoHkđ gks pđk FKA cđj dh l đent"V us igpkuk fd **h**, **m_e** vđđ **e** ođ iz kx l sgh l gh ijeK.kq l kb"K i ktr gskđ vr% **h**, **m_e** vđđ **e** l sgh yckbz dh foek okyh fd l h jkf'k dh jpuk dhft, vđđ i đ"V dhft, fd bl dk l đ; kRed eku] ođro ea l gh ifjek.k dh dksV dk gđ

- 12.15** gkbMđstu ijeK.kq dh i fke mđkđtr voLFkk ea byđVđđ dh ođy mđtz yxHlx - 3.4 eV gđ
 - (a) bl voLFkk ea byđVđđ dh xfrt mđtz D; k gđ
 - (b) bl voLFkk ea byđVđđ dh flfkr mđtz D; k gđ
 - (c) ; fn flfkr mđtz ođ 'đđ; Lrj ođ p; u ea ifjorđ dj fn; k tk, rks mđj fn, x, mđkđa ea l s dksđ l k mđkj ifjofrđ gskđ\
- 12.16** ; fn cđj dk Dokđehđj.k vđHlxđhr (dks kh; l đx = $nh/2\pi$) iđfr dk ey fu; e gđrks ; g xđh; xfr dh n'kk ea Hkh ykxwgksuk pđg, A rc ge l đz ođ pkđa vđđ xđka dh dđkđvka ođ Dokđehđj.k ođ fo"K; ea dHkh pđz D; ka ugha đjrs.
- 12.17** i fke cđj đf=đT; k vđđ E; vđksud gkbMđstu ijeK.kq [vFKđr dksV ijeK.kq ftl ea yxHlx 207 **m_e** nđ; eku dk ½. kofs'kr E; vđđ (μ) i đvđđ ođ pkđa vđđ ?kđrk gđ dh fuEure voLFkk mđtz dks i ktr djus dk ifjdyu dhft, A

