4. (a) The average time that the atom spends in this excited state is equal to Δt, so by using $\Delta E.\Delta t = \frac{h}{2\pi}$

$\Rightarrow$ Uncertainty in energy $= \frac{h/2\pi}{\Delta t}$

$= \frac{6.6\times10^{-34}}{2\times3.14\times10^{-8}} = 1.05\times10^{-26}\,J = 6.56\times10^{-8}\,eV$

5. (a) After the removal of first electron remaining atom will be hydrogen like atom.

So energy required to remove second electron from the atom $E = 13.6\times\frac{2^2}{1} = 54.4\ eV$

$\therefore$ Total energy required = 24.6 + 54.4 = 79 eV.

6. (a) Electron after absorbing 10.2 eV energy goes to its first excited state (n=2) from ground state (n = 1).

$\therefore$ Increase in momentum $= \frac{h}{2\pi}$

$= \frac{6.6\times10^{-34}}{6.28} = 1.05\times10^{-34}\,J\text{-}s.$

7. (a) Using $\Delta E \propto Z^2$ ($\because$ n_1 and n_2 are same)

$\Rightarrow \frac{hc}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 = \text{constant}$

$\Rightarrow \lambda_1 Z_1^2 = \lambda_2 Z_2^2 = \lambda_3 Z_3^2 = \lambda_4 Z_4^2$

$\Rightarrow \lambda_1\times1 = \lambda_2\times1^2 = \lambda_3\times2^2 = \lambda_4\times3^3$

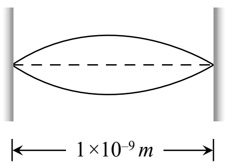
$\Rightarrow \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$.

8. (d) $mvr = \frac{h}{2\pi}$ (for first orbit)

$\Rightarrow m\omega r^2 = \frac{h}{2\pi} \Rightarrow m\times2\pi\nu\times r^2 = \frac{h}{2\pi} \Rightarrow \nu = \frac{h}{4\pi^2 mr^2}$

$= \frac{6.6\times10^{-34}}{4(3.14)^2\times9.1\times10^{-31}\times(0.53\times10^{-10})^2} = 6.5\times10^{15}\,\frac{rev}{sec}$

9. (b) It will form a stationary wave



$\lambda = 2l = 2\times10^{-9}\,m$

$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}}$

$\Rightarrow E = \frac{h^2}{2m\lambda^2} = 6\times10^{-20}\,J$

10. (d) Suppose closest distance is r, according to conservation of energy.

$400\times10^3\times1.6\times10^{-19} = 9\times10^9\frac{(Ze)(2e)}{r}$

$\Rightarrow 6.4\times10^{-14} = \frac{9\times10^9\times(82\times1.6\times10^{-19})\times(2\times1.6\times10^{-19})}{r}$

$\Rightarrow r = 5.9\times10^{-13}\,m = 0.59\,pm.$

11. (a) Here radius of electron orbit $r \propto 1/m$ and energy $E \propto m$, where m is the mass of the electron.

Hence energy of hypothetical atom

$E_0 = 2\times(-13.6\,eV) = -27.2\,eV$ and radius $r_0 = \frac{a_0}{2}$

12. (a) Electronic configuration of iodine is 2, 8, 18, 18, 7,

Here $r_n = (0.053\times10^{-9}\,m)\frac{n^2}{Z}$

Here $n = 5$ and $Z = 53$, hence $r_n = 2.5\times10^{-11}\,m$.

13. (a) $N \propto \left[\frac{1}{\sin^4\theta/2}\right] \Rightarrow N_1 = 7\times\frac{1}{(\sin30^o)^4} = 112$

and $N_2 = 7\times\frac{1}{(\sin60^o)^4} = 12.5$.

14. (d) $E_n = -13.6\frac{Z^2}{n^2}\,eV$. Required energy for said transition

$\Delta E = E_3 - E_1 = 13.6\,Z^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$

$\Rightarrow \Delta E = 13.6\times3^2\left[\frac{8}{9}\right] = 108.8\ eV$

$\Rightarrow \Delta E = 108.8\times1.6\times10^{-19}\,J$

Now $\Delta E = \frac{hc}{\lambda} = 108.8\times1.6\times10^{-19}$

$\Rightarrow \lambda = \frac{6.6\times10^{-34}\times3\times10^8}{108.8\times1.6\times10^{-19}} = 0.11374\times10^{-7}\,m = 113.74\,\mathring{A}$

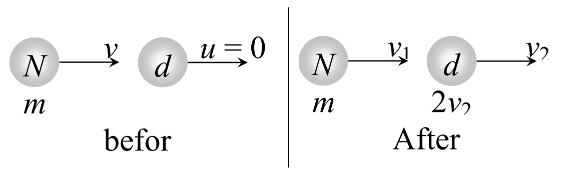
15. (c) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\Rightarrow \frac{1}{970.6\times10^{-10}} = 1.097\times10^7\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right] \Rightarrow n_2 = 4$

$\therefore$ Number of emission lines $N = \frac{n(n-1)}{2} = \frac{4\times3}{2} = 6$

16. (d) Neutron velocity = v, mass = m

Deuteron contains 1 neutron and 1 proton, mass = $2m$



In elastic collision both momentum and *K.E.* are conserved $p_i = p_f$

$mv = m_1v_2 + m_2v_2 \Rightarrow mv = mv_1 + 2mv_2$ ... (i)

By conservation of kinetic energy

$$\frac{1}{2}mv^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}(2m)v_2^2 \quad \text{... (ii)}$$

By solving (i) and (ii) we get

$$v_1 = \frac{m_1 - m_2}{m_1 + m_2}v + \frac{2m_2}{(m_1 + m_2)}v \Rightarrow v_1 = \frac{m_1 + 2m}{3m} = -\frac{v}{3}$$

$$K_i = \frac{1}{2}mv^2, \quad K_f = \frac{1}{2}mv_1^2 \Rightarrow \frac{K_i - K_f}{K_i} = 1 - \frac{v_1^2}{v^2}$$

$$= 1 - \frac{1}{9} = \frac{8}{9}$$ (Fractional change in *K.E.*)

17. (c) In hydrogen atom $E_n = -\frac{Rhc}{n^2}$

Also $E_n \propto m$; where m is the mass of the electron. Here the electron has been replaced by a particle whose mass is double of an electron. Therefore, for this hypothetical atom energy in n^{th} orbit will be given by $E_n = -\frac{2Rhc}{n^2}$

The longest wavelength λ_{max} (or minimum energy) photon will correspond to the transition of particle from $n = 3$ to $n = 2 \Rightarrow$

$$\frac{hc}{\lambda_{max}} = E_3 - E_2 = Rhc\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

This gives $\lambda_{max} = \frac{18}{5R}$.

18. (d) As the transition $n = 4$ and $n = 3$, results in *UV* radiation and infrared radiation involves smaller amounts of energy *UV*. So we require a transition involving initial values of n greater than 4 *e.g.* $5 \to 4$.

19. (c) $\frac{hc}{\lambda} = E = eV$

$$\Rightarrow \lambda = \frac{hc}{eV} - \frac{6.6\times10^{-34}\times3\times10^8}{1.6\times10^{-19}\times4.9} = 2525\,\mathring{A}$$

20. (d) Rydberg constant $R = \frac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}$

Velocity $v = \frac{Ze^2}{2\varepsilon_0 nh}$ and energy $E = -\frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$

Now, it is clear from above expressions $R.v \propto n$

21. (b) In second excited state $n = 3$

So $l_H = l_{Li} = 3\left(\frac{h}{2\pi}\right)$

While $E \propto Z^2$ and $Z_H = 1$, $Z_{Li} = 3$

So $|E_{Li}| = 9|E_H|$ or $|E_H| < |E_{Li}|$

22. (c) Since the ${}^{133}_{55}Cs$ has larger size among the four atoms gives, thus the electrons present in the outermost orbit will be away from the nucleus and the electrostatic force experienced by electrons due to nucleus will be minimum. Therefore the energy required to liberate electron from outer will be minimum in the case of ${}^{133}_{55}Cs$

23. (d)

24. (a) Potential energy $U = eV = eV_0 \ln\frac{r}{r_0}$

$\therefore$ Force $F = -\left|\frac{dU}{dr}\right| = \frac{eV_0}{r}$.

$\therefore$ The force will provide the necessary centripetal force. Hence $\frac{mv^2}{r} = \frac{eV_0}{r} \Rightarrow v = \sqrt{\frac{eV_0}{m}}$ .....(i)

and $mvr = \frac{nh}{2\pi}$ .....(ii)

From equation (i) and(ii) $mr = \left(\frac{n}{2}\right.$

25. (d) $(r_m) = \left(\frac{m^2}{Z}\right)(0.53\mathring{A}) = (n\times0.53\mathring{A}) \Rightarrow \frac{m^2}{Z} = n$

$m = 5$ for ${}_{100}Fm^{257}$ (the outermost shell)

and $z = 100 \Rightarrow n = \frac{(5)^2}{100} = \frac{1}{4}$

26. (d) Energy radiated $= 1.4\ kW/m^2$

$$= 1.4\ kJ/\sec m^2 = \frac{1.4\ kJ}{\frac{1}{86400}day\,m^2} = \frac{1.4\times86400}{day\,m^2}$$

Total energy radiated/day

$$= \frac{4\pi\times(1.5\times10^{11})^2\times1.4\times86400}{1}\frac{kJ}{day} = E$$

$$\therefore E = mc^2 \Rightarrow m = \frac{E}{c^2}$$

$$= \frac{4\pi(1.5\times10^{11})^2\times1.4\times86400}{(3\times10^8)^2} = 3.8\times10^{14}\ kg.$$

27. (c) The equation is $O^{17} \to {}_0n^1 + O^{16}$

$\therefore$ Energy required = B.E. of O^{17} – B.E. of O^{16}

$= 17 \times 7.75 - 16 \times 7.97 = 4.23\ MeV$

28. (c) $\Delta = mc^2 - m_0c^2 = \frac{m_0c^2}{\sqrt{1-(v^2/c^2)}} - m_0c^2$

$$= m_0c^2\left(\frac{1}{\sqrt{1-(v^2/c^2)}} - 1\right) = 0.511\left(\frac{1}{\sqrt{0.75}} - 1\right)$$

$= 0.079\ MeV$

29. (c,d) Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less then the sum of masses of it's constituent particles ${}^{20}_{10}Ne$ is made up of 10 protons plus 10 neutrons. Therefore, mass of ${}^{20}_{10}Ne$ nucleus $M_1 < 10(m_p + m_n)$

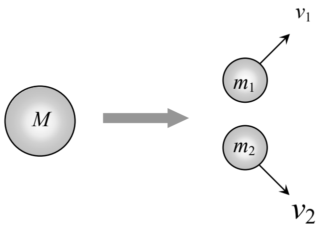
Also heavier the nucleus, more is he mass defect thus $20(m_n + m_p) - M_2 > 10(m_p + m_n) - M_1$

or $10(m_p + m_n) > M_2 - M_1$

$\Rightarrow M_2 < M_1 + 10(m_p + m_n) \Rightarrow M_2 < M_1 + M_1$

$\Rightarrow M_2 < 2M_1$.

30. (a)



By conservation of momentum $m_1v_1 = m_2v_2$

$\Rightarrow \frac{v_1}{v_2} = \frac{8}{1} = \frac{m_2}{m_1}$ …… (i)

Also from $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$.

31. (a) Since nuclear density is constant hence mass $\propto$ volume.

32. (c) Mass defect $= 3 \times 2.014 - 4.001 - 1.007 - 1.008$

$= 0.026\ amu = 0.026 \times 931 \times 10^6 \times 1.6 \times 10^{-19}\ J$

$= 3.82 \times 10^{-12}\ J$

Power of star $= 10^{16} W$

Number of deuterons used $= \frac{10^{16}}{\Delta M} = 0.26 \times 10^{28}$

Deuteron supply exhausts in $\frac{10^{40}}{0.26 \times 10^{28}} = 10^{12} s$.

33. (a) Since electron and positron annihilate

$\lambda = \frac{hc}{E_{Total}} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{(0.51 + 0.51) \times 10^6 \times 1.6 \times 10^{-19}}$

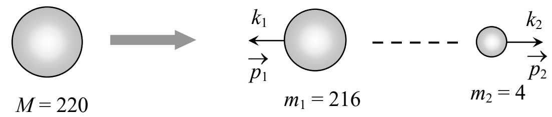
$= 1.21 \times 10^{-12} m = 0.012 \mathring{A}$.

34. (a) Kinetic energy of the molecules of a gas at a temp. T is $\frac{3}{2}kT$

$\therefore$ To initiate the reaction $\frac{3}{2}kT = 7.7 \times 10^{-14}\ J$

$\Rightarrow \frac{3}{2} \times 1.38 \times 10^{-23}\ T = 7.7 \times 10^{-14} \Rightarrow T = 3.7 \times 10^9 K$.

35. (b)



Q-value of the reaction is 5.5 eV

i.e. $k_1 + k_2 = 5.5\ MeV$

……(i)

By conservation of linear momentum

$p_1 = p_2 \Rightarrow \sqrt{2(216)k_1} = \sqrt{2(4)k_2}$

$\Rightarrow k_2 = 54\ k_1$

……(ii)

On solving equation (i) and (ii) we get k_2 = 5.4 MeV.

36. (b) By the formula $N = N_0 e^{-\lambda t}$

Given $\frac{N}{N_0} = \frac{1}{20}$ and $\lambda = \frac{0.6931}{3.8} \Rightarrow 20 = e^{\frac{0.6931 \times t}{3.8}}$

Taking log of both sides

or log 20 $= \frac{0.6931 \times t}{3.8} \log_{10} e$

or $1.3010 = \frac{0.6931 \times t \times 0.4343}{3.8} \Rightarrow t = 16.5$ days.

37. (b) $N = N_0 e^{-\lambda t}$

$\therefore 0.9 N_0 = N_0 e^{-\lambda \times 5} \Rightarrow 5\lambda = \log_e \frac{1}{0.9}$ ...... (i)

and $xN_0 = N_0 e^{-\lambda \times 20} \Rightarrow 20\lambda = \log_e \left(\frac{1}{x}\right)$ ...... (ii)

Dividing (i) by (ii), we get

$\frac{1}{4} = \frac{\log_e(1/0.9)}{\log_e(1/x)} = \frac{\log_{10}(1/0.9)}{\log_{10}(1/x)} = \frac{\log_{10} 0.9}{\log_{10} x}$

$\Rightarrow \log_{10} x = 4 \log_{10} 0.9 \Rightarrow x = 0.658 = 65.8\%$

38. (c) If in the rock there is no Y element, then the time taken by element X to reduce to $\frac{1}{8}th$ the initial value will be equal to $\frac{1}{8} = \left(\frac{1}{2}\right)^n$ or $n = 3$

Therefore, from the beginning three half life time is spent. Hence the age of the rock is $= 3 \times 1.37 \times 10^9 = 4.11 \times 10^9\ years$.

39. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{64} = \left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^n \Rightarrow n = 6$.

After 6 half lives intensity emitted will be safe.

$\therefore$ Total time taken $= 6 \times 2 = 12\,hrs.$

40. (a) $\frac{dN}{dt} = \lambda N;\ \lambda = \frac{0.6931}{t_{12}} = \frac{0.6931}{1620 \times 365 \times 24 \times 60 \times 60}$,

$N = \frac{6.023 \times 10^{23}}{226}$

$\therefore \frac{dN}{dt} = \frac{0.6931 \times 6.023 \times 10^{23}}{1620 \times 365 \times 24 \times 60 \times 60 \times 226} = 3.61 \times 10^{10}$

41. (a) $\lambda = \lambda_1 + \lambda_2 \Rightarrow \frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2}$

$\therefore T = \frac{T_1 T_2}{T_1 + T_2} = \frac{810 \times 1620}{810 + 1620} = 540\ years$

Hence $\frac{1}{4}th$ of material remain after 1080 *years.*

42. (b) Similar to Q. 40.

43. (c) $(T_{1/2})_x = (t_{\text{mean}})_y$

$\Rightarrow \frac{0.693}{\lambda_x} = \frac{1}{\lambda_y} \Rightarrow \lambda_x = 0.693\lambda_y$ or $\lambda_x < \lambda_y$

Also rate of decay = λN

Initially number of atoms (N) of both are equal but since $\lambda_y > \lambda_x$, therefore, y will decay at a faster rate than x.

44. (c) $\lambda_\alpha = \frac{1}{1620}$ *per year* and $\lambda_\beta = \frac{1}{405}$ *per year* and it is given that the fraction of the remained activity $\frac{A}{A_0} = \frac{1}{4}$

Total decay constant

$\lambda = \lambda_\alpha + \lambda_\beta = \frac{1}{1620} + \frac{1}{405} = \frac{1}{324}\ per\,year$

We know that $A = A_0 e^{-\lambda t} \Rightarrow t = \frac{1}{\lambda}\log_e \frac{A_0}{A}$

$\Rightarrow t = \frac{1}{\lambda}\log_e 4 = \frac{2}{\lambda}\log_e 2 = 324 \times 2 \times 0.693 = 449\ years.$

45. (d) $n = \frac{24}{24 \times 138.6} = \frac{1}{138.6}$; Now

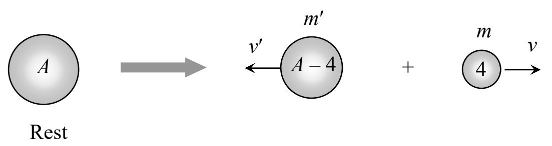
$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{1/138.6}$

$\Rightarrow N = 10{,}00000\left(\frac{1}{2}\right)^{1/138.6} = 995011$

So number of disintegration

$= 1000000 - 995011 = 4989 \approx 5000$.

46. (a)



According to conservation of momentum

$4v = (A-4)v' \Rightarrow v' = \frac{4v}{A-4}$.

47. (b) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{20} = 0.03465$

Now time of decay $t = \frac{2.303}{\lambda}\log\frac{N_0}{N}$

$\Rightarrow t_1 = \frac{2.303}{0.03465}\log\frac{100}{67} = 11.6\,\text{min}\ min$

and $t_2 = \frac{2.303}{0.03465}\log\frac{100}{33} = 32\,min$

Thus time difference between points of time $= t_1 - t_2 = 32 - 11.6 = 20.4\ min \approx 20\ min.$

48. (d) $N_1 = N_0 e^{-10\lambda t}$ and $N_2 = N_0 e^{-\lambda t}$

$\Rightarrow \frac{N_1}{N_2} = \frac{1}{e} = e^{-1} = e^{(-10\lambda + \lambda)t} = e^{-9\lambda t} \Rightarrow t = \frac{1}{9\lambda}$.

49. (a) $N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow N_A = 10\left(\frac{1}{2}\right)^{t/1}$ and $N_B = 1\left(\frac{1}{2}\right)^{t/2}$

Given $N_A = N_B \Rightarrow 10\left(\frac{1}{2}\right)^t = \left(\frac{1}{2}\right)^{t/2}$

$\Rightarrow 10 = \left(\frac{1}{2}\right)^{-t/2} \Rightarrow 10 = 2^{t/2}$. Taking log both the sides.

$\log_{10}10 = \frac{t}{2}\log_{10}2 \Rightarrow 1 = \frac{t}{2} \times 0.3010 \Rightarrow t = 6.62$ years.

50. (b) Here $T_{1/2} = 20$ *minutes;* we know $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$

For 20% decay $\frac{N}{N_0} = \frac{80}{100} = \left(\frac{1}{2}\right)^{t_1/20}$ ..... (i)

For 80% decay $\frac{N}{N_0} = \frac{20}{100} = \left(\frac{1}{2}\right)^{t_2/20}$ ..... (ii)

Dividing (ii) by (i)

$\frac{1}{4} = \left(\frac{1}{2}\right)^{\frac{(t_2 - t_1)}{20}}$; on solving we get $t_2 - t_1 = 40\ min.$

51. (d) Here the activity of the radioactive sample reduces to half in 140 days. Therefore, the half life of the sample is 140 days. 280 days is it's two half lives. So before two half lives it's activity was $(2^2 \times$ present activity).

$\therefore$ Initial activity = $2^2 \times 6000 = 24000\,dps$

52. (a) Excitation energy $\Delta E = E_2 - E_1$

$= 13.6\, Z^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$\Rightarrow 40.8 = 13.6 \times \frac{3}{4} \times Z^2 \Rightarrow Z = 2.$

Now required energy to remove the electron from ground state

$= \frac{+13.6 Z^2}{(1)^2} = 13.6(Z)^2 = 54.4\, eV.$

53. (b) Rate of disintegration $\frac{dN}{dt} = 10^{17}\, s^{-1}$

Half life $T_{1/2} = 1445$ year

= 1445 × 365 × 24 × 60 ×60 = 4.55 × 10^{10} *sec*

Now decay constant

$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{4.55 \times 10^{10}} = 1.5 \times 10^{-11}$ per sec

The rate of disintegration

$\frac{dN}{dt} = \lambda \times N_0 \Rightarrow 10^{17} = 1.5 \times 10^{-11} \times N_0$

$\Rightarrow N_0 = 6.6 \times 10^{27}$.

54. (b) $P = \frac{nE}{t} \Rightarrow 300 \times 10^6 = \frac{n \times 170 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

∴ Number of atoms per sec $\frac{n}{t} = 1.102 \times 10^{19}$

Number of atoms per hour = 1.02 × 10^{19} × 3600

= 3.97 × 10^{22}.

55. (a) According to kinetic interpretation of temperature

$K.E. = \left(\frac{1}{2}mv^2\right) = \frac{3}{2}kT.$

$\Rightarrow 10.2 \times 1.6 \times 10^{-19} = \frac{3}{2} \times (1.38 \times 10^{-23})T$

$\Rightarrow T = 7.9 \times 10^4 K.$

56. (a) R_0 = Initial activity = 1 micro curie = 3.7 × 10^4 *d ps*

r = Activity in 1 cm^3 of blood at *t* = 5 *hrs*

$= \frac{296}{60}\, dps = 4.93\, dps$

R = Activity of whole blood at time *t* = 5 *hr,*

Total volume should be $V = \frac{R}{r} = \frac{R_0 e^{-\lambda t}}{r}$

$= \frac{3.7 \times 10^4 \times 0.7927}{4.93}$ = 5.94 × 10^3 cm^3 = 5.94 *Litre*.

57. (b) Let ground state energy (in *eV*) be E_1

Then from the given condition

$E_{2n} - E_1 = 204\, eV$ or $\frac{E_1}{4n^2} - E_1 = 204\, eV$

$\Rightarrow E_1\left(\frac{1}{4n^2} - 1\right) = 204\, eV$ …..(i)

and $E_{2n} - E_n = 40.8\, eV$

$\Rightarrow \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1\left(-\frac{3}{4n^2}\right) = 40.8\, eV$ …..(ii)

From equation (i) and (ii), $\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow$

$n = 2$

58. (b) Here $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{1/3}$

where *n* = Number of half lives $= \frac{1}{3}$

$\Rightarrow \frac{N}{N_0} = \frac{1}{1.26} \Rightarrow \frac{N_U}{N_{Pb} + N_U} = \frac{1}{1.26}$

$\Rightarrow N_{Pb} = 0.26\, N_U \Rightarrow \frac{N_{Pb}}{N_U} = 0.26$

59. (b) For K_α X-ray line

$\frac{1}{\lambda_\alpha} = R(Z-1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}(Z-1)^2$

On putting the given values

$\frac{1}{0.76 \times 10^{-10}} = \frac{3}{4} \times 1.09 \times 10^7 (Z-1)^2$

$\Rightarrow (Z-1)^2 \approx 1600 \Rightarrow Z - 1 = 40 \Rightarrow Z = 41$

60. (a) Maximum energy is liberated for transition $E_n \rightarrow 1$ and minimum energy for $E_n \rightarrow E_{n-1}$

Hence $\frac{E_1}{n^2} - E_1 = 52.224\, eV$ ……(i)

and $\frac{E_1}{n^2} - \frac{E_1}{(n-1)^2} = 1.224\, eV$ …..(ii)

Solving equations (i) and (ii) we get

$E_1 = -54.4\, eV$ and $n = 5$

Now $E_1 = -\frac{13.6\, Z^2}{1^2} = -54.4\, eV.$ Hence $Z = 2$

61. (a) Activity of substance that has 2000 disintegration/sec

$= \frac{2000}{3.7 \times 10^{10}} = 0.054 \times 10^{-6}\, ci = 0.054\, \mu ci$

The number of radioactive nuclei having activity *A*

$N = \frac{A}{\lambda} = \frac{2000 \times T_{1/2}}{\log_e 2}$

$= \frac{2000 \times 138.6 \times 24 \times 3600}{0.693} = 3.45 \times 10^{10}$

62. (a) Maximum number of nuclei will be present when rate of decay = rate of formation $\Rightarrow$ $\lambda N = \alpha \Rightarrow N = \frac{\alpha}{\lambda}$

63. (b) $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$\Rightarrow \frac{3}{5} = \left(\frac{27}{A}\right)^{1/3} \Rightarrow \frac{27}{125} = \frac{27}{A} \Rightarrow A = 125$

Number of nuclei in atom X
$= A - 52 = 125 - 52 = 73.$

64. (c) 1 week ≈ 7 days $\simeq 7 \times 24 hrs \simeq 14$ half lives

Number of atoms left $= \frac{No}{(2)^{14}}$, Activity = $N\lambda$

$\therefore$ Activity left is $\frac{1}{(2)^{14}}$ times the initial

$\Rightarrow \frac{1}{(2)^{14}} \times 1$ *curie* $= \frac{1}{16384} \times 1$ curie $\cong 61 \times 10^{-6}$ curie

$\approx 60\mu$ *curie.*

65. (a) $m_0c^2 = 0.54\ MeV$ and K.E. $= mc^2 - m_0c^2$

Also $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{1-(0.8)^2}} = \frac{m_0}{0.6}$

$\therefore E = mc^2 = \frac{m_0}{0.6}c^2 = \frac{m_0 c}{0.6} = \frac{0.5 H}{0.6} = 0.9\ MeV$

$\therefore$ K.E.= (0.9 – 0.54) = 0.36 *MeV.*

Graphical Questions

1. (a) B.E. per nucleon is maximum for Fe^{56}. For further detail refer theory.

2. (a) $\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = 2\pi c\bar{\nu} \Rightarrow \omega \propto \bar{\nu}$.

3. (c)

4. (d) The total number of atoms neither remains constant (as in option (a) nor can ever increase (as in option (b) and (c)). They will continuously decrease with time. Therefore option (d) is correct.

5. (c) $N = N_0 e^{-\lambda t} \Rightarrow \frac{dN}{dt} = -N_0 \lambda e^{-\lambda t}$

i.e. Rate of decay $\left(\frac{dN}{dt}\right)$ varies exponentially with time (t).

6. (d) Rate $R = -\frac{dN}{dt} = \lambda N_0 e^{-\lambda t} = \lambda N \Rightarrow \frac{R}{N} = \lambda$ (constant)

i.e. graph between $\frac{R}{N}$ and t, be a straight line parallel to the time axis.

7. (b) Read time for 50 count rate, it gives half life period of 3 *hrs*, one small square gives 600 counts (10 × 60). The number of small squares between graph and time axis are approx 24

Hence count rate = $24 \times 600 = 14400$

8. (b) Number of atoms undecayed $N = N_0 e^{-\lambda t}$

Number of atoms decayed $= N_0 - N = N_0(1 - e^{-\lambda t})$

$\Rightarrow$ Decayed fraction $f = \frac{N_0 - N}{N_0} = 1 - e^{-\lambda t}$

i.e. fraction will rise up to 1, following exponential path as shown in graph (B).

9. (c) Energy is released in a process when total Binding energy (B.E.) of the nucleus is increased or we can say when total *B.E.* of products is more than the reactants. By calculation we can see that only in case of option (c), this happens.

Given $W \to 2Y$

B.E. of reactants = 120 × 75 = 900 *MeV*

and *B.E.* of products = $2 \times (60 \times 85) = 1020\ MeV$

i.e. B.E. of products > *B.E.* of reactants.

10. (d) $N = N_0 e^{-\lambda t}$ and $A = A_0 e^{-\lambda t} = \lambda N_0 e^{-\lambda t}$

$\therefore N_{decayed} = N_0 - N = N_0 - N_0 e^{-\lambda t} \Rightarrow N_{decayed} = N_0 - \frac{A}{\lambda}$

This is equation of straight line with negative slope.

11. (d) Radius of n^{th} orbit $r_n \propto n^2$, graph between r_n

and n is a parabola. Also, $\frac{r_n}{r_1}=\left(\frac{n}{1}\right)^2 \Rightarrow \log_e\left(\frac{r_n}{r_1}\right)=2\log_e(n)$

Comparing this equation with $y = mx + c$,

Graph between $\log_e\left(\frac{r_n}{r_1}\right)$ and $\log_e(n)$ will be a straight line, passing from origin.

Similarly it can be proved that graph between $\log_e\left(\frac{f_n}{f_1}\right)$ and $\log_e n$ is not a straight line.

12. (d) By using $N=N_0e^{-\lambda t}$ and $\frac{dN}{dt}=-\lambda N.$

It shows that N decreases exponentially with time.

13. (b) Activity $=-\frac{dN}{dt}=\lambda N=\lambda\ N_0e^{-\lambda t}$

i.e., graph between activity and t, be exponential having negative slope.

14. (d) Activity $A=\lambda\ N_0e^{-\lambda t}$ $\Rightarrow$ $\log_e A=\log_e \lambda\ N_0+\log_e e^{-\lambda t}$

$\Rightarrow \log_e A=\log_e C-\lambda t$ (Take $\lambda\ N_0 = C$)

$\Rightarrow \log_e A=-\lambda t+\log_e C$

This is the equation of a straight line having negative slope (= – λ) and positive intercept on $\log_e A$ axis.

15. (c) Charge density is uniform inside and then falls rapidly near the surface of the nucleus.

16. (a) $R=R_0A^{1/3}$; where $R_0=1.2\times10^{-15}m.$

$\Rightarrow \log_e R = \log_e R_0+\frac{1}{3}\log_e A$

This is the equation of a straight line with positive slope.

17. (b) $\left|\frac{dN}{dt}\right|=\lambda N \Rightarrow \left|\frac{dN}{dt}\right|\propto N$

18. (c) Number of atom decayed $N=N_0(1-e^{-\lambda t})$

N will increase with time (t) exponentially.

19. (a) $A_n=\pi r_n^2 \Rightarrow \frac{A_n}{A_1}=\left(\frac{r_n}{r_1}\right)^2=\left(\frac{n}{1}\right)^4$ $(\because r_n\propto n^2)$

Taking $\log_e$ both the side $\log_e\frac{A_n}{A_1}=4\log_e(n)$

Comparing it with $y = mx + c$, graph (4) is correct.

Assertion and Reason

1. (c) In fusion, lighter nuclei are used so, fusion is not possible with ^{35}Cl. Also binding energy of ^{35}Cl is not too small.

2. (a) $^{90}_{38}Sr$ decays to $^{90}_{39}Y$ by the emission of $\beta-$rays. Sr gets absorbed in bones along with calcium.

Reason is also true. $^{90}Sr\xrightarrow{\beta}{}^{90}Y$ which emits $\beta-$rays of very high energy. Sr does not emit $\gamma-$rays. The damage is by the $\beta-$rays only.

3. (b) Neutron is about 0.1 more massive than proton. But the unique thing about the neutron is that while it is heavy, it has no charge (it is neutral). This lack of charge gives it the ability to penetrate matter without interacting as quickly as the beta particles or alpha particles.

4. (b) Bohr postulated that electrons in stationary orbits around the nucleus do not radiate.

This is the one of Bohr's postulate. According to this the moving electrons radiate only when they go from one orbit to the next lower orbit.

5. (c) Nuclear stability depends upon the ratio of neutron to proton. If the n/p ratio is more than the critical value, then a neutron gets converted into a proton forming a β^- particle in the process. $n\rightarrow p+e^-$

The β^- particle (e^-) is emitted from the nucleus in some radioactive transformation. So electrons do not exist in the nucleus but they result in some nuclear transformation.

6. (a) ${}_ZX^A\rightarrow 2({}_2He^4)+2({}_{-1}e^0)+2\gamma+{}_{Z-2}X^{A-8}$

7. (a) Experimentally, it is found that the average radius of a nucleus is given by

$R=R_0A^{1/3}$ where $R_0=1.1\times10^{-15}m=1.1\ fm$

and $A=$ mass number

8. (b)

9. (b) Rutherford confirmed the repulsive force on α-particle due to nucleus varies with distance according to inverse square law and that the positive charges are concentrated at the centre and not distributed throughout the atom.

10. (a) In α-particle scattering experiment, Rutherford found a small number of α-particles which were scattered back through an angle approaching to $180°$. This is possible only if the positive charges are concentrated at the centre or nucleus of the atom.

11. (e) According to classical electromagnetic theory, an accelerated charge continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence they will be losing their energy continuously and the orbital radius will go on decreasing and form spiral and finally the electron will fall on the nucleus.

12. (c) According to postulates of Bohr's atom model, the electron revolve round the nucleus in fixed orbit of definite radii. As long as the electron is in a certain orbits it does not radiate any energy.

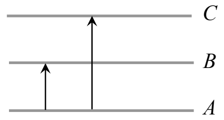
13. (b) Maximum number of photon is given by all the transitions possible $= {}^4C_2 = 6$

Minimum number of transition = 1,

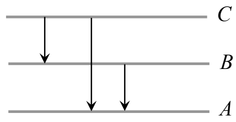
that is directly jump from 4 to 1.

14. (b) When the atom gets appropriate energy from outside, then this electron rises to some higher energy level. Now it can return either directly to the lower energy level or come to the lowest energy level after passing through other lower energy lends, hence all possible transitions take place in the source and many lines are seen in the spectrum.

15. (d) Emission transitions can take place between any higher energy level and any energy level below it while absorption transitions start from the lowest energy level only and may end at any higher energy level. Hence number of absorptions transitions between two given energy levels is always less than the number of emission transitions between same two levels.



Absorption



Emission

16. (a) We knows that an electron is very light particle as compared to an α-particle. Hence electron cannot scatter the α-particle at large angles, according to law of conservation of momentum. On the other hand, mass of nucleus is comparable with the mass of α-particle, hence only the nucleus of atom is responsible for scattering of α-particles.

17. (c) All those elements which are heavier than lead are radioactive. This is because in the nuclei of heavy atoms, besides the nuclear attractive forces, repulsive forces between the protons are also effective and these forces reduce the stability of the nucleus. Hence, the nuclei of heavier elements are being converted into lighter and lighter elements by emission of radioactive radiation. When they are converted into lead, the emission is stopped because the nucleus of lead is stable (or lead is most stable elements in radioactive series).

18. (d) The penetrating power is maximum in case of gamma rays because gamma rays are an electromagnetic radiation of very small wavelength.

19. (b) β-particles, being emitted with very high speed compared to α-particles, pass very little time near the atoms of the medium. So the probability of the atoms being ionised is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth.

20. (b) β-particles are emitted with very high velocity (up to 0.99 *c*). So, according to Einstein's theory of relatively, the mass of a β-particle is much higher compared to is` its rest mass (m_0). The velocity of electrons obtained by other means is very small compared to *c* (Velocity of light). So its mass remains nearly m_0. But β-particle and electron both are similar particles.

21. (c) Radioactivity $= -\frac{dN}{dt} = \lambda N = \frac{0.693N}{T}$

$$= \frac{0.693 \times 10^8}{50} = \frac{0.693 \times 1.2 \times 10^8}{60} = 0.693 \times 2 \times 10^6.$$

Radioactivity is proportional to $1/T_{1/2}$, and not to $T_{1/2}$.

22. (c) Fragments produced in the fission of U^{235} are radioactive. When uranium undergoes fission, barium and krypton are not the only products. Over 100 different isotopes of more than 20 different elements have been detected among fission products. All of these atoms are, however, in the middle of the periodic table, with atomic numbers ranging from 34 to 58. Because the neutron-proton ratio needed for stability in this range is much smaller than that of the original uranium nucleus, the residual nuclei called fission fragments, always have too many neutrons for stability. A few free neutrons are liberated during fission and the fission fragments undergo a series of beta decays (each of which increases *Z* by one and decreases *N* by one) until a stable nucleus is reached. During decay of the fission fragments, an average of 15 *MeV* of additional energy is liberated.

23. (b) Electron capture occurs more often than positron emission in heavy elements. This is because if position emission is energetically allowed, electron capture is necessarily allowed, but the reverse is not true *i.e.* when electron capture is energetically allowed, positron emission is not necessarily allowed.

24. (e) The whole mass of the atom is concentrated at nucleus and $M_{nucleus}$ < (Sum of the masses of nucleous) because, when nucleous combines, some energy is wasted.