

## THE NUCLEUS CHAPTER - 46

1.  $M = Am_p$ ,  $f = M/V$ ,  $m_p = 1.007276 \text{ u}$   
 $R = R_0 A^{1/3} = 1.1 \times 10^{-15} A^{1/3}$ ,  $u = 1.6605402 \times 10^{-27} \text{ kg}$   

$$= \frac{A \times 1.007276 \times 1.6605402 \times 10^{-27}}{4/3 \times 3.14 \times R^3} = 0.300159 \times 10^{18} = 3 \times 10^{17} \text{ kg/m}^3$$
  
 $f$  in CGS = Specific gravity =  $3 \times 10^{14}$ .
2.  $f = \frac{M}{V} \Rightarrow V = \frac{M}{f} = \frac{4 \times 10^{30}}{2.4 \times 10^{17}} = \frac{1}{0.6} \times 10^{13} = \frac{1}{6} \times 10^{14}$   
 $V = 4/3 \pi R^3$   
 $\Rightarrow \frac{1}{6} \times 10^{14} = 4/3 \pi \times R^3 \Rightarrow R^3 = \frac{1}{6} \times \frac{3}{4} \times \frac{1}{\pi} \times 10^{14}$   
 $\Rightarrow R^3 = \frac{1}{8} \times \frac{100}{\pi} \times 10^{12}$   
 $\therefore R = \frac{1}{2} \times 10^4 \times 3.17 = 1.585 \times 10^4 \text{ m} = 15 \text{ km}$ .
3. Let the mass of ' $\alpha$ ' particle be  $xu$ .  
 $\alpha$  particle contains 2 protons and 2 neutrons.  
 $\therefore$  Binding energy =  $(2 \times 1.007825 \text{ u} + 1 \times 1.00866 \text{ u} - xu)C^2 = 28.2 \text{ MeV}$  (given).  
 $\therefore x = 4.0016 \text{ u}$ .
4.  $\text{Li}^7 + p \rightarrow \text{I} + \alpha + E$ ;  $\text{Li}^7 = 7.016 \text{ u}$   
 $\alpha = {}^4\text{He} = 4.0026 \text{ u}$ ;  $p = 1.007276 \text{ u}$   
 $E = \text{Li}^7 + p - 2\alpha = (7.016 + 1.007276) \text{ u} - (2 \times 4.0026) \text{ u} = 0.018076 \text{ u}$   
 $\Rightarrow 0.018076 \times 931 = 16.828 = 16.83 \text{ MeV}$ .
5.  $B = (Zm_p + Nm_n - M)C^2$   
 $Z = 79$ ;  $N = 118$ ;  $m_p = 1.007276 \text{ u}$ ;  $M = 196.96 \text{ u}$ ;  $m_n = 1.008665 \text{ u}$   
 $B = [(79 \times 1.007276 + 118 \times 1.008665) \text{ u} - Mu]c^2$   
 $= 198.597274 \times 931 - 196.96 \times 931 = 1524.302094$   
 so, Binding Energy per nucleon =  $1524.3 / 197 = 7.737$ .
6. a)  $\text{U}^{238} {}_2\text{He}^4 + \text{Th}^{234}$   
 $E = [M_u - (N_{\text{He}} + M_{\text{Th}})]u = 238.0508 - (234.04363 + 4.00260)u = 4.25487 \text{ MeV} = 4.255 \text{ MeV}$ .  
 b)  $E = \text{U}^{238} - [\text{Th}^{234} + 2n'_0 + 2p'_1]$   
 $= \{238.0508 - [234.64363 + 2(1.008665) + 2(1.007276)]\}u$   
 $= 0.024712 \text{ u} = 23.0068 = 23.007 \text{ MeV}$ .
7.  ${}^{223}\text{Ra} = 223.018 \text{ u}$ ;  ${}^{209}\text{Pb} = 208.981 \text{ u}$ ;  ${}^{14}\text{C} = 14.003 \text{ u}$ .  
 ${}^{223}\text{Ra} \rightarrow {}^{209}\text{Pb} + {}^{14}\text{C}$   
 $\Delta m = \text{mass } {}^{223}\text{Ra} - \text{mass } ({}^{209}\text{Pb} + {}^{14}\text{C})$   
 $\Rightarrow = 223.018 - (208.981 + 14.003) = 0.034$ .  
 Energy =  $\Delta M \times u = 0.034 \times 931 = 31.65 \text{ Me}$ .
8.  $E_{Z,N} \rightarrow E_{Z-1,N} + p_1 \Rightarrow E_{Z,N} \rightarrow E_{Z-1,N} + {}^1_1\text{H}$  [As hydrogen has no neutrons but protons only]  
 $\Delta E = (M_{Z-1,N} + N_H - M_{Z,N})c^2$
9.  $E_2N = E_{Z,N-1} + {}^1_0n$ .  
 Energy released = (Initial Mass of nucleus - Final mass of nucleus) $c^2 = (M_{Z,N-1} + M_0 - M_{Z,N})c^2$ .
10.  $\text{P}^{32} \rightarrow \text{S}^{32} + {}^0_1\bar{\nu} + {}^0_1\beta$   
 Energy of antineutrino and  $\beta$ -particle  
 $= (31.974 - 31.972)u = 0.002 \text{ u} = 0.002 \times 931 = 1.862 \text{ MeV} = 1.86$ .
11.  $\text{In} \rightarrow \text{P} + e^-$   
 We know : Half life =  $0.6931 / \lambda$  (Where  $\lambda$  = decay constant).  
 Or  $\lambda = 0.6931 / 14 \times 60 = 8.25 \times 10^{-4} \text{ s}^{-1}$  [As half life = 14 min =  $14 \times 60 \text{ sec}$ ].  
 Energy =  $[M_n - (M_p + M_e)]u = [(M_{\text{nu}} - M_{\text{pu}}) - M_{\text{pe}}]c^2 = [0.00189 \text{ u} - 511 \text{ KeV}/c^2]$   
 $= [1293159 \text{ eV}/c^2 - 511000 \text{ eV}/c^2]c^2 = 782159 \text{ eV} = 782 \text{ KeV}$ .

12.  ${}^{226}_{88}\text{Ra} \rightarrow {}^4_2\alpha + {}^{222}_{86}\text{Rn}$   
 ${}^{19}_8\text{O} \rightarrow {}^{19}_9\text{F} + {}^0_{-1}\beta + {}^0_0\bar{\nu}$   
 ${}^{13}_{25}\text{Al} \rightarrow {}^{25}_{12}\text{MG} + {}^0_{-1}\text{e} + {}^0_0\bar{\nu}$
13.  ${}^{64}\text{Cu} \rightarrow {}^{64}\text{Ni} + \text{e}^- + \nu$   
 Emission of neutrino is along with a positron emission.  
 a) Energy of positron = 0.650 MeV.  
 Energy of Neutrino = 0.650 – KE of given positron = 0.650 – 0.150 = 0.5 MeV = 500 Kev.  
 b) Momentum of Neutrino =  $\frac{500 \times 1.6 \times 10^{-19}}{3 \times 10^8} \times 10^3 \text{ J} = 2.67 \times 10^{-22} \text{ kg m/s.}$
14. a)  ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca} + {}^0_{-1}\text{e} + {}^0_0\bar{\nu}$   
 ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + {}^0_{-1}\text{e} + {}^0_0\bar{\nu}$   
 ${}^{40}_{19}\text{K} + {}^0_{-1}\text{e} \rightarrow {}^{40}_{18}\text{Ar}$   
 ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca} + {}^0_{-1}\text{e} + {}^0_0\bar{\nu}.$   
 b)  $Q = [\text{Mass of reactants} - \text{Mass of products}]c^2$   
 $= [39.964\text{u} - 39.9626\text{u}] = [39.964\text{u} - 39.9626\text{u}]c^2 = (39.964 - 39.9626) 931 \text{ Mev} = 1.3034 \text{ Mev.}$   
 ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + {}^0_{-1}\text{e} + {}^0_0\bar{\nu}$   
 $Q = (39.9640 - 39.9624)\text{uc}^2 = 1.4890 = 1.49 \text{ Mev.}$   
 ${}^{40}_{19}\text{K} + {}^0_{-1}\text{e} \rightarrow {}^{40}_{18}\text{Ar}$   
 $Q_{\text{value}} = (39.964 - 39.9624)\text{uc}^2.$
15.  ${}^6_3\text{Li} + \text{n} \rightarrow {}^7_3\text{Li} ; {}^7_3\text{Li} + \text{r} \rightarrow {}^8_3\text{Li}$   
 ${}^8_3\text{Li} \rightarrow {}^8_4\text{Be} + \text{e}^- + \nu^-$   
 ${}^8_4\text{Be} \rightarrow {}^4_2\text{He} + {}^4_2\text{He}$
16.  ${}^{\text{C}} \rightarrow {}^{\text{B}} + \beta^+ + \nu$   
 mass of C = 11.014u ; mass of B = 11.0093u  
 Energy liberated = (11.014 – 11.0093)u = 29.5127 Mev.  
 For maximum K.E. of the positron energy of  $\nu$  may be assumed as 0.  
 $\therefore$  Maximum K.E. of the positron is 29.5127 Mev.
17. Mass  ${}^{238}\text{Th} = 228.028726 \text{ u} ; {}^{224}\text{Ra} = 224.020196 \text{ u} ; \alpha = {}^4_2\text{He} \rightarrow 4.00260\text{u}$   
 ${}^{238}\text{Th} \rightarrow {}^{224}\text{Ra}^* + \alpha$   
 ${}^{224}\text{Ra}^* \rightarrow {}^{224}\text{Ra} + \nu(217 \text{ Kev})$   
 Now, Mass of  ${}^{224}\text{Ra}^* = 224.020196 \times 931 + 0.217 \text{ Mev} = 208563.0195 \text{ Mev.}$   
 $\text{KE of } \alpha = E({}^{226}\text{Th}) - E({}^{224}\text{Ra}^* + \alpha)$   
 $= 228.028726 \times 931 - [208563.0195 + 4.00260 \times 931] = 5.30383 \text{ Mev} = 5.304 \text{ Mev.}$
18.  ${}^{12}\text{N} \rightarrow {}^{12}\text{C}^* + \text{e}^+ + \nu$   
 ${}^{12}\text{C}^* \rightarrow {}^{12}\text{C} + \nu(4.43 \text{ Mev})$   
 Net reaction :  ${}^{12}\text{N} \rightarrow {}^{12}\text{C} + \text{e}^+ + \nu + \nu(4.43 \text{ Mev})$   
 Energy of  $(\text{e}^+ + \nu) = N^{12} - (C^{12} + \nu)$   
 $= 12.018613\text{u} - (12)\text{u} - 4.43 = 0.018613 \text{ u} - 4.43 = 17.328 - 4.43 = 12.89 \text{ Mev.}$   
 Maximum energy of electron (assuming 0 energy for  $\nu$ ) = 12.89 Mev.
19. a)  $t_{1/2} = 0.693 / \lambda$  [ $\lambda \rightarrow$  Decay constant]  
 $\Rightarrow t_{1/2} = 3820 \text{ sec} = 64 \text{ min.}$   
 b) Average life =  $t_{1/2} / 0.693 = 92 \text{ min.}$   
 c)  $0.75 = 1 \text{ e}^{-\lambda t} \Rightarrow \ln 0.75 = -\lambda t \Rightarrow t = \ln 0.75 / -0.00018 = 1598.23 \text{ sec.}$
20. a) 198 grams of Ag contains  $\rightarrow N_0$  atoms.  
 $1 \mu\text{g of Ag contains} \rightarrow N_0/198 \times 1 \mu\text{g} = \frac{6 \times 10^{23} \times 1 \times 10^{-6}}{198} \text{ atoms}$

- Activity =  $\lambda N = \frac{0.693}{t_{1/2}} \times N = \frac{0.693 \times 6 \times 10^{17}}{198 \times 2.7}$  disintegrations/day.
- $= \frac{0.693 \times 6 \times 10^{17}}{198 \times 2.7 \times 3600 \times 24}$  disintegration/sec =  $\frac{0.693 \times 6 \times 10^{17}}{198 \times 2.7 \times 36 \times 24 \times 3.7 \times 10^{10}}$  curie = 0.244 Curie.
- b)  $A = \frac{A_0}{2^{t/t_{1/2}}} = \frac{0.244}{2 \times \frac{7}{2.7}} = 0.0405 = 0.040$  Curie.
21.  $t_{1/2} = 8.0$  days ;  $A_0 = 20 \mu\text{Ci}$
- a)  $t = 4.0$  days ;  $\lambda = 0.693/8$
- $A = A_0 e^{-\lambda t} = 20 \times 10^{-6} \times e^{-(0.693/8) \times 4} = 1.41 \times 10^{-5} \text{ Ci} = 14 \mu\text{Ci}$
- b)  $\lambda = \frac{0.693}{8 \times 24 \times 3600} = 1.0026 \times 10^{-6}.$
22.  $\lambda = 4.9 \times 10^{-18} \text{ s}^{-1}$
- a) Avg. life of  $^{238}\text{U} = \frac{1}{\lambda} = \frac{1}{4.9 \times 10^{-18}} = \frac{1}{4.9} \times 10^{-18} \text{ sec.}$
- $= 6.47 \times 10^3 \text{ years.}$
- b) Half life of uranium =  $\frac{0.693}{\lambda} = \frac{0.693}{4.9 \times 10^{-18}} = 4.5 \times 10^9 \text{ years.}$
- c)  $A = \frac{A_0}{2^{t/t_{1/2}}} \Rightarrow \frac{A_0}{2^{t/t_{1/2}}} = \frac{A_0}{A} = 2^{t/t_{1/2}} = 2^2 = 4.$
23.  $A = 200, A_0 = 500, t = 50 \text{ min}$
- $A = A_0 e^{-\lambda t}$  or  $200 = 500 \times e^{-50 \times 60 \times \lambda}$
- $\Rightarrow \lambda = 3.05 \times 10^{-4} \text{ s.}$
- b)  $t_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{0.000305} = 2272.13 \text{ sec} = 38 \text{ min.}$
24.  $A_0 = 4 \times 10^5 \text{ disintegration / sec}$
- $A' = 1 \times 10^6 \text{ dis/sec ; } t = 20 \text{ hours.}$
- $A' = \frac{A_0}{2^{t/t_{1/2}}} \Rightarrow 2^{t/t_{1/2}} = \frac{A_0}{A'} \Rightarrow 2^{t/t_{1/2}} = 4$
- $\Rightarrow t/t_{1/2} = 2 \Rightarrow t^{1/2} = t/2 = 20 \text{ hours} / 2 = 10 \text{ hours.}$
- $A'' = \frac{A_0}{2^{t/t_{1/2}}} \Rightarrow A'' = \frac{4 \times 10^5}{2^{100/10}} = 0.00390625 \times 10^6 = 3.9 \times 10^3 \text{ disintegrations/sec.}$
25.  $t_{1/2} = 1602 \text{ Y ; Ra} = 226 \text{ g/mole ; Cl} = 35.5 \text{ g/mole.}$
- 1 mole  $\text{RaCl}_2 = 226 + 71 = 297 \text{ g}$
- 297g = 1 mole of Ra.
- $0.1 \text{ g} = \frac{1}{297} \times 0.1 \text{ mole of Ra} = \frac{0.1 \times 6.023 \times 10^{23}}{297} = 0.02027 \times 10^{22}$
- $\lambda = 0.693 / t_{1/2} = 1.371 \times 10^{-11}.$
- Activity =  $\lambda N = 1.371 \times 10^{-11} \times 0.02027 \times 10^{22} = 2.779 \times 10^9 = 2.8 \times 10^9 \text{ disintegrations/second.}$
26.  $t_{1/2} = 10 \text{ hours, } A_0 = 1 \text{ ci}$
- Activity after 9 hours =  $A_0 e^{-\lambda t} = 1 \times e^{\frac{-0.693}{10} \times 9} = 0.5359 = 0.536 \text{ Ci.}$
- No. of atoms left after 9<sup>th</sup> hour,  $A_9 = \lambda N_9$
- $\Rightarrow N_9 = \frac{A_9}{\lambda} = \frac{0.536 \times 10 \times 3.7 \times 10^{10} \times 3600}{0.693} = 28.6176 \times 10^{10} \times 3600 = 103.023 \times 10^{13}.$
- Activity after 10 hours =  $A_0 e^{-\lambda t} = 1 \times e^{\frac{-0.693}{10} \times 10} = 0.5 \text{ Ci.}$
- No. of atoms left after 10<sup>th</sup> hour
- $A_{10} = \lambda N_{10}$

$$\Rightarrow N_{10} = \frac{A_{10}}{\lambda} = \frac{0.5 \times 3.7 \times 10^{10} \times 3600}{0.693/10} = 26.37 \times 10^{10} \times 3600 = 96.103 \times 10^{13}.$$

$$\text{No. of disintegrations} = (103.023 - 96.103) \times 10^{13} = 6.92 \times 10^{13}.$$

27.  $t_{1/2} = 14.3$  days ;  $t = 30$  days = 1 month

As, the selling rate is decided by the activity, hence  $A_0 = 800$  disintegration/sec.

$$\text{We know, } A = A_0 e^{-\lambda t} \quad [\lambda = 0.693/14.3]$$

$$A = 800 \times 0.233669 = 186.935 = 187 \text{ rupees.}$$

28. According to the question, the emission rate of  $\gamma$  rays will drop to half when the  $\beta^+$  decays to half of its original amount. And for this the sample would take 270 days.

$\therefore$  The required time is 270 days.

29. a)  $P \rightarrow n + e^+ + \nu$  Hence it is a  $\beta^+$  decay.

b) Let the total no. of atoms be  $100 N_0$ .

	Carbon	Boron
Initially	$90 N_0$	$10 N_0$
Finally	$10 N_0$	$90 N_0$

$$\text{Now, } 10 N_0 = 90 N_0 e^{-\lambda t} \Rightarrow 1/9 = e^{\frac{-0.693}{20.3} \times t} \quad [\text{because } t_{1/2} = 20.3 \text{ min}]$$

$$\Rightarrow \ln \frac{1}{9} = \frac{-0.693}{20.3} t \Rightarrow t = \frac{2.1972 \times 20.3}{0.693} = 64.36 = 64 \text{ min.}$$

30.  $N = 4 \times 10^{23}$ ;  $t_{1/2} = 12.3$  years.

$$\text{a) Activity} = \frac{dN}{dt} = \lambda n = \frac{0.693}{t_{1/2}} N = \frac{0.693}{12.3} \times 4 \times 10^{23} \text{ dis/year.}$$

$$= 7.146 \times 10^{14} \text{ dis/sec.}$$

$$\text{b) } \frac{dN}{dt} = 7.146 \times 10^{14}$$

$$\text{No. of decays in next 10 hours} = 7.146 \times 10^{14} \times 10 \times 3600 = 257.256 \times 10^{17} = 2.57 \times 10^{19}.$$

$$\text{c) } N = N_0 e^{-\lambda t} = 4 \times 10^{23} \times e^{\frac{-0.693}{12.3} \times 6.16} = 2.82 \times 10^{23} = \text{No. of atoms remained}$$

$$\text{No. of atoms disintegrated} = (4 - 2.82) \times 10^{23} = 1.18 \times 10^{23}.$$

31. Counts received per  $\text{cm}^2 = 50000$  Counts/sec.

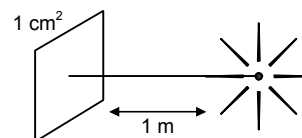
$$N = N_0 \text{ of active nucleic} = 6 \times 10^{16}$$

$$\text{Total counts radiated from the source} = \text{Total surface area} \times 50000 \text{ counts/cm}^2$$

$$= 4 \times 3.14 \times 1 \times 10^4 \times 5 \times 10^4 = 6.28 \times 10^9 \text{ Counts} = dN/dt$$

$$\text{We know, } \frac{dN}{dt} = \lambda N$$

$$\text{Or } \lambda = \frac{6.28 \times 10^9}{6 \times 10^{16}} = 1.0467 \times 10^{-7} = 1.05 \times 10^{-7} \text{ s}^{-1}.$$



32. Half life period can be a single for all the process. It is the time taken for  $1/2$  of the uranium to convert to lead.

$$\text{No. of atoms of } U^{238} = \frac{6 \times 10^{23} \times 2 \times 10^{-3}}{238} = \frac{12}{238} \times 10^{20} = 0.05042 \times 10^{20}$$

$$\text{No. of atoms in Pb} = \frac{6 \times 10^{23} \times 0.6 \times 10^{-3}}{206} = \frac{3.6}{206} \times 10^{20}$$

$$\text{Initially total no. of uranium atoms} = \left( \frac{12}{238} + \frac{3.6}{206} \right) \times 10^{20} = 0.06789$$

$$N = N_0 e^{-\lambda t} \Rightarrow N = N_0 e^{\frac{-0.693}{t/t_{1/2}}} \Rightarrow 0.05042 = 0.06789 e^{\frac{-0.693}{4.47 \times 10^9}}$$

$$\Rightarrow \log \left( \frac{0.05042}{0.06789} \right) = \frac{-0.693t}{4.47 \times 10^9}$$

$$\Rightarrow t = 1.92 \times 10^9 \text{ years.}$$

33.  $A_0 = 15.3$  ;  $A = 12.3$  ;  $t_{1/2} = 5730$  year

$$\lambda = \frac{0.6931}{T_{1/2}} = \frac{0.6931}{5730} \text{ yr}^{-1}$$

Let the time passed be  $t$ ,

$$\text{We know } A = A_0 e^{-\lambda t} = \frac{0.6931}{5730} \times t \Rightarrow 12.3 = 15.3 \times e^{-\lambda t}$$

$$\Rightarrow t = 1804.3 \text{ years.}$$

34. The activity when the bottle was manufactured =  $A_0$

$$\text{Activity after 8 years} = A_0 e^{-\frac{0.693}{12.5} \times 8}$$

Let the time of the mountaineering =  $t$  years from the present

$$A = A_0 e^{-\frac{0.693}{12.5} \times t} ; A = \text{Activity of the bottle found on the mountain.}$$

$$A = (\text{Activity of the bottle manufactured 8 years before}) \times 1.5\%$$

$$\Rightarrow A_0 e^{-\frac{0.693}{12.5} \times t} = A_0 e^{-\frac{0.693}{12.5} \times 8} \times 0.015$$

$$\Rightarrow \frac{-0.693}{12.5} t = \frac{-0.693 \times 8}{12.5} + \ln[0.015]$$

$$\Rightarrow 0.05544 t = 0.44352 + 4.1997 \Rightarrow t = 83.75 \text{ years.}$$

35. a) Here we should take  $R_0$  at time is  $t_0 = 30 \times 10^9 \text{ s}^{-1}$

$$\text{i) } \ln(R_0/R_1) = \ln\left(\frac{30 \times 10^9}{30 \times 10^9}\right) = 0$$

$$\text{ii) } \ln(R_0/R_2) = \ln\left(\frac{30 \times 10^9}{16 \times 10^9}\right) = 0.63$$

$$\text{iii) } \ln(R_0/R_3) = \ln\left(\frac{30 \times 10^9}{8 \times 10^9}\right) = 1.35$$

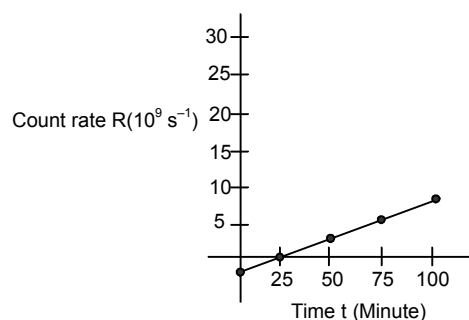
$$\text{iv) } \ln(R_0/R_4) = \ln\left(\frac{30 \times 10^9}{3.8 \times 10^9}\right) = 2.06$$

$$\text{v) } \ln(R_0/R_5) = \ln\left(\frac{30 \times 10^9}{2 \times 10^9}\right) = 2.7$$

$$\text{b) } \therefore \text{ The decay constant } \lambda = 0.028 \text{ min}^{-1}$$

$$\text{c) } \therefore \text{ The half life period} = t_{1/2}.$$

$$t_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{0.028} = 25 \text{ min.}$$



36. Given : Half life period  $t_{1/2} = 1.30 \times 10^9$  year ,  $A = 160 \text{ count/s} = 1.30 \times 10^9 \times 365 \times 86400$

$$\therefore A = \lambda N \Rightarrow 160 = \frac{0.693}{t_{1/2}} N$$

$$\Rightarrow N = \frac{160 \times 1.30 \times 365 \times 86400 \times 10^9}{0.693} = 9.5 \times 10^{18}$$

$$\therefore 6.023 \times 10^{23} \text{ No. of present in 40 grams.}$$

$$6.023 \times 10^{23} = 40 \text{ g} \Rightarrow 1 = \frac{40}{6.023 \times 10^{23}}$$

$$\therefore 9.5 \times 10^{18} \text{ present in} = \frac{40 \times 9.5 \times 10^{18}}{6.023 \times 10^{23}} = 6.309 \times 10^{-4} = 0.00063.$$

$$\therefore \text{ The relative abundance at 40 k in natural potassium} = (2 \times 0.00063 \times 100)\% = 0.12\%.$$

37. a)  $P + e \rightarrow n + \nu$  neutrino [ $a \rightarrow 4.95 \times 10^7 \text{ s}^{-1/2}$ ;  $b \rightarrow 1$ ]  
 b)  $\sqrt{f} = a(z - b)$   
 $\Rightarrow \sqrt{c/\lambda} = 4.95 \times 10^7 (79 - 1) = 4.95 \times 10^7 \times 78 \Rightarrow C/\lambda = (4.95 \times 78)^2 \times 10^{14}$   
 $\Rightarrow \lambda = \frac{3 \times 10^8}{14903.2 \times 10^{14}} = 2 \times 10^{-5} \times 10^{-6} = 2 \times 10^{-4} \text{ m} = 20 \text{ pm}.$
38. Given : Half life period =  $t_{1/2}$ , Rate of radio active decay =  $\frac{dN}{dt} = R \Rightarrow R = \frac{dN}{dt}$   
 Given after time  $t \gg t_{1/2}$ , the number of active nuclei will become constant.  
 i.e.  $(dN/dt)_{\text{present}} = R = (dN/dt)_{\text{decay}}$   
 $\therefore R = (dN/dt)_{\text{decay}}$   
 $\Rightarrow R = \lambda N$  [where,  $\lambda$  = Radioactive decay constant,  $N$  = constant number]  
 $\Rightarrow R = \frac{0.693}{t_{1/2}} (N) \Rightarrow R t_{1/2} = 0.693 N \Rightarrow N = \frac{R t_{1/2}}{0.693}.$
39. Let  $N_0$  = No. of radioactive particle present at time  $t = 0$   
 $N$  = No. of radio active particle present at time  $t$ .  
 $\therefore N = N_0 e^{-\lambda t}$  [ $\lambda$  - Radioactive decay constant]  
 $\therefore$  The no. of particles decay =  $N_0 - N = N_0 - N_0 e^{-\lambda t} = N_0 (1 - e^{-\lambda t})$   
 We know,  $A_0 = \lambda N_0$ ;  $R = \lambda N_0$ ;  $N_0 = R/\lambda$   
 From the above equation  
 $N = N_0 (1 - e^{-\lambda t}) = \frac{R}{\lambda} (1 - e^{-\lambda t})$  (substituting the value of  $N_0$ )
40.  $n = 1 \text{ mole} = 6 \times 10^{23}$  atoms,  $t_{1/2} = 14.3 \text{ days}$   
 $t = 70 \text{ hours}$ ,  $dN/dt$  in root after time  $t = \lambda N$   
 $N = N_0 e^{-\lambda t} = 6 \times 10^{23} \times e^{\frac{-0.693 \times 70}{14.3 \times 24}} = 6 \times 10^{23} \times 0.868 = 5.209 \times 10^{23}.$   
 $5.209 \times 10^{23} \times \frac{-0.693}{14.3 \times 24} = \frac{0.0105 \times 10^{23}}{3600} \text{ dis/hour}.$   
 $= 2.9 \times 10^{-6} \times 10^{23} \text{ dis/sec} = 2.9 \times 10^{17} \text{ dis/sec}.$   
 Fraction of activity transmitted =  $\left( \frac{1 \mu\text{Ci}}{2.9 \times 10^{17}} \right) \times 100\%$   
 $\Rightarrow \left( \frac{1 \times 3.7 \times 10^8}{2.9 \times 10^{17}} \times 100 \right) \% = 1.275 \times 10^{-11} \%$ .
41.  $V = 125 \text{ cm}^3 = 0.125 \text{ L}$ ,  $P = 500 \text{ K pa} = 5 \text{ atm}.$   
 $T = 300 \text{ K}$ ,  $t_{1/2} = 12.3 \text{ years} = 3.82 \times 10^8 \text{ sec}.$  Activity =  $\lambda \times N$   
 $N = n \times 6.023 \times 10^{23} = \frac{5 \times 0.125}{8.2 \times 10^{-2} \times 3 \times 10^2} \times 6.023 \times 10^{23} = 1.5 \times 10^{22} \text{ atoms}.$   
 $\lambda = \frac{0.693}{3.82 \times 10^8} = 0.1814 \times 10^{-8} = 1.81 \times 10^{-9} \text{ s}^{-1}$   
 Activity =  $\lambda N = 1.81 \times 10^{-9} \times 1.5 \times 10^{22} = 2.7 \times 10^3 \text{ disintegration/sec}$   
 $= \frac{2.7 \times 10^{13}}{3.7 \times 10^{10}} \text{ Ci} = 729 \text{ Ci}.$
42.  ${}_{83}^{212}\text{Bi} \rightarrow {}_{81}^{208}\text{Tl} + {}_2^4\text{He}(\alpha)$   
 ${}_{83}^{212}\text{Bi} \rightarrow {}_{84}^{212}\text{Po} + e^-$   
 $t_{1/2} = 1 \text{ h}.$  Time elapsed = 1 hour  
 at  $t = 0$   $\text{Bi}^{212}$  Present = 1 g  
 $\therefore$  at  $t = 1$   $\text{Bi}^{212}$  Present = 0.5 g  
 Probability  $\alpha$ -decay and  $\beta$ -decay are in ratio 7/13.  
 $\therefore$  Tl remained = 0.175 g  
 $\therefore$   $\text{Po}$  remained = 0.325 g

43. Activities of sample containing  $^{108}\text{Ag}$  and  $^{110}\text{Ag}$  isotopes =  $8.0 \times 10^8$  disintegration/sec.

a) Here we take  $A = 8 \times 10^8$  dis./sec

$$\therefore \text{i) } \ln(A_1/A_{01}) = \ln(11.794/8) = 0.389$$

$$\text{ii) } \ln(A_2/A_{02}) = \ln(9.1680/8) = 0.1362$$

$$\text{iii) } \ln(A_3/A_{03}) = \ln(7.4492/8) = -0.072$$

$$\text{iv) } \ln(A_4/A_{04}) = \ln(6.2684/8) = -0.244$$

$$\text{v) } \ln(5.4115/8) = -0.391$$

$$\text{vi) } \ln(3.0828/8) = -0.954$$

$$\text{vii) } \ln(1.8899/8) = -1.443$$

$$\text{viii) } \ln(1.167/8) = -1.93$$

$$\text{ix) } \ln(0.7212/8) = -2.406$$

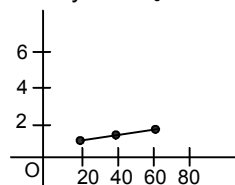
b) The half life of  $^{110}\text{Ag}$  from this part of the plot is 24.4 s.

c) Half life of  $^{110}\text{Ag} = 24.4$  s.

$$\therefore \text{decay constant } \lambda = 0.693/24.4 = 0.0284 \Rightarrow t = 50 \text{ sec,}$$

$$\text{The activity } A = A_0 e^{-\lambda t} = 8 \times 10^8 \times e^{-0.0284 \times 50} = 1.93 \times 10^8$$

d)



e) The half life period of  $^{108}\text{Ag}$  from the graph is 144 s.

44.  $t_{1/2} = 24$  h

$$\therefore t_{1/2} = \frac{t_1 t_2}{t_1 + t_2} = \frac{24 \times 6}{24 + 6} = 4.8 \text{ h.}$$

$$A_0 = 6 \text{ rci ; } A = 3 \text{ rci}$$

$$\therefore A = \frac{A_0}{2^{t/t_{1/2}}} \Rightarrow 3 \text{ rci} = \frac{6 \text{ rci}}{2^{t/4.8\text{h}}} \Rightarrow \frac{t}{24.8\text{h}} = 2 \Rightarrow t = 4.8 \text{ h.}$$

45.  $Q = qe^{-t/CR}$  ;  $A = A_0 e^{-\lambda t}$

$$\frac{\text{Energy}}{\text{Activity}} = \frac{1q^2 \times e^{-2t/CR}}{2CA_0 e^{-\lambda t}}$$

Since the term is independent of time, so their coefficients can be equated,

$$\text{So, } \frac{2t}{CR} = \lambda t \quad \text{or, } \lambda = \frac{2}{CR} \quad \text{or, } \frac{1}{\tau} = \frac{2}{CR} \quad \text{or, } R = 2 \frac{\tau}{C} \text{ (Proved)}$$

46.  $R = 100 \Omega$  ;  $L = 100 \text{ mH}$

$$\text{After time } t, i = i_0 (1 - e^{-t/LR}) \quad N = N_0 (e^{-\lambda t})$$

$$\frac{i}{N} = \frac{i_0 (1 - e^{-tR/L})}{N_0 e^{-\lambda t}} \quad i/N \text{ is constant i.e. independent of time.}$$

$$\text{Coefficients of } t \text{ are equal } -R/L = -\lambda \Rightarrow R/L = 0.693/t_{1/2}$$

$$= t_{1/2} = 0.693 \times 10^{-3} = 6.93 \times 10^{-4} \text{ sec.}$$

47. 1 g of 'I' contain 0.007 g  $\text{U}^{235}$  So, 235 g contains  $6.023 \times 10^{23}$  atoms.

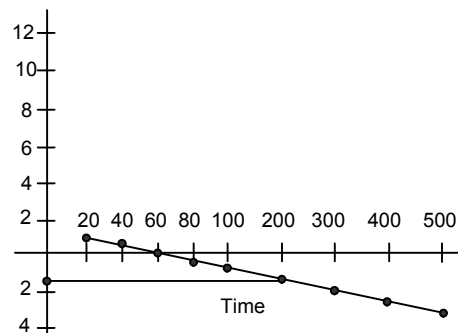
$$\text{So, 0.7 g contains } \frac{6.023 \times 10^{23}}{235} \times 0.007 \text{ atom}$$

$$1 \text{ atom given } 200 \text{ Mev. So, 0.7 g contains } \frac{6.023 \times 10^{23} \times 0.007 \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{235} \text{ J} = 5.74 \times 10^{-8} \text{ J.}$$

48. Let  $n$  atoms disintegrate per second

$$\text{Total energy emitted/sec} = (n \times 200 \times 10^6 \times 1.6 \times 10^{-19}) \text{ J} = \text{Power}$$

$$300 \text{ MW} = 300 \times 10^6 \text{ Watt} = \text{Power}$$



$$300 \times 10^6 = n \times 200 \times 10^6 \times 1.6 \times 10^{-19}$$

$$\Rightarrow n = \frac{3}{2 \times 1.6} \times 10^{19} = \frac{3}{3.2} \times 10^{19}$$

$6 \times 10^{23}$  atoms are present in 238 grams

$$\frac{3}{3.2} \times 10^{19} \text{ atoms are present in } \frac{238 \times 3 \times 10^{19}}{6 \times 10^{23} \times 3.2} = 3.7 \times 10^{-4} \text{ g} = 3.7 \text{ mg.}$$

49. a) Energy radiated per fission =  $2 \times 10^8$  ev

$$\text{Usable energy} = 2 \times 10^8 \times 25/100 = 5 \times 10^7 \text{ ev} = 5 \times 1.6 \times 10^{-12}$$

$$\text{Total energy needed} = 300 \times 10^8 = 3 \times 10^8 \text{ J/s}$$

$$\text{No. of fission per second} = \frac{3 \times 10^8}{5 \times 1.6 \times 10^{-12}} = 0.375 \times 10^{20}$$

$$\text{No. of fission per day} = 0.375 \times 10^{20} \times 3600 \times 24 = 3.24 \times 10^{24} \text{ fissions.}$$

- b) From 'a' No. of atoms disintegrated per day =  $3.24 \times 10^{24}$

We have,  $6.023 \times 10^{23}$  atoms for 235 g

$$\text{for } 3.24 \times 10^{24} \text{ atom} = \frac{235}{6.023 \times 10^{23}} \times 3.24 \times 10^{24} \text{ g} = 1264 \text{ g/day} = 1.264 \text{ kg/day.}$$

50. a)  ${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^3_1\text{H} + {}^1_1\text{H}$

$$Q \text{ value} = 2M({}^2_1\text{H}) = [M({}^3_1\text{H}) + M({}^1_1\text{H})]$$

$$= [2 \times 2.014102 - (3.016049 + 1.007825)]u = 4.0275 \text{ Mev} = 4.05 \text{ Mev.}$$

- b)  ${}^2_1\text{H} + {}^2_1\text{H} \rightarrow {}^3_2\text{He} + n$

$$Q \text{ value} = 2[M({}^2_1\text{H}) - M({}^3_2\text{He}) + M_n]$$

$$= [2 \times 2.014102 - (3.016049 + 1.008665)]u = 3.26 \text{ Mev} = 3.25 \text{ Mev.}$$

- c)  ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + n$

$$Q \text{ value} = [M({}^2_1\text{H}) + M({}^3_1\text{H}) - M({}^4_2\text{He}) + M_n]$$

$$= (2.014102 + 3.016049) - (4.002603 + 1.008665)]u = 17.58 \text{ Mev} = 17.57 \text{ Mev.}$$

$$51. \text{ PE} = \frac{Kq_1q_2}{r} = \frac{9 \times 10^9 \times (2 \times 1.6 \times 10^{-19})^2}{r} \quad \dots(1)$$

$$1.5 \text{ KT} = 1.5 \times 1.38 \times 10^{-23} \times T \quad \dots(2)$$

$$\text{Equating (1) and (2)} \quad 1.5 \times 1.38 \times 10^{-23} \times T = \frac{9 \times 10^9 \times 10.24 \times 10^{-38}}{2 \times 10^{-15}}$$

$$\Rightarrow T = \frac{9 \times 10^9 \times 10.24 \times 10^{-38}}{2 \times 10^{-15} \times 1.5 \times 1.38 \times 10^{-23}} = 22.26087 \times 10^9 \text{ K} = 2.23 \times 10^{10} \text{ K.}$$

52.  ${}^4_1\text{H} + {}^4_1\text{H} \rightarrow {}^8_2\text{Be}$

$$M({}^4_1\text{H}) \rightarrow 4.0026 \text{ u}$$

$$M({}^8_2\text{Be}) \rightarrow 8.0053 \text{ u}$$

$$Q \text{ value} = [2 M({}^4_1\text{H}) - M({}^8_2\text{Be})] = (2 \times 4.0026 - 8.0053) \text{ u}$$

$$= -0.0001 \text{ u} = -0.0931 \text{ Mev} = -93.1 \text{ Kev.}$$

53. In 18 g of  $N_0$  of molecule =  $6.023 \times 10^{23}$

$$\text{In 100 g of } N_0 \text{ of molecule} = \frac{6.023 \times 10^{26}}{18} = 3.346 \times 10^{25}$$

$$\therefore \% \text{ of Deuterium} = 3.346 \times 10^{26} \times 99.985$$

$$\text{Energy of Deuterium} = 30.4486 \times 10^{25} = (4.028204 - 3.016044) \times 93$$

$$= 942.32 \text{ ev} = 1507 \times 10^5 \text{ J} = 1507 \text{ mJ}$$

