TOPIC : NUCLEAR PHYSICS
EXERCISE # 1

SECTION (A)

1. For hydrogen nucleus mass number is equal to atomic number, else mass number is more than atomic number.

2. Radius of O_5^{189} = $r_0 A_{O5}^{1/3}$

Radius of that nucleus = $\frac{1}{3} \times r_0 \left(A_{O_5}\right)^{\frac{1}{3}} = r_0 \left(\frac{189}{27}\right)^{\frac{1}{3}} = r_0\, 7^{1/3}$

∴ **A for that nucleus = 7**

3. Nuclear density is constant hence, mass ∝ volume or $m \propto V$

4. $R = R_0\, A^{1/3}$

$\ln \frac{R}{R_0} = \frac{1}{3} \ln A$

It is similar to y = mx.

5. 1 amu = 931 Me V

6. Number of neutron = M – Z

7. Weight of positron is equal to weigth of electron.

9. Mass energy equivalence relation $E = mc^2$ was given by Einstein.

10. $m = \frac{4}{3}\pi r^3 d$

$r \propto (m)^{1/3}$

$\frac{r_1}{r_2} = \left(\frac{135}{5}\right)^{1/3} = (27)^{1/3} = 3.$

11. If R is the radius of the nucleus, the corresponding volume $\frac{4}{3}\pi R^3$ has been found to be proportional to A.

This relationship is expressed in inverse from as

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

The value of R_0 is 1.2×10^{-15} m, e.e., 1.2 fm

Therefore, $\frac{R_{Al}}{R_{Te}} = \frac{R_0 (A_{Al})^{1/3}}{R_0 (A_{Te})^{1/3}}$

$\frac{R_{Al}}{R_{Te}} = \frac{(A_{Al})^{1/3}}{(A_{Te})^{1/3}} = \frac{(27)^{1/3}}{(125)^{1/3}} = \frac{3}{5}$ or $R_{Te} = \frac{5}{3} \times R_{Al} = \frac{5}{3} \times 3.6 = 6$ fm

12. Density of nuclear matter is independent of mass number, so the required ratio is 1 : 1,

Alternative :

$A_1 : A_2 = 1 : 3$

Their radi will be in the ratio

$R_0\, A_1^{1/3} : R_0\, A_2^{1/3} = 1 : 3^{1/3}$

Density = $\frac{A}{\frac{4}{3}\pi R^3}$ ∴ $\rho_{A1} : \rho_{A2} = \frac{1}{\frac{4}{3}\pi R_0^3 . 1^3} : \frac{3}{\frac{4}{3}\pi R_0^3 (3^{1/3})^3} = 1 : 1$

Their nuclear densities will be the same.

13. Law of conservation of momentum gives

$m_1v_1 = m_2v_2 \Rightarrow \frac{m_1}{m_2} = \frac{v_2}{v_1}$

But m = $\frac{4}{3}\pi r^3 \rho$

or $m \propto r^3$

$\therefore \frac{m_1}{m_2} = \frac{r_1^3}{r_2^3} = \frac{v_2}{v_1} \Rightarrow \frac{r_1}{r_2} = \left(\frac{1}{2}\right)^{1/3}$

$\therefore r_1 : r_2 = 1 : 2^{1/3}$

14. R R₀ (1)$^{1/3}$

$$\frac{R_{Al}}{R_{Te}} = \frac{R_0(A_{Al})^{1/3}}{R_0(A_{Te})^{1/3}} = \frac{3}{5}$$

$\therefore R_{Te} = \frac{5}{3} \times 3.6$

$R_{Te} = 6$ Fermi

16. Order of 1 fermi 1 fermi

17. $\rho = \frac{Am_p}{\frac{4}{3}\pi R^3} = \frac{Am_p}{\frac{4}{3}\pi(R_0A^{1/3})^3} = \frac{3m_p}{4\pi R_0^3} = \frac{3 \times 1.67 \times 10^{-27}}{4 \times 3.14 \times (1.1 \times 10^{-15})^3} = 3 \times 10^{17}$ kg/m^3

19. Out of α-rays, β-rays, γ-rays and X-rays, penetrating power is minimum for α-rays and maximum for γ-rays.

SECTION (B)

1. Nuclear force do not exist when seperation is greater than 1 fermi.

2. Nucleus is stable but nuetrons and protons cannot be stable when seperated. So binding energy of nucleus is greater. So mass of nucleus is smaller.

3. (4) the binding energy per nucleon in a nucleus varies in a way that depends on the actual value of A.

4. (1), (2) & (3) are correct descrition of binding energy of a nucleus.

5. Q = (2BE$_{He}$ – BE$_{Li}$)
= (2 × 7.06 × 4 – 5.60 × 7) Mev **= 17.28 Mev.**

6. Nuclear force is charge independent

7. Energy released = $E_{Q^{2n}} - 2E_{P^n}$ = y – 2x = –(2x – y)

8. for $_ZX^A$, Z = (1 + 1 + 1) – 1 = 2 and A = (1 + 1 + 2) – 0 = 4

9. Neutrino is produced in β^+ emission.

13. Binding energy

BE = (M$_{nucleus}$ – M$_{nucleous}$) c^2

= (M$_0$ – 8M$_p$ – 9 M$_n$) c^2

18. EP = (8 × 7.06 – 7 × 5.60) MeV = 17.28 MeV

19. Nuclear binding energy = (mass of nucleus – mass of nucleons) C_2 = (M_o – 8M_P – 9M_N)C_2

20. It is order of MeV

21. As a proton is lighter than a neutron, proton can not be converted into neutron without providing energy from outside. Reverse is possible. The weak interaction force is responsible in both the processes (i) conversion of p to n and (ii) conversion of n to p.

22. We know that whenever there is fusion or fission or nucleoids and nuclei. Some mass is lest (mass defect) which converts into energy. So, net mass of products is slightly less than that of initial substances.

23. Process in which resultant nuclei with greater BEPN will release energy. So,
R → 2s will consume energy
P→ Q + S will consume energy
P → 2R will release energy
Q → R + S will consume energy

24. Energy of each γ- ray photon = E = mc_2 = 0.0016 × 931.5 MeV = 1.5 MeV

25. In beta decay, atomic number increases by 1 whereas the mass number remains the same. Therefore, following equation can be possible

$_{6429}Cu \longrightarrow {}_{6430}Zn + {}_{-1}e_0$

26. Energy is released in a process when total binding energy of the nucleus (= binding energy per nucleon x number of nucleons)is increased or we can say, when total binding energy of products is more than the reactants. By calculation we can see the only in case of option (C), this happens.
Given W → 2Y
Binding energy of reactants = 120 × 7.5 = 900 MeV
and binding energy of products = 2 (60 × 8.5) = 1020 MeV > 900 MeV

SECTION (C)

1. $^4_2He + {}^{14}_7N \rightarrow {}^{17}_8O + {}^1_1H$

2. In β_- emission, An antineutrino is produced
$n \rightarrow p + e_- + \overline{\nu}$

3. Specific activity of 1 gm radium is 1 Curie.

4. (1) When a β_--particle is emitted from a nucleus, no. of proton increases and number of neutron decreases. Hence the neutron-proton ratio is decreased

8. (1) beta rays are electron beam i.e., cathode rays
(2) gamma rays are e.m. wave not neutrons.
(3) alpha particle are doubly ionized helium atoms
(4) neutrons are slightly heavier than protons
so (2), (3) and (4) are wrong options

10. According to question reaction may be expressed as $_2He_4 + {}_7N_{14} \longrightarrow {}_8O_{17} + {}_1X_1$ (proton)
So, particle X is proton ($_1H_1$)

11. When α-particle is emitted, mass number decreases by 4 units and atomic number by 2 units. When β-particle is is emitted, mass number remains same while atomic number increases by 1 unit. Let a – α-particle and b – β-particles be emitted. Then from conservation of mass unmber

$234 = 222 + 4a$

$\Rightarrow \quad a = \frac{234-222}{4} = 3$

From conservation of atomic number (charge)

$92 = 87 + 2a - b \times 1$

or $\quad 92 - 87 = 2 \times 3 - b$

$\Rightarrow \quad b = 6 - 5 = 1$

$\therefore \quad a = 3, b = 1$

13. By conservation of linear momentum

$0 = 234\vec{v} + 4\vec{u}$

$\vec{v} = \frac{-4\vec{u}}{234} \Rightarrow$ speed $v = \frac{4u}{234}$

14. Since, 8 α-particles and 2β- particles are emitted so, new atomic number

$Z' = Z - 8 \times 2 + 2 \times 1 = 92 - 16 + 2 = 78$

16. Beta decay can involve the emission of either electrons or positrons. The electrons or positrons emitted in β - decay do not exist inside the nucleus. They are only creasted at the time of emission, They are only created at the time of emission Just as photons are creasted whem an atom makes a transition from higher to a lower energy state.In nagative β decay a neutron in the mucleus is transformed into a proton, an antineutrino Hence in radioactive decay process the negatively charged, emitted b- particles are the electrons produced as a result of the decay of neutrons present inside the nucles.

19. Beta decay can involve the emission of either electrons or positrons. The electrons or positrons emitted in a β-decay don not exist inside the nucleus. They are only created at the time of emission, just a photons are created when an atom makes a transition from higher to a lower energy state.

In negative B-decay a neutron in the nucleus is transformed into a proton, an electron and an antineutrino. Hence, in radioactive decay process, the negatively charged emitted β-particles are the electrons produced as a result of the decay of neutrons preset inside the nucleus.

20. ${}^{A}_{Z}X + {}^{1}_{0}n \rightarrow {}^{7}_{3}Li + {}^{4}_{2}He$

It implies that

$A + 1 = 7 + 4$

$\Rightarrow$ $A = 10$

and $Z + 0 = 3 + 2$

$\Rightarrow$ $Z = 5$

Thus, it is Boron ${}^{10}_{5}B$

21. Gamma-photon.

23. Gamma ray is electromagnetic radiation which does not involve any change in proton number or neutron number

24. For $_ZX_A$, Z = 0 + 5 – 2 = 3 and A = 1 + 10 – 4 = 7

25. ${}^{22}_{10}Ne \rightarrow {}^{14}_{6}X + 2\alpha$

26. (1) The emitted β- particles have varying energy.

(2) e_- or e_+ does not exists inside the nucleus.

(3) $\bar{v}$ does carry momentum.

(4) In β-decay mass number does not change.

30. When an α-particle is emitted, mass number of nuclide X is reduced to 4, and its charge number is reduced to 2, But when a β-particle is emitted, mass number of remains the same and its charge number is increased by 1. Hence, the resulting nuclide has alomic mass A – 4 and atomic number Z – 1.

$ZX^A \xrightarrow{-a} Z-2\ Y^{A-4} \xrightarrow{-\beta} Z-1\ Y^{A-4}$

31. In gamma ray emission the energy is released from uncleus so that nucleus get stablished

32. In any nuclear reaction mass number and atomic number should remain conserved. Reaction (3) satisfies this condition. Also, for ${}^{239}_{93}NP$, neutron to proton ratio is greater than 1.52, which makes it unstable.

33. We have

$K_\alpha = \frac{m_y}{m_y + m_\alpha}.Q$ $\Rightarrow K_\alpha = \frac{A-4}{A}.Q$ $\Rightarrow 48 = \frac{A-4}{A}.50$ $\Rightarrow A = 100$

34. $R = \frac{mv}{qB}$

$R_P = \frac{m_P v}{eB}$

$R_{235_U} = \frac{m_{235_U}.V}{eB}$, $R_{238U} = \frac{m_{238U}\ .\ V}{eB}$

$\Rightarrow \Delta X = 2(\Delta R) = \frac{2(m_{238U} - m_{235U})\ V}{eB} = \frac{2 \times 3m_P V}{eB} = 2 \times 3 \times 10 \text{ mm} = 60 \text{ mm}$

35. During γ-decay atomic number (Z) and mass number (A) does not change. So the correct option is (C) because in all other options either Z, A or both is/are changing.

36. The magnitude of momentum of the daughter nucleus and α-particles will be equal

Q = KE of daughter nucleus + KE of α-particle = $\frac{p^2}{2m_d} + \frac{p^2}{2m_\alpha} = \frac{p^2}{2}\left(\frac{m_\alpha + m_d}{m_\alpha .\ m_d}\right)$

KE of α-particle = $\frac{p^2}{2m_\alpha} = \frac{1}{m_\alpha} \times \frac{m_\alpha . m_d}{m_\alpha + m_d} . Q = \frac{216}{220} \times 5.5$ Mev. = **5.4 Mev.**

SECTION (D)

1. $T_{avg.} = \frac{1}{\lambda}$ $\Rightarrow$ $T_{1/2} = \frac{\ln 2}{\lambda} < T_{avg.}$

So more than half the nuclei decay.

2. $64 = 2^6$

After 6 half lives activity will become = $\frac{1}{64}$

Hence required time = 6 × 2h **= 12h .**

3. The weight will not change appreciably as the process is β - decay, because no. of nucleons in β–decay do not change.

4. $N = \frac{N_0}{2^4} = \frac{N_0}{16}$,

% amount remaining = $\frac{N \times 100}{N_0} = \frac{N_0}{16} \times \frac{100}{N_0} = 6.25\%$

5. For stable product $\frac{dN}{dt} = -\lambda N \Rightarrow 0 = -\lambda N \Rightarrow \lambda = 0$

6. $\frac{dN}{dt} = \lambda N \Rightarrow \frac{dN}{N} = \lambda dt = \frac{0.693}{t_{1/2}} dt = \frac{0.693}{1.4 \times 10^{10}} \times 1 = 4.95 \times 10^{-11}$

7. $R = R_0 \left(\frac{1}{2}\right)^n$ ....(1)

Here R = activity of radioactive substance after n half lives = $\frac{R_0}{16}$ (given)

Substituting in equation (1), we get n = 4

∴ $t = (n)t_{1/2} = (4)\ (100\ \mu s) = 400\ \mu s$

$R = R_0 \left(\frac{1}{2}\right)^n$ ....(1)

$\therefore$ $t = (n)t_{1/2} = (4)\ (100\ \mu s) = 400\ \mu s$

8. $A_P = A_Q\, e^{-\lambda t} = A_Q\, e^{-\frac{1}{T}t}$ $\therefore$ $t = T\, \ell n \frac{A_Q}{A_P}$

9. No. of atoms of A after 2hrs. = $\frac{N_0}{4}$

No of atoms of B after 2hrs. = $\frac{N_0}{2}$

$\frac{(dN/dt)_A}{(dN/dt)_B} = \frac{\lambda_A N_A}{\lambda_B N_B} = \frac{(T_{1/2})_B . N_A}{(T_{1/2})_A . N_B} = \frac{2}{1} \times \frac{1}{2} = \mathbf{1}$

10. After 5 days N = 90%
After 10 days N = 90 – 9 = 81 %
After 15 days 81 – $\frac{10}{100} \times 81$ ≈ 73%

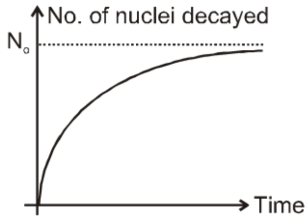
11. No. of disintegration in time t is

$N = N_0\,(1 - e^{-\lambda t}) = 10 \times 10^5\,(1 - e^{-\frac{\ln 2}{138.6} \times 1})$

$\approx 10 \times 10^5 \times \frac{\ln 2}{138.6}$ (using e^x expansion) $= 10^6 \times \frac{0.693}{138.6} = 5000.$

12. **Key Idea:** Total no. of nuclei remained after n half-lives is $N = N_0 \left(\frac{1}{2}\right)^n$. Total time given = 80 min Number of half-lives of A, $n_A = \frac{80\ \min}{20\ \min} = 4$ ⇒ Number of half-lives of B, $n_B = \frac{80\ \min}{40\ \min} = 2$

Number of nuclei remained undecayed $N = N_0 \left(\frac{1}{2}\right)^n$ where N_0 is initial number of nuclei



$\therefore$ $\frac{N_A}{N_B} = \frac{\left(\frac{N_A}{N_B}\right)^{n_A}}{\left(\frac{1}{2}\right)^{nB}}$ or $\frac{N_A}{N_B} = \frac{1}{4}$

NOTE : The graph between number of nuclei decayed with time is shown along side,

13. **Key Ieda :** In a-particle emission atomic mass decreases by 4 unit and atomic number decreases by 2 unit. IN β-particle emission, atomic mass remains unchanged and atomic numgber increases by 1 unit. Tje reaction can be shown as

$_nX_m \xrightarrow{\alpha} {}_{n-2}Y_{m-4}$

$_{n-2}Y_{m-4} \xrightarrow{2\beta} {}_nX_{m-4}$

Thus, the resulting mucleus is the isotope of parent uncleus and is $_nX_{m-4}$.

15. Remaining quantity

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

$N = 10.38 \left(\frac{1}{2}\right)^{19/3.8} = 10.38 \left(\frac{1}{2}\right)^{5} = \frac{10.38}{32} = 0.32$ g

16. Remaining quantity

$N = N_0 \left(\frac{1}{2}\right)^{n} = N_0 \left(\frac{1}{2}\right)^{5} = \frac{N_0}{32} = \frac{N_0}{30 \times N_0} \times 100 = 3.125\%$

17. ${}_5B_{10} + {}_0n_1 \longrightarrow {}_3Li_7 + {}_2He_4$ Total atomic number and mass number should be same on both sides of the equation.

20. If decay constant is λ,

Mean life $\tau = \frac{1}{\lambda}$ and Half life = $\frac{\log_e 2}{\lambda}$

21. Given half life,

T = 12 days

Fraction decayed = $\frac{7}{8}$

$\therefore$ Fraction undecayed = $1 - \frac{7}{8} = \frac{1}{8}$

$\therefore$ $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^n$ or $\left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^n$

Number of half lives

n = 3

$\therefore$ Time, taken for $\frac{7}{8}$ th sample to decayes

t = 3T = 3 × 12 = 36 days

22. N_0 is the initial amount of substance and N is the amount left after decay.

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

n = no. of half lives = $\frac{1}{t_1/2} = \frac{15}{5} = 3$

Therefore, $N = N_0 \left(\frac{1}{2}\right)^3 = \frac{N_0}{8}$

24. Here : Half life $T_{1/2}$ = 3.6 days

Amount left after time t,

$N = \frac{1}{32} \times N_0$

Number of half lives is given by

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

or $\frac{\frac{N_0}{32}}{N_0} = \left(\frac{1}{2}\right)^n$ or $\frac{1}{32} = \frac{1}{2^n}$ or n = 5 or $\frac{t}{t_{1/2}} = 5$

Hence, time of deeay

$t = 5 \times t_{1/2} = 5 \times 3.5 \approx 18$ days

25. Ratio of left mass to original = $\frac{1}{16} = \left(\frac{1}{2}\right)^4$
i.e., 16 g of substance has reduced to 1 g after 4 half lives.
$\therefore$ half life of substance = $\frac{120}{4}$ = 30 days

26. The decay rate R of a radioactive element is the unmber of decays per second.
$\therefore$ $n = R = \lambda N$
where λ = decay constant = $\frac{0.693}{\text{half}-\text{life}} = \frac{0.693}{T}$
$\therefore$ $n = \frac{0.693}{T} N$ or $T = \frac{0.693N}{n}$ s

29. Since 8α - particles 4β_- particles and 2β_+ - particles are emitted, so new atomic number
$Z = Z - 8 \times 2 + 4 \times 1 - 2 \times 1$
$= 92 - 16 + 4 - 2 = 92 - 14 = 78$

35. If N is the number of radioactive nuclei present at some instant, then
$N = N_0 e^{\lambda 1 t}$
The constant N_0 represents the number of radioactive nuclei at t = 0
Now, $\frac{N_1}{N_2} = \frac{e^{-\lambda_1 t}}{e^{-\lambda_2 t}}$ or $\frac{N_1}{N_2} = \frac{e^{-5\lambda t}}{e^{-\lambda t}} = e^{-4\lambda t}$
but $\frac{N_1}{N_2} = \frac{1}{e}$ (as provided)
Therefore, $\frac{1}{e} = \frac{1}{e^{4\lambda t}}$ or $4\lambda t = 1$ or $t = \frac{1}{4\lambda}$

36. $N = N_0 (1 - e^{-\lambda t})$
$\Rightarrow$ $\frac{N_0 - N}{N_0} = e^{-\lambda t}$ $\therefore$ $\frac{1}{8} = e^{-\lambda t}$
$\Rightarrow$ $8 = e^{\lambda t}$ $\Rightarrow$ $3 \ln 2 = \lambda t$ $\Rightarrow$ $\lambda = \frac{3 \times 0.693}{15}$
$t_{1/2} = \frac{0.693}{3 \times 0.693} \times 15$ $t_{1/2}$ = 5 min

37. 3.18×10^{15} atoms

38. In one half life, half of the nuclei will decay as $T_{av.} > T_{1/2}$, more than half of the nuclei will decay in one average life time.
$\frac{\ln 2}{\lambda_x} = \frac{1}{\lambda_y}$ $\Rightarrow \lambda_y > \lambda_x$
Rate of decay
$\left|\frac{dN}{dt}\right| = \lambda.N.$
Aliter. $\therefore$ $\left|\frac{dN}{dt}\right|_y > \left|\frac{dN}{dt}\right|_x$
or $\frac{0.693}{\lambda_x} = \frac{1}{\lambda_y}$

∴ $\lambda_x = 0.693\ \lambda_y$

$\lambda_x < \lambda_y$ or fo?kVu nj =λ N

39. $\frac{dN}{dt} = \frac{dN_\alpha}{N} + \frac{dN_\beta}{N}$

⇒ $\lambda dt = \lambda_1 dt + \lambda_2 dt$ ⇒ $\frac{\ell n2}{T} = \frac{\ell n2}{T_1} + \frac{\ell n2}{T_2}$ ⇒ $T = \frac{T_1T_2}{T_1+T_2}$

40. $\lambda = \lambda_1 + \lambda_2$ ⇒ $\frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2}$ ⇒ $T = \frac{T_1T_2}{T_1+T_2}$ = 324 years

$\frac{N_0}{4} = N_0 e^{-t/T}$

$-\frac{t}{T} = \ell n\frac{1}{4}$ = –1.386 ⇒ t = 449 years

41. $N_{x_1} = N_0\ e^{-10\lambda t}$

$N_{x_2} = N_0\ e^{-\lambda t}$

As per given

$\frac{N_{x_1}}{N_{x_2}} = e^{-9\lambda t} = \frac{1}{e}$ ⇒ $t = \frac{1}{9\lambda}$

42. Initial activity = $\left|\frac{dN}{dt}\right| = \lambda N_0 = \boldsymbol{\lambda}.\frac{m}{M}.\mathbf{N_A}$

44. Activity reduces from 6000 dps to 3000 dps in 140 days. It implies that half-life of the radioactive sample is 140 days. In 280 days (or two half-lives) activity will remain 1/4th of the initial activity. Hence the initial activity of the sample is - 4 × 6000 dps = 24000 dps

Therefore, the currect option is (4)

45. Givan $N_0\lambda = 5000$ $N\lambda = 1250$ $N = N_o\ e^{-\lambda t} = N_o e^{-5\lambda}$

where λ is decay constant per min

$N\lambda = N_o\lambda e^{-5\lambda}$

$1250 = N_o\lambda e^{-54}$ ∴ $e^{-5\lambda} = \frac{5000}{1250}$ 4

$e^{-5\lambda} = 4$

$5\lambda = 2lon_e,2$

$\lambda = 0.4 \text{ In } 2$

46. No. of radioactive nuclei (Reactant) should decrease continuously.

47. Given that $\lambda_1 N_1 = 5\mu Ci$

$\lambda_2 N_2 = 10\mu Ci$

$\lambda_2 N_2 = 2\lambda_1 N_1$

Also $N_1 = 2N_2$

Then $\lambda_2 N_2 = 2\lambda_1(2N_2)$

$\lambda_2 = 4\lambda_1$ ⇒ $4T_2 = T_1$

SECTION (E)

1. To start chain reaction mass should be greater than or equal to critical mass.

5. $_{92}U^{235} + n \longrightarrow {}_{54}Xe^{139} + {}_{38}Y^{94} + 3n$

7. (3) The energy released per unit mass is more in fusion and that per atom is more in fission.

8. Fusion reaction is possible at high temperature because kinetic energy is high enough to overcome repulsion between nuclei.

9. No. of nuclear spliting per second is

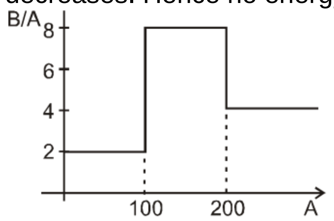
$N = \frac{100MW}{200MeV} = \frac{100}{200 \times 1.6 \times 10^{-19}}$ S_{-1}

No. of neutrons Liberated = $\frac{100}{200} \times \frac{1}{1.6 \times 10^{-19}} \times 2.5\ S_{-1} = \frac{125}{16} \times 10_8\ S_{-1}$

10. (1) For 1 < A < 50, on fusion mass number for compound nucleus is less than 100. B/A remains same. Hence no energy is released

(2) For 51 < A < 100, on fusion mass no. of compound nucleus is between 100 and 200. B/A increases. Hence energy is released.

(3) On fission for 100 < A < 200, the mass no. for fission nuclei will be between 50 to 100. B/A decreases. Hence no energy is released.



11. $^{236}_{92}U \to ^{140}_{54} \times + ^{a_4}_{38}Sr + ^{1}_{0}x + ^{1}_{0}y$ x = y = n

Q = 236 × 7.5 – (140 × 8.5 + 94 × 8.5) = 1770 – (1190 + 799) = 219 MeV

In A and D energy and charge conservation is followed

So $Q = K_{xe} + K_{Sr} + K_x + K_y = 129 + 86 + 4 = 219$

In D,

$p_{xe} > p_{Sr} + p_x + p_y$

so conservation of momentum will not hold

12. $Q = (BE_x + BE_y - BE_u) = (2 \times 117 \times 8.5 - 236 \times 7.6)$ Mev.

= 200 MeV. Approximatly

14. Boran rods in nuclear reactor are used as a controller.

19. Cd-rods absorb neutrons, while heavy water and graphite slow down the neutrons and water acts as a coolant.

20. In nuclear reactors the mederators are used to decrease (slowdown) the speed of neutrons. Heavy water, raphite is used for this purpose. While heavy water is the best moderator.

21. In fission of uranium, there are three neutrons in each fission. Hence, this reaction becomes a chain reaction $= -13.6 \times \frac{3}{4} = -10.2$ eV

22. The energy released in sun and hydrogen bomb are due to nuclear fusion.

25. $\frac{3}{2}kT = 7.7 \times 10_{-14}J$

$T = \frac{2 \times 7.7 \times 10^{-14}}{3 \times 1.38 \times 10^{-23}} = 3.7 \times 10_9\ K$

26. The multiplication factor (k) is an importanti reactor parameter and is the ratio of number of particlular generation to the number present at the begining of htenext gentration. It is a measure of growth rate of the neutrons in the reactor. For k = 1, the operation of the reactor is said to be critical.

EXERCISE # 2

1. According to theory of relativity, $m = \frac{m_o}{\sqrt{\left(1-\frac{\upsilon^2}{c^2}\right)}}$

Here $\upsilon = 0.8$ c

$\therefore \quad m = \frac{m_o}{\sqrt{\left\{1-\left(1-\frac{\upsilon^2}{c^2}\right)^2\right\}}} = \frac{m_o}{\sqrt{1-0.64}} = \frac{m_o}{0.6} = \frac{5}{3} m_0$

2. Since, here nuclear target is heavy it can be assumed safely that it will remain stationary and will not move due to the Coulombic interaction force.

At distancce lof closest approach relative velocity of two particles is v, Here target is considered as stationary so ∝ - particle comes to rest instantaneously at distance closest approach Let required distance is r then from work energy - theorem.

$o - \frac{mv^2}{2} = -\frac{1}{4\pi\varepsilon_0}\frac{ze \times 2e}{r}$

$r \propto \frac{1}{m} \Rightarrow \propto \frac{1}{v^2}$

$\propto ze^2$

3. According to law of conservation of energy, kinetic energy of α – particle

= the potential energy of α – particle at distance of closest approach.

i.e $\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$ $\quad\therefore\quad$ 5 Me V = $\frac{9\times10^9\times(2e)\times(92e)}{r}$ $\left(\because \frac{1}{2}mv^2 = 5 \text{ MeV}\right)$

$\Rightarrow \quad r = \frac{9\times10^9\times2\times92\times\left(1.6\times10^{-19}\right)^2}{5\times10^6\times1.6\times10^{-19}}$ $\quad\therefore\quad$ $r = 5.3 \times 10^{-14}$ m $\approx 10^{-12}$ cm

4. $\Delta m = 4m_{He} - m_0$

$\Delta m = .176$

Binding energy per/Nucleon = .176/16 amu = 10.24 meV

5. In the case of formation of a nucleus the evolution of energy to the binding energy of the nucleus takes place due to disappearance of a fraction of the total mass, If the quantity of mass disappearing is ΔM, then the binding energy is

$BE = \Delta MC^2$

From the above discussion, it is clear that the mass of the nucleuses must be less than the sum of the masses of the consituent neutrons and protons. We can then write.

$\Delta M = ZM_p + NM_n - M(A, Z)$

Where M (A, Z) is the mass of the atom of mass number A and atomic number Z. Hence, the binding energy of the nucleus is

$BE = [ZM_P + NM_n - M(A, Z)]C^2$

$BE = [ZM_P + (A - Z)M_n - M(A,Z)]C^2$ Where N = A – Z number of neutrons,

6. Binding energy of a nucleus containing N neutrons and Z protons is

$BE = [NM_n + ZM_p - M(A, Z)]c^2$

$\Rightarrow \quad \frac{BE}{c^2} = NM_n + ZM_p - M(A, Z)$

$\Rightarrow \quad \frac{BE}{c^2} = (A - Z)M_n + ZM_p - M(A, Z)$ (as N = A – Z)

$\Rightarrow \quad M(A, Z) = ZM_p + (A - Z)M_n - BE/c^2$

7. As given

$_1H_2 + {_1H_2} \rightarrow {_2He_4}$ + energy
The binding energy per nucleon of deuteron ($_1H_2$)
= 1.1 MeV
∴ Total binding energy
= 2 × 1.1 = 2.2 MeV
The binding energy per nucleon of helium
($_2He_4$) = 7 MeV
∴ Total binding energy
= 4 × 7 = 28 MeV
Hence, energy released in above process
= 28 – 2 × 2.2 = 28 – 4.4 = 23.6 MeV

8. β^+**decay**
A proton in the nucleus of $_6C_{11}$ transforms into a neutron and a new nucleus $_5B_{11}$ is formed with the emission of an antimatter electron (positron) and neutrino.
The equation is given by

$$_6C_{11} \rightarrow {_5B^{11}} + {_1\beta^o} + v + Q$$

Q-value of reaction is Δmc^2
= [M($_6C_{11}$) - 6M$_e$ - M($_5B_{11}$)+ 5M$_e$ -M$_e$]C$_2$
= [M($_6C_{11}$)- M($_5M_{11}$)- 2M$_e$]C$_2$
= 11.011434 - 11.009305 - 2 × 0.000548] uc$_2$
= [0.001033]uc$_2$
= 0.001033 × 931.5 MeV
= 0.962 MeV

9. Let n_1 and n_2 be the number of atoms in $\frac{10}{5}$ B and $\frac{11}{5}$ B isotopes. Atomic weight

$$= \frac{n_1 \times \left(\text{At. of } {}^{10}_{5}B\right) + n_2 \times \left(\text{At. of } {}^{11}_{5}B\right)}{n_1 + n_2}$$

or $10.81 = \frac{n_1 \times 10 + n_2 \times 11}{n_1 + n_2}$
or $10.81\ n_1 + 10.81\ n_2 = 10\ n_1 + 11\ n_2$
or $0.81\ n_1 = 0.19\ n_2$
or $\frac{n_1}{n_2} = \frac{0.19}{0.81} = \frac{19}{81}$

10. Nuclear reaction can be shown as

$$_{90}X_{232} \xrightarrow{n_2He^4} Y \xrightarrow{n'_1\beta^0} {_{86}M_{220}}$$

Since, atomeic mass and atomic number remain conserved in unclear reaction, so,
90 = 2n + (– n') + 86
⇒ 2n – n' = 4 … (i)
and 232 = 4n + 0 + 220
⇒ 4n = 12
∴ n = 3
Substituting the valve of n in equation
(i), we get 2 × 3 – n' = 4
⇒ n' = 6 – 4 = 2
Hence, 3 α-particles and 2β-particles will be disintegrated.

11. Given: $N_0\lambda = 5000$, $N\lambda = 1250$
$N = N_0 e^{-\lambda t} = N_0 e^{-5\lambda}$
$1250 = N_0 \lambda e^{-5\lambda}$
∴ $\frac{N_0\lambda}{N_0\lambda e^{-5\lambda}} = \frac{5000}{1250} = 4$

$e^{5\lambda} = 4$
$5\lambda = 2 \log_e 2$
$\lambda = 0.4 \ln 2$

12. $A = A_0 e^{-\lambda t}$
$\ell n A = \ell n A_0 - \lambda t$
$\Rightarrow y = c - mx$ equation of straight line.
ℓn A versus t is a linearly decreasing graph with slope depending to λ. As λ does not change, slope remains same.

13. $n = \lambda N \;\; = \lambda = \frac{n}{N}$
$\therefore \; t_{1/2} = \frac{0.69}{\lambda} = \frac{0.69\ N}{n}$

14. No. of nucleons of P, $N_P = \frac{m}{10} \times N_A$
No. of nucleons of Q, $N_Q = \frac{m}{20} \times N_A$
No. of nucleons of P after 20 days, $N_P{}' = \frac{N_P}{4}$
Let no. of nucleons of Q after 20 days be $N_Q{}'$
$\therefore \quad \frac{N_{P'}}{N_{Q'}} = \frac{1}{4} \Rightarrow \frac{\frac{M}{40} \times N_A}{N_{Q'}} = \frac{1}{2} \quad \Rightarrow N_{Q'} = \frac{mN_A}{20} = N_Q$
$N_Q{}'$ **= 2 ×** $N_P{}'$ **=** $\frac{N_P}{2}$ **=** $\mathbf{N_Q}$
Thus no chage in number of Nucleons of Q. Hence its half life is infinity.

15. $\frac{M}{M_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$
Here : M_0 = 100 g, t = 16 days, $T_{1/2}$ = 4 days
From eq (1), we get
$\therefore \quad m = 100 \left(\frac{1}{2}\right)^{16/4} = 100 \times \left(\frac{1}{2}\right)^4 = 100 \times \frac{1}{16} = 6.25$ g

16. Number of nuclei remained after time t can be written as
$N = N_0 e^{-\lambda t}$
Where N_0 is initial number of uncle of both the substances.
$N_1 = N_0\, e^{-5\lambda t}$ … (i)
and $N_2 = N_0\, e^{-\lambda t}$ … (ii)
Divinding Eq. (i) by Eq. (ii), we obtain
$\frac{N_1}{N_2} = \left(\frac{1}{e}\right)^2 = \frac{1}{e^2}$
Hence, $\frac{1}{e^2} = \frac{1}{e^{4\lambda t}}$
Comparing the powers, we get
$2 = 4\lambda t$

or $t = \frac{2}{4\lambda} = \frac{1}{2\lambda}$

17. $\frac{\ell n2}{\lambda_X} = \frac{1}{\lambda_Y}$ $= \lambda_Y = 1.4\lambda_X$, $\lambda_Y > \lambda_X$, Y will decay faster than X

18. Total energy produced in a day = $24 \times 60 \times 60 \times 10^6$
200 MeV energy is produced from 235 g Uranium
i.e. $200 \times 10^6 \times 1.6 \times 10^{-19}$ J energy is produced from 235g uranium
so uranium required in $24 \times 60 \times 60 \times 10^6$ seconds is $\frac{235 \times 24 \times 60 \times 60 \times 10^6}{200 \times 10 \times 1.6 \times 10^{-19}}$ = 1.05g

19. **Kdy Idea :**In a nuclear reaction, atomic mass and charge number remain conserved,
For a nuclear reaction to be com,pleted, the mass number and charge number on both sides should be same.
If we com,plete the equation by choice (1), then the complete reaction is
Total atomic number on on LHS = 92 + 0 = 92
$_{92}U_{235} + {}_0n_1 \rightarrow {}_{38}Sr_{90} + {}_{54}Xe_{143} + 3{}_0n_1$
Total atomic unmber on RHS
= 38 + 54 + 0 = 92
Total atomic unmber on RHS = 235 + 1 = 236
Total atomic unmber on RHS
= 90 + 143 + 3 × 1 = 236
Thus, choice (1) is correct,

EXERCISE # 3
PART - I

1. In a nuclear reaction conservation of charge +2e and mass 4m. Emission of an α- particle reduces the mass of the radionuclide by 4 and its atomic number by2. β-particle are negatively charged particles with rest mass as well as charge same as that of electrons. γ-particles carry no charge and mass.
Radioactive reaction will be as follows

$${}^A_Z X \longrightarrow {}^{A}_{Z+1} Y + \beta^0_{-1}$$
$${}^{A}_{Z+1} Y \longrightarrow {}^{A-4}_{Z-1} B^0 + \alpha^4_2$$
$${}^{A-4}_{Z-1} B^0 \longrightarrow {}^{A-4}_{Z-1} B + \gamma$$

2. Let the radioactive subtance be ${}^A_Z X$ Radioactive transition is given by
$${}^A_Z X \xrightarrow{-a} {}^{A-4}_{Z-2} X \xrightarrow{-2\beta} {}^{A-4}_{Z} X$$
The atoms of element having same atomic number but dirrerent mass numbers are called isotopes
so, ${}^A_Z X$ and ${}^{A-4}_{Z} X$ are isotopes

3. As $\frac{X}{Y} = \frac{1}{15}$

The ratio of number of atoms remained undecayed $\frac{X}{X_o} = \frac{1}{16}$

Active fraction $\frac{X}{X_o}$ or $\frac{N}{N_o} = \frac{1}{16}$

where $\frac{N}{N_o} = \left(\frac{1}{2}\right)^{t/T1/2}$

$$\Rightarrow \left(\frac{1}{2}\right)^{t/t_1/2} = \frac{1}{16} = \left(\frac{1}{2}\right)^4$$

or $\frac{t}{T_{1/2}} = 4$

Given, half-life of X = 50 yr

t = 4×50

= 200 yr **Ans.**

Ionization power depends on momentum of particle which again depends on the mass of the particle as

$p = \sqrt{2mE}$

Here E = constant

So, ionization power $\propto \sqrt{m}$

As the mass increases in the given order

$m_\alpha > m_p > M_e$

Hence, the ionization power in increasing order is given by

$IP_\alpha > IP_p > IP_e$

4. For ${}^{7}_{3}Li$ nucleus,

Mass defect, ΔM = 0.042 u

∴ 1 u = 931.5 MeV/c^2

∴ ΔM = 0.042 × 931.5 MeV/c^2 = 39.1 MeV/c^2

Binding energy, $E_b = \Delta Mc^2 = \left(39.1\frac{MeV}{c^2}\right) c^2$ = 39.1 MeV

Binding energy per nucleon, $E_{bn} = \frac{E_b}{A} = \frac{39.1 \ \ MeV}{7}$ = 5.6 MeV

5. According to activity law

$R = R_0e^{-\lambda t}$ ...(i)

where,

R_0 = initial activity at t = 0

R = activity at time t

λ = decay constant

According to given problem,

$R_0 = N_0$ counts per minute

$R = \frac{N_0}{e}$ counts per minute

t = 5 minutes

Substituting these values in equation (i), we get

$\frac{N_0}{e} = N_0e^{-5\lambda}$

$e^{-1} = e^{-5\lambda}$

5λ = 1 or $\lambda = \frac{1}{5}$ per minute

At $t = T_{1/2}$, theactivity R reduces to $\frac{R_0}{2}$.

where $T_{1/2}$ = half life of a radioactive sample

From equation (i), we get

$\frac{R_0}{2} = R_0e^{-\lambda T_{1/2}}$

$e^{\lambda T_{1/2}} = 2$

Taking natural logarithms of both sides of above equation, we get

$\lambda T_{1/2} = \log_e 2$

or $T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{\log_e 2}{\left(\frac{1}{5}\right)} = 5\log_e 2$ minutes

6. At the distance of closest approach d, Kinetic energy = Potential energy

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r_0}$$ where,

Ze = charge of target nucleus
2e = charge of alpha nucleus

$\frac{1}{2}m\upsilon^2$ = kinetic energy of alpha nucleus of mass m moving with velocity u

or $r_0 = \frac{2Ze^2}{4\pi\varepsilon_0\left(\frac{1}{2}m\upsilon^2\right)}$ ∴ $r_0 \propto \frac{1}{m}$

7. $A_1 = \lambda N_1$ at time t_1
$A_2 = \lambda N_2$ at time t_2
Therefore, number of nuclei decayed during time interval $(t_2 - t_1)$ is

$$N_1 - N_2 = \frac{[A_1 - A_2]}{\lambda}$$

8. ${}_1H_2 + {}_1H_2 \rightarrow {}_2He_4 + \Delta E$
The binding energy per nucleon of a deuteron = 1.1 MeV
∴ Total binding energy = 2 × 1.1 = 2.2 MeV
The binding energy per nucleon of a helium nuclei = 7 MeV
∴ Total binding energy = 4 × 7 = 28 MeV
∴ Hence, energy released
$\Delta E = (28 - 2 \times 2.2) = 23.6$ MeV

9. Initially $P \rightarrow 4N_o$
$Q \rightarrow N_o$
Half life $T_P = 1$ min.
$T_Q = 2$ min.
Let after time t number of nuclie of P and Q are equal

that is $\frac{4\ N_o}{2^{t/1}} = \frac{N_o}{2^{t/2}}$

or $\frac{4}{2^{t/2}} = 1$ or $t = 4$ min

so at t = 4 min

$N_P = \frac{(4\ N_o)}{2^{4/1}} = \frac{N_o}{4}$

at t = 4 min. $N_Q = \frac{N_o}{2^{4/2}} = \frac{N_o}{4}$

or population of R

$= \left(4N_o - \frac{N_o}{4}\right) + \left(N_o - \frac{N_o}{4}\right) = \frac{9N_o}{2}$

10. Number of X: N_x
Number of Y: N_y

$\frac{N_x}{N_y} = \frac{1}{15}$

Part of $N_x = \frac{1}{16}(N_x + N_y) = \frac{1}{2^4}(N_x + N_y)$
So total 4 half lives are passed so age of rock is
4 × 50 = 200 years

11. $E = mc^2$

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

So mass decay per second

$\frac{dm}{dt} = \frac{1}{c^2}\frac{dE}{dt} = \frac{1}{c^2}$ (Power in watt)

$= \frac{1}{(3\times10^8)^2} \times 1000 \times 10^3$ and mass decay per hour $= \frac{dm}{dt} \times 60 \times 60$

$\frac{1}{(3\times10^8)^2} \times 10^6 \times 3600 = 4 \times 10^{-8}$ kg. = 40 microgram

12. Momentum

$Mu = \frac{E}{c} = \frac{h\upsilon}{c}$

Recoil energy

$\frac{1}{2} Mu^2 = \frac{1}{2}\frac{M^2u^2}{M} = \frac{1}{2M}\left(\frac{h\upsilon}{c}\right)^2 = \frac{h^2\upsilon^2}{2Mc^2}$

13. α–particle ${}_2He^4$

during β_{-1} emission neutron converts into proton

So new Nucleus is

${}_nX_{m-4}$

15. $R = R_0 (A)^{1/3}$

$\frac{R_2}{R_1} = \left(\frac{A_2}{A_1}\right)^{1/3} = \left(\frac{64}{27}\right)^{1/3} = \frac{4}{3}$

$R_2 = 3.6 \times \frac{4}{3} = 4.8$ m   Ans. (3)

16. $N_1 = \frac{N_{01}}{(2)^{t/20}}$ ⇒ $N_2 = \frac{N_{02}}{(2)^{t/10}}$

$N_1 = N_2$

$\frac{40}{(2)^{t/20}} = \frac{160}{(2)^{t/10}}$ ⇒ $2^{t/20} = 2^{\left(\frac{t}{10}-2\right)}$

$\frac{t}{20} = \frac{t}{10} - 2$ ⇒ $\frac{t}{20} - \frac{t}{10} = 2$

$\frac{t}{20} = 2$ ⇒ $t = 40$

17. $N_1 = N_0 e^{-\lambda t}$ $N_1 = \frac{1}{3} N_0$

$\frac{N_0}{3} = N_0 e^{-\lambda t_2}$ ....(i)

$N_2 = \frac{2}{3}N_0$

$\frac{2}{3}N_0 = N_0 e^{-\lambda t_1}$ ....(ii)

From eq. (i) and (ii)

$\frac{1}{2} = e^{-\lambda(t_2 - t_1)}\theta$

$\lambda (t_2 – t_1) = \ell n2$

$t_2 – t_1 = \frac{\ell n2}{\lambda} = T_{1/2}$ = 50 days

18. Δm = 0.02566 u

energy = 0.02866 × 931 26.7 MeV

As $_1H_2 + _1H_2 \rightarrow _2He_4$ energy liberated (MeV) is = 13.35 MeV = 6.675 MeV

19. value of x is $\frac{1}{8} = \frac{x_0}{8} = \frac{x_0}{2^3}$ ⇒ t = 3T = 3 × 20 = 60

Alternate :

	X	→	Y_0
at t = 0	N_0		0
at t = t	N		$N_0 – N$

$\frac{N}{N_0 - N} = \frac{1}{7}$ ⇒ $\frac{N}{N_0} = \frac{1}{8}$

t = 3t ⇒ 3 × 20 = 60

20. $_4Li_7 + _1H_1 \longrightarrow _2(_2He_4)$

BE of products = (5.6 MeV) × 7 + 0 = 39.2 MeV

E_i = –39.2 MeV

BE of reactant = (7.06) × 4 × 2 = 56.48 MeV

E_f = – 56.48 MeV

As nuclear energy decreases, so some energy will be released

$Q_{release} = E_i – E_f$ = (–39.2) – (–56.48) = 17.28 MeV

21.

	X	→	Y
t = 0	N_0		0
at time t	$N_0 – x$		x

$\frac{N_0 - x}{x} = \frac{1}{7}$ ⇒ $x = \frac{7N_0}{8}$

So remaining nuclei of X = $N_0 – x = \frac{N_0}{8} = \frac{N_0}{2^3}$

So three half life periods would have been passed. ⇒ $t = 3\ t_{1/2} = 3 \times 1.4 \times 10^9 = 4.2 \times 10^9$ year

22. $R = R_0 (A)^{1/3}$

$R_{Al} = R_0 (27)^{1/3} = 3R_0$

$R_{Te} = R_0 (125)^{1/3} = 5R_0 = \frac{5}{3} R_{Al}$

23. $N_1 = 0.6\ N_0$

$N_2 = 0.15\ N_0$

$\frac{N_2}{N_1} = \left(\frac{1}{2}\right)^2$ so two half life period has passed. So time taken = $2t_{1/2}$ = 2 × 30 = 60 minutes **Ans.**

24. $N_A = N_0e^{-8\lambda t}$ $N_B = N_0e^{-\lambda t}$

This N_B will always be greater than N_A

Assuming $\frac{N_A}{N_B} = \frac{1}{e} = e^{-7\lambda t}$ ⇒ $7\lambda t = 1$ ⇒ $t = \frac{1}{7\lambda}$

25. $N_0 = 600 \longrightarrow N_f$ = 600 – 450 = 150

$N \rightarrow \left(\frac{1}{2}\right)^2$ ⇒ 2 half life periods have been passed

So $t = 2t_{1/2}$ = 2 × 10 = 20 minutes

26. Given that the rate of radioactive disintegration rate = $\frac{dN}{dt} = 10^{10}$

$t_{1/2} = \frac{0.693}{\lambda} = 2.2 \times 10^9$ $\Rightarrow$ $\frac{1}{\lambda} = \frac{2.2\times10^9}{0.693}$

As we know $\Rightarrow$ $\frac{dN}{dt} = \lambda N$ $\Rightarrow$ $N = \frac{1}{\lambda}\frac{dN}{dt} = \frac{2.2\times10^9}{0.693} \times 10^{10} = 3.17 \times 10^{19}$

PART - II

1. If binding energy of product nuclei is greater then energy is released.

2. $\frac{2}{3}N_0 = N_0 e^{-\lambda t_1}$ $\Rightarrow$ $\frac{1}{3}N_0 = N_0 e^{-\lambda t_2}$ $\Rightarrow$ $2 = e^{\lambda(t_2 - t_1)}$

$\lambda(t_2 - t_1) = \ell n\, 2$ $\Rightarrow$ $(t_2 - t_1) = \frac{\ell n 2}{\lambda} = 20$ min.

3. **Statement–1:** Energy of β_- particle from 0 to maximum so $E_1 - E_2$ is the continuous energy spectrum.
Statement–2 : For energy conservation and momentum at least three particles daughter nucleus $+\beta_{-1}$ and antineutron.

4. ${}_0n_1 \to {}_1H_1 + {}_{-1}e_0 + \bar{\nu} + Q$
$\Delta m = m_n - m_\alpha - m_e = (1.6725 \times 10^{-27} - 1.6725 \times 10^{-27} - 9 \times 10^{-31})$ kg $= -9 \times 10^{-31}$ kg
Energy $= 9\times 10^{-31} \times (3 \times 10^8)^2 = 0.511$ MeV
Which is nearly equal to 0.73 Mev but as energy will be required. Since mass is increasing. So answer = –0.511 Mev either (1) or bonus.

5. $\Delta E = h\nu$

$\nu = \frac{\Delta E}{h} = k\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{k2n}{n^2(n-1)^2} \approx \frac{2k}{n^3} \propto \frac{1}{n^3}$ **Ans. (4)**

6. A B
$T_A = 20$ min $T_B = 40$ min

$$\frac{\left(1-\frac{N}{N_0}\right)_A}{\left(1-\frac{N}{N_0}\right)_B} = \frac{1-\frac{1}{2^{t/t_{1/2}}}}{1-\frac{1}{2^{t/t_{1/2}}}} = \frac{1-\frac{1}{2^{\frac{80}{20}}}}{1-\frac{1}{2^{\frac{80}{40}}}} = \frac{1-\frac{1}{16}}{1-\frac{1}{4}} = \frac{\frac{15}{16}}{\frac{3}{4}} = \frac{5}{4}$$

7. $\frac{N_B}{N_A} = \frac{N_0(1-e^{-\lambda t})}{N_0 e^{-\lambda t}}$

$0.3 = e^{\lambda t} - 1$ $\Rightarrow$ $T = \frac{\ell n(2)}{\lambda}$

$1.3 = e^{\lambda t}$ $\Rightarrow$ $\lambda = \frac{\ell n(2)}{T}$

$\ell n(1.3) = \lambda t$ $\Rightarrow$ $t = \frac{\ell n(1.3)}{\ell n(2)} \times T$

8. Activity $= \lambda \cdot N$
$\Rightarrow$ $\lambda_A N_A = 10$ $\Rightarrow$ $\lambda_B N_B = 20$

$\frac{\lambda_A}{\lambda_B}\cdot\frac{N_A}{N_B} = \frac{1}{2}$ $\Rightarrow$ $\frac{\lambda_A}{\lambda_B}\cdot 2 = \frac{1}{2}$

$\frac{\lambda_A}{\lambda_B} = \frac{1}{4}$ $\Rightarrow$ $\frac{t_{1/2_B}}{t_{1/2_A}} = \frac{1}{4}$

9. $A = \lambda N$
Initially $N = N_0$
$A_A = A_B$
$\lambda_A N_{0_A} = \lambda_B N_{0_B}$

$(T_{1/2})_A = \frac{\ell n(2)}{\lambda_A}$ $\Rightarrow$ $\ell n(2) = \frac{\ell n(2)}{\lambda_A}$

$\lambda_A = 1$ at time t

$\frac{A_B}{A_A} = e^{-3t} = \frac{\lambda_B N_{0_B} e^{-\lambda_B t}}{\lambda_A N_{0_A} e^{-\lambda_A t}}$ ⇒ $e^{-3t} = e^{(\lambda_A - \lambda_B)t}$

$-3 = \lambda_A - \lambda_B$ ⇒ $\lambda_B = 1 + 3 = 4$ ⇒ $(T_{1/2})_B = \frac{\ln(2)}{\lambda_B} = \frac{\ln(2)}{4}$

10. $\frac{1600}{(2)^n} = 100$

$2^n = 16$

$n = 4$

$4t_{1/2} = 8s$

$t_{1/2} = 2$ s

t = 6 sec {3 half-life} ⇒ $\frac{1600}{2^3} = 200$

11. Q = 12 × 7.86 + 8 × 7.07 – 20 × 8.03

Q = 94.32 + 56.56 – 160.6 = –9.72

12. Change in Z = (6 × 2) – 4 = 8

Change in A = 6 × 4 = 24

$^{232}_{90}TH \xrightarrow[4\beta^-]{6\alpha} {}^{208}_{82}P_B$