Exercise-1

Marked Questions can be used as Revision Questions.

OBJECTIVE QUESTIONS

Section (A) : Properties of Nucleus

A-1. Sol. Experimental fact.

A-2 Sol. For hydrogen nucleus mass number is equal to atomic number, else mass number is more than atomic number.

A-3

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

$O_5^{189} = r_0 A_{O5}^{1/3}$

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**

Section (B) : Mass Defect and Binding Energy

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

B-2 Sol. 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.

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

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

B-5 Sol. Q = $(2BE_{He} - BE_{Li})$
= (2 × 7.06 × 4 – 5.60 × 7) Mev
= 17.28 Mev.

Section (C) : Radioactive Decay and Displacement Law

C-1 Sol. ${}_2^4He + {}_7^{14}N \rightarrow {}_8^{17}O + {}_1^1H$

C-2 Sol. In β^- emission, An antineutrino is produced

$n \rightarrow p + e^- + \overline{\nu}$

C-3 Sol. Specific activity of 1 gm radium is 1 Curie.

Section (D) : Statistical Law of Radioactive Decay

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

So more than half the nuclei decay.

D-2 Sol. $64 = 2^6$

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

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

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

D-4 **Sol.** $N = \frac{N_0}{2^4} = \frac{N_0}{16}$,

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

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

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

Section (E) : Nuclear Fission And Fusion

E-1 **Sol.** To start chain reaction mass should be greater than or equal to critical mass.

E-4 **Sol.** ${}_{92}U^{235} + n \longrightarrow {}_{54}Xe^{139} + {}_{38}Y^{94} + 3n$

E-6 **Sol.** (3) The energy released per unit mass is more in fusion and that per atom is more in fission.

E-7 **Sol.** Fusion reaction is possible at high temperature because kinetic energy is high enough to overcome repulsion between nuclei.

Exercise-2

Marked Questions can be used as Revision Questions.

PART - I : OBJECTIVE QUESTIONS

1. **Sol.** $R = R_0 A^{1/3}$

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

It is similar to y = mx.

2. **Sol.** Nuclear force is charge independent

3. **Sol.** (A) 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

4. **Sol.** The decay law will remain same even in the train. The velocities of the α-particle and the recoiling nucleus will be same on the ground and in the train with respect to train.

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

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

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

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

7. **Sol.** (4) $n = \lambda N \;\; = \lambda = \frac{n}{N}$

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

8. **Sol.** 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.

9. **Sol.** (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.

10. **Sol.** Energy released $E_{Q^{2n}} = E_{P^n} - 2 = y - 2x = -(2x - y)$

11. **Sol.** 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 $N_Q{}'$

$\therefore \; \frac{N_{P'}}{N_{Q'}} = \frac{1}{4} \Rightarrow \frac{\frac{M}{40} \times N_A}{N_{Q'}} = \frac{1}{2}$

$\Rightarrow N_{Q'} = \frac{mN_A}{20} = N_Q$

$N_Q{}' = 2 \times N_P{}' = \frac{N_P}{2} = N_Q$

Thus no chage in number of Nucleons of Q. Hence its half life is infinity.

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

13. **Sol.** Energy of each γ- ray photon = $E = mc^2 = 0.0016 \times 931.5$ MeV = 1.5 MeV

14. **Sol.** 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 $\frac{235 \times 24 \times 60 \times 60 \times 10^6}{200 \times 10 \times 1.6 \times 10^{-19}} = 1.05$g

PART - II : MISCELLANEOUS QUESTIONS

Section (A) : Assertion//Reasoning

A-1. **Sol.** Statement-2 is true by definition and correctly explains the staement-1, namely, $_ZX^A$ undergoes 2 α decays, 2β decays (negative β) and 2 γ decays. As a result the daughter product is .

A-2. **Sol.** Minimum kinetic energy of bombarding Nucleus should be more than 30 MeV.

A-3. Sol. Spontaneous fission occurs to lower the binding energy of product nuclei. So statement 1 is true and statement 2 is false.

Section (B) : Match the column

B-1 Ans. (1 → q); (2 → s); (3 → r); (4 → s)

Sol. Let m_x, m_y be nuclear masses of x and y

A. $m_x - m_y - m_\alpha = (M_x - zm_e) - [M_y - (z-2)m_e] - (M_{He} - 2m_e)$

B. $m_x - m_y - m_e = (M_x - zm_e) - [M_y - (z+1)m_e] - m_e = M_x - M_y$

C. $m_x - m_y - m_e = (M_x - zm_e) - [M_y - (z-1)m_e] - m_e = M_x - M_y - 2m_e$

D. $(m_e + m_x) - m_y = m_e + (M_x - zm_e) - [M_y - (z-1)m_e] = M_x - M_y$ (K-capture) (K–dsipj)

Section (C) : One or More Than One Options Correct

C-1.* Sol. The total number of nucleons will be A - 4 and the number of neutrons will be A - Z - 3.

C-2. Sol. As the number of protons increases, Coulomb repulsive force among protons increases. To compensate, number of neutrons which are neutral is increased.

C-3. Sol. $\left|\frac{dN}{dt}\right| = \lambda N = \frac{\ln 2}{T_{1/2}} \times \frac{1 \times 6.02 \times 10^{23}}{238}$

$\Rightarrow T_{\frac{1}{2}} = \frac{\ln 2 \times 6.023 \times 10^{23}}{238 \times 1.24 \times 10^{4}}$ = **4.5 × 10⁹ yrs.**

The activity = number of disintegration per second = 1.24×10^4 dps

C-4. Sol. ${}_7N^{14} + n \rightarrow {}_3Li^7 + 4p + 4n$

$\rightarrow {}_3Li^7 + 2\alpha$

$\rightarrow {}_3Li^7 + \alpha + 4p + 2\beta^-$

C-5. Sol. Given , $\lambda = 0.173$

$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{0.173}$ 4

Also $N_0 - N = N_0 e^{-\lambda t}$

For , $t = \frac{1}{0.173}$ year :

$N_0 - N = \frac{N_0}{e} = 0.37 N_0$

C-6. Sol. (3, 4)

Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less than the sum of masses of its 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 the mass defect.

Thus. $20\,(m_n + m_p) - M_2 > 10\,(m_p + m_n) - M_1$

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

or $M_2 < M_1 + 10(m_p + m_n)$

Now since $M_1 < 10(m_p + m_n)$

∴ $M_2 < 2M_1$

C-7. Sol. Let at time t, number of radioactive nuclei are N.

Net rate of formation of nuclei of A

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

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

$-\frac{1}{\lambda}\left[\ell n(\alpha - \lambda N)\right]_{N_0}^{N} = t$

$\ell n \frac{\alpha - \lambda N}{\alpha - \lambda N_0} = -\lambda t$

$N = \frac{1}{\lambda}[\alpha - (\alpha - \lambda N_0)\, e^{-\lambda t}]$

Exercise-3

Marked Questions can be used as Revision Questions.

PART - I : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

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

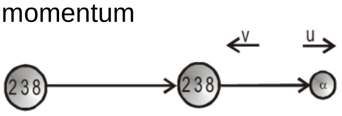
Thus, $N = N_0\left(\frac{1}{2}\right)^n$

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

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

$= \frac{N_0}{8}$

3. Sol. By conservation of linear momentum



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

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

4. Sol. Given : $N_0\lambda = 5000$, $N\lambda = 1250$

$N = N_0 e^{-\lambda t} = N_0 e^{-5\lambda}$

$1250 = N_0 \lambda e^{-5\lambda}$

$\therefore \frac{N_0\lambda}{N_0\lambda e^{-5\lambda}} = \frac{5000}{1250} = 4$

$e^{5\lambda} = 4$

$5\lambda = 2 \log_e 2$

$\lambda = 0.4 \ln 2$

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

$Z' = Z - 8 \times 2 + 2 \times 1$

$= 92 - 16 + 2$

$= 78$

6. **Sol.** Protons cannot be emitted by radioactive substances during decay, because proton remains inside nucleous.

7. **Sol.** $\frac{3}{2}kT = 7.7 \times 10^{-14}$J

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

$= 3.7 \times 10^{9}$ K

8. **Sol.** Law of conservation of momentum gives

$m_1v_1 = m_2v_2$

$\Rightarrow \quad \frac{m_1}{m_2} = \frac{v_2}{v_1}$

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

or $\quad m \propto r^3$

$\therefore \quad \frac{m_1}{m_2} = \frac{r_1^3}{r_2^3} = \frac{v_2}{v_1}$

$\Rightarrow \quad \frac{r_1}{r_2} = \left(\frac{1}{2}\right)^{1/3}$

$\therefore \quad r^1 : r^2 = 1 : 2^{1/3}$

9. **Sol.** As given

${}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4$ + energy

The binding energy per nucleon of deuteron (${}_1H^2$)

= 1.1 MeV

$\therefore$ Total binding energy

= 2 × 1.1 = 2.2 MeV

The binding energy per nucleon of helium

(${}_2He^4$) = 7 MeV

$\therefore$ Total binding energy

= 4 × 7 = 28 MeV

Hence, energy released in above process

= 28 – 2 × 2.2 = 28 – 4.4 = 23.6 MeV

10. **Sol.** 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 $\quad \frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

$\therefore \quad 5 \text{ MeV} = \frac{9 \times 10^9 \times (2e) \times (92e)}{r} \quad \left(\because \frac{1}{2}mv^2 = 5\text{MeV}\right)$

$\Rightarrow \quad r = \frac{9 \times 10^9 \times 2 \times 92 \times (1.6 \times 10^{-19})^2}{5 \times 10^6 \times 1.6 \times 10^{-19}}$

$\therefore \quad r = 5.3 \times 10^{-14}$ m $\approx 10^{-12}$ cm

11. **Sol.** $N = N_0(1 - e^{-\lambda t})$

$\Rightarrow \quad \frac{N_0 - N}{N_0} = e^{-\lambda t}$

∴ $\frac{1}{8} = e^{-\lambda t}$

⇒ $8 = e^{\lambda t}$ ⇒ $3 \ln 2 = \lambda t$ ⇒ $\lambda = \frac{3 \times 0.693}{15}$

$t_{1/2} = \frac{0.693}{3 \times 0.693} \times 15$ $t_{1/2} = 5$ min

12. Sol. $R\ R_0\ (A)^{1/3}$

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

∴ $R_{Te} = \frac{5}{3} \times 3.6$

$R_{Te} = 6$ Fermi

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

It implies that

$A + 1 = 7 + 4$

⇒ $A = 10$

and $Z + 0 = 3 + 2$

⇒ $Z = 5$

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

15. Sol. Gamma-photon.

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

18. Sol. Nuclear binding energy = (mass of nucleus – mass of nucleons) $C^2 = (M_o - 8M_P - 9M_N)C^2$

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

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

21. Sol. For heavy nucleus binding energy per nucleon decreases with increasing Z while for light nuclei it increases with increasing Z.

22. Sol. **Ans. (4)**

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

Directions : Question number 23 – 25 are based on the following paragraph.

23. Sol. Energy is released

∴ $(B.E.)_{product} > (B.E.)_{Reactant}$

24. Sol. $Q = \Delta m\, c^2 = \frac{1}{2} \times \left(\frac{M}{2}\right) v^2 + \frac{1}{2} \times \left(\frac{M}{2}\right) v^2$

$\Delta mc^2 = \frac{1}{2} \times Mv^2$ ⇒ $v = c\sqrt{\frac{2\Delta m}{M}}$

25. **Sol.** $_{Z}X^{A} \longrightarrow 3\,_2He^4 + \,_{Z-8}Y^{A-12} + 2\,_{+1}e^0 + 2\,\upsilon$

number of proton = Z – 8

number of neutron = (A – 12) – (Z – 8) = A – Z – 4

ratio is $\frac{A-Z-4}{Z-8}$

26. **Sol.** $\frac{2}{3}N_0 = N_0 e^{-\lambda t_1}$ ⇒ $\frac{1}{3}N_0 = N_0 e^{-\lambda t_2}$

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

$\lambda(t_2 - t_1) = \ell n\, 2$

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

27. **Sol.** **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.

28. **Sol.** $_0n^1 \rightarrow \,_1H^1 + \,_{-1}e^0 + \bar{\nu} + Q$

$\Delta m = m_n - m_\alpha - m_e$

$= (1.6725 \times 10^{-27} - 1.6725 \times 10^{-27} - 9 \times 10^{-31})$ 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.

29. **Sol.** $\Delta E = h\nu$

$\nu = \frac{\Delta E}{h} = k\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{k2n}{n^2(n-1)^2}$

$\approx \frac{2k}{n^3} \propto \frac{1}{n^3}$ **Ans. (4)**

30. **Ans.** **(3)**

Sol. A B

$T_A = 20$ min $T_B = 40$ min

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

31. **Ans.** **(3)**

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

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

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

$\ell n(1.3) = \lambda t$

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

PART - II : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1.

Sol. **(i)** 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.

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

Here R = activity of radioactive substance after n half lives

$= \frac{R_0}{16}$ (given)

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

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

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

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

2. **Sol.** The magnitude of momentum of the daughter nucleus and α-particles will be equal

Q = KE of daughter nucleus + KE of α-particle

$= \frac{p^2}{2m_d} + \frac{p^2}{2m_\alpha}$

KE of α-particle $= \frac{p^2}{2m_\alpha} = \frac{1}{m_\alpha} \times \frac{m_\alpha . m_d}{m_\alpha + m_d} . \alpha$

$= \frac{216}{220} \times 5.5$ Mev. = **5.4 Mev.**

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

4. **Sol.** 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 correct option is (D)

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

Δm = .0.011 amu $\qquad \Delta E = \Delta M\ C^2 = 0$

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

6. **Sol.** **(B)**

Number of nuclei left after 2 half lives $= \frac{N_0}{4}$

probability of a nucleus decaying = no. of nuclei decayed total no. $= \frac{3N_0/4}{N_0} = \frac{3}{4}$

7. **Ans.** (A)
Sol. Since energy is released in a fission process, the rest mass energy must decrease.

8. **Sol.** 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 $\lambda_2 N_2 = 2\lambda_1(2N_2)$
$\lambda_2 = 4\lambda_1$
Ans. (A)

9. **Ans.** **4**

Sol. $\lambda = \frac{0.693}{1386} = 5 \times 10^{-4}$
Number decayed = $N_0 - N(t)$
% age Decayed = $\frac{N_0 - N(t)}{N_0} \times 100$
$= (1 - e^{-\lambda t}) \times 100$
$\lambda t \times 100$
$= 5 \times 10^{-4} \times 80 \times 100 = 4$

10. **Ans.** **(C)**
Sol. (p) In α decay mass number decreses by 4 and atomic number decreases by 2.
(q) In β^+ decay mass number remains unchanged while atomic number decreases by 1.
(r) In Fission, parent nucleus breaks into allmost two equal fragments.
(s) In proton emission both mass number and atomic number decreases by 1.

11. **Ans.** **(C)**
Sol (A) $3^{Li^7} \rightarrow _2He^4 + _1H^3$
$\Delta m = [M_{Li} - M_{He} - M_{H^3}]$
$= [6.01513 - 4.002603 - 3.016050]$
$= -1.003523u$
Δm is negative so reaction is not possible.
(B) $84^{Po^{210}} \rightarrow 83^{Bi^{209}} + 1^{P^1}$
Δm is negative so reaction is not possible.
(C) $1^{H^2} \rightarrow 2^{He^4} + 3^{Li^6}$
Δm is Positive so reaction is possible.
(D) $30^{Zn^{70}} + 34^{Se^{82}} \rightarrow 64^{Gd^{152}}$
Δm is Positive so reaction is not possible.

12. **Ans.** **(A)**
Sol $84^{Po^{210}} + 2^{He^4} \rightarrow 82^{Pb^{206}}$
$\Delta m = [M_{PO} - M_{He} - M_{Pb}] = 0.008421$ u
$Q = 0.008421 \times 932$ MeV = 5422 KeV
$K_\alpha = \frac{210}{214} \times 5422$ KeV
= 5320 KeV

13. **Ans** **3**

Sol. $E' \times \frac{12.5}{100} = E$

$E = \frac{E'}{8}$ (E = Power requirement to the village, E' = Power of plant)

$E = \frac{E'}{2^3}$

Number of half life = 3

So total time required = 3 × T years

14. Ans. 2

Sol. $A_P = A_0 \ e^{\frac{-t}{\tau}}$, $A_Q = A_0 \ e^{\frac{-t}{2\tau}}$

$R_P = \frac{A_0}{\tau} e^{\frac{-t}{\tau}}$, $R_Q = \frac{A_0}{2\tau} e^{\frac{-t}{2\tau}}$

at $t = 2\tau$

$\frac{R_P}{R_Q} = \frac{\frac{A_0}{\tau} e^{-2}}{\frac{A_0}{2\tau} e^{-1}} = \frac{2}{e}$

15. Ans. (C)

Sol. $A = A_0 2^{-t/T_H}$

$\Rightarrow \frac{A_0}{64} = A_0 2^{-t/T_H}$

$\Rightarrow 6 = \frac{t}{T_H}$ $\Rightarrow$ $t = 6T_H = 108$ days

16. Ans. (C)

Sol. $E = \frac{3}{5} \frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$

$n + {}^{15}_{8}O \longrightarrow {}^{15}_{7}N + {}^{1}_{1}H$

$Q = \left(M_n + M_{O_8^{15}} - m_{N_7^{15}} - M_{H_1^1}\right) C^2$

= 0.003796 × 931.5 = 3.5359 MeV

$\Delta E = \frac{3}{5} \times \frac{e^2}{4\pi\varepsilon_0} \times \frac{1}{R}(8 \times 7 - 7 \times 6)$

$= \frac{3}{5} \times (1.44 \ \text{MeV fm}) \times \frac{1}{R} \times 14 = 3.5359$ MeV

R = 3.42 fm

Additional Problems For Self Practice (APSP)

PART-I : PRACTICE TEST PAPER

1. **Sol.** BE of X = 6A
BE of Y = 6A – 2 + 1 = 6A – 1
[Because absorption of energy decreases BE and releas of energy increases BE]
In Y nuclues there are A + 1 nuclues.

$\therefore \quad \frac{BE}{nucleon} = \frac{6A-1}{A+1}$

2. **Sol.** We have $K_\alpha = \frac{m_y}{m_y + m_\alpha}.Q \quad \Rightarrow K_\alpha = \frac{A-4}{A}.Q \quad \Rightarrow 48 = \frac{A-4}{A}.50 \quad \Rightarrow A = 100$

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

$$^{64}_{29}Cu \longrightarrow {}^{64}_{30}Zn + {}_{-1}e^0$$

4. **Sol.** 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 $\frac{0.693}{\lambda_x} = \frac{1}{\lambda_y} \quad \therefore \quad \lambda_x = 0.693\,\lambda_y$

$\lambda_x < \lambda_y$ or $= \lambda N$

5. **Sol.** Let $^{10}_{5}B$ and $^{11}_{5}B$ be in the ratio m:n .
Average atomic weight

$10.81 = \frac{m \times 10 + n \times 11}{m+n} \Rightarrow \frac{m}{n} = \frac{0.19}{0.81} = \frac{19}{81}$

6. **Sol.** $\frac{dN}{dt} = \frac{dN_\alpha}{N} + \frac{dN_\beta}{N}$

$\Rightarrow \lambda dt = \lambda_1 dt + \lambda_2 dt$

$\Rightarrow \frac{\ell n2}{T} = \frac{\ell n2}{T_1} + \frac{\ell n2}{T_2}$

$\Rightarrow T = \frac{T_1 T_2}{T_1 + T_2}$

7. **Sol.** $\lambda = \lambda_1 + \lambda_2 \quad \Rightarrow \frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2}$

$\Rightarrow T = \frac{T_1T_2}{T_1+T_2}$ = 324 years

$\frac{N_0}{4} = N_0e^{-t/T}$

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

$\Rightarrow$ t = 449 years

8. **Sol.** No. of nuclear spliting per second is

N = $\frac{100MW}{200MeV} = \frac{100}{200\times1.6\times10^{-19}}$ S^{-1}

No. of neutrons Liberated = $\frac{100}{200} \times \frac{1}{1.6\times10^{-19}} \times 2.5\ S^{-1}$

$= \frac{125}{16} \times 10^{8}\ S^{-1}$

9. **Sol.** R = $\frac{mv}{qB}$

$R_P = \frac{m_Pv}{eB}$

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

$\Rightarrow \Delta X = 2(\Delta R) = \frac{2(m_{238U} - m_{235U})V}{eB}$

$= \frac{2\times3m_PV}{eB}$ = 2 × 3 × 10 mm = 60 mm

10. **Sol.** $A = A_0\, e^{-\lambda t}$

$\ell n\, A = \ell n\, A_0 - \lambda t$

$\Rightarrow$ 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.

11. **Sol.** Order of 1 fermi 1 fermi

12. **Ans.** **(2)**

Sol. Initially P → $4N_o$

Q → 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 $\frac{4N_o}{2^{t/1}} = \frac{N_o}{2^{t/2}}$

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

so at t = 4 min

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

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

or population of R

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

13. **Sol.** $E = \Delta mc^2 = 1.66 \times 10^{-27} \times (3 \times 10^8)^2 \approx 931$ MeV

14. Sol. For $_ZX^A$, Z = 0 + 5 – 2 = 3 and A = 1 + 10 – 4 = 7

15. Sol. 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 $W \rightarrow 2Y$

Binding energy of reactants = 120 × 7.5 = 900 MeV
and binding energy of products = 2 (60 × 8.5) = 1020 MeV > 900 MeV

16. Sol. No. of radioactive nuclei (Reactant) should decrease continuously.

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

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

21. Sol. It is order of MeV

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

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

24.

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

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

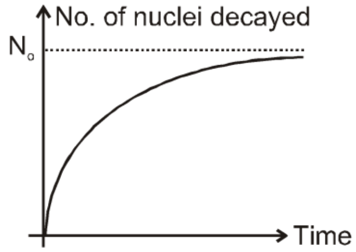
As per given

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

25. Sol. **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



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

or $\quad \frac{N_A}{N_B} = \frac{1}{4}$

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

26. **Sol.** **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 ${}_nX^{m-4.}$

27. **Sol.** **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,

${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{38}Sr^{90} + {}_{54}Xe^{143} + 3({}_0n)^1 +$

28. **Sol.** Remaining quantity

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

29. **Sol.** ${}_5B^{10} + {}_0n^1 \quad {}_3Li^7 + {}_2He^4$ Total atomic number and mass number should be same on both sides of the equation.

PART - II : PRACTICE QUESTIONS

1. **Sol.** for ${}_ZX^A$,, Z = (1 + 1 + 1) – 1 = 2 and ,A = (1 + 1 + 2) – 0 = 4

${}_2X^4$, α

2. **Sol.** Neutrino is produced in β^+ emission.

8. **Sol.** According to question reaction may be expressed as $_2He^4 + {_7}N^{14} \longrightarrow {_8}O^{17} + {_1}X^1$ (proton)
So, particle X is proton ($_1H^1$)

10. **Sol.** 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.

11. **Sol.** 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,

$BE = \Delta MC^2$

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

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

12. **Sol.** 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

13. **Sol.** 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.
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$N_1 = N_0\,e^{-5\lambda t}$ … (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 $t = \frac{2}{4\lambda} = \frac{1}{2\lambda}$