27

Nuclei

TOPIC 1
Nucleus and Radioactivity

01 A radioactive nucleus ${}_Z^AX$ undergoes spontaneous decay in the sequence

$${}_Z^AX \longrightarrow {}_{Z-1}B \longrightarrow {}_{Z-3}C \longrightarrow {}_{Z-2}D,$$

where Z is the atomic number of element X. The possible decay particles in the sequence are **[NEET 2021]**

(a) α, β^-, β^+ (b) α, β^+, β^-
(c) β^+, α, β^- (d) β^-, α, β^+

Ans. *(c)*

As we know that,

In α-decay, the atomic number is decreased by 2 units.

$$X_Z^A \longrightarrow {}_{Z-2}^{A-4}Y + {}_2^4\text{He}$$

In β^+-decay, the atomic number is decreased by 1 unit.

$$X_Z^A \longrightarrow {}_{Z-1}^{A}Y + {}_{+1}^{0}e + \bar{\nu}$$

In β^--decay, the atomic number is increased by 1 unit.

$$X_Z^A \longrightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \bar{\nu}$$

From the above relations, the spontaneous decay given in question can be written as

$$X_Z^A \xrightarrow{\beta^+} {}_{Z-1}B \xrightarrow{\alpha} {}_{Z-3}C \xrightarrow{\beta^-} {}_{Z-2}D$$

The possible decay particles in the sequence are β^+, α, β^-.

02 The half-life of a radioactive nuclide is 100 h. The fraction of original activity that will remain after 150 h would be **[NEET 2021]**

(a) $\frac{1}{2}$ (b) $\frac{1}{2\sqrt{2}}$ (c) $\frac{2}{3}$ (d) $\frac{2}{3\sqrt{2}}$

Ans. *(b)*

Given, the half-life of a radioactive nuclide, $t_{1/2} = 100$ h

As we know,

$$A = \frac{A_0}{2^{t/t_{1/2}}}$$

Here, A_0 is the original activity of the nuclide, A is the activity of the nuclide after time t.

$$\Rightarrow \frac{A}{A_0} = 2^{t/t_{1/2}} = 2^{-\frac{150}{100}}$$

$$= 2^{-3/2} = \frac{1}{2\sqrt{2}}$$

So, the fraction of original activity that will remain after 150 h will be $\frac{1}{2\sqrt{2}}$.

03 What happens to the mass number and atomic number of an element when it emits γ-radiation? **[NEET (Oct.) 2020]**

(a) Mass number decreases by four and atomic number decreases by two.
(b) Mass number and atomic number remain unchanged.
(c) Mass number remains unchanged, while atomic number decreases by one.
(d) Mass number increases by four and atomic number increases by two.

Ans. *(b)*

When an atom emits γ-radiation from its nucleus, then there is no change in its atomic number and mass number.

04 The half-life of a radioactive sample undergoing α-decay is 1.4×10^{17} s. If the number of nuclei in the sample is 2.0×10^{21}. The activity of the sample is nearly **[NEET (Oct.) 2020]**

(a) 10^4 Bq (b) 10^5 Bq
(c) 10^6 Bq (d) 10^3 Bq

Ans. *(a)*

Given, $T_{1/2} = 1.4 \times 10^{17}$ s

Number of nuclei in the sample,

$$N = 2.0 \times 10^{21}$$

$\therefore$ Activity of the sample $= \lambda N$

$$= \frac{0.693}{T_{1/2}} \times 2 \times 10^{21}$$

$$= \frac{0.693}{1.4 \times 10^{17}} \times 2 \times 10^{21}$$

$$= 0.99 \times 10^4$$

$$\simeq 1 \times 10^4 \text{Bq} \simeq 10^4 \text{ Bq}$$

05 The rate of radioactive disintegration at an instant for a radioactive sample of half life 2.2×10^9 s is 10^{10} s^{-1}. The number of radioactive atoms in that sample at that instant is **[NEET (Odisha) 2019]**

(a) 3.17×10^{20} (b) 3.17×10^{17}
(c) 3.17×10^{18} (d) 3.17×10^{19}

Ans. *(d)*

Given, half life $T_{1/2} = 2.2 \times 10^9$ s

Rate of disintegration, $R = 10^{10}$ s^{-1}

If N be the number of nuclei present, then the rate of disintegration is

$$\frac{dN}{dt} = \lambda N \quad (\lambda = \text{decay constant})$$

$$\Rightarrow R = \lambda N \text{ or } N = \frac{R}{\lambda} \quad \text{...(i)}$$

Also, the half life is given by,

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

$$\Rightarrow \lambda = \frac{0.693}{T_{1/2}} \quad \text{...(ii)}$$

From Eq. (i) and (ii), we get

$$N = \frac{R}{0.693} \times T_{1/2}$$

$$= \frac{10^{10} \times 2.2 \times 10^9}{0.693}$$

$$= 3.17 \times 10^{19}$$

06 α-particle consists of **[NEET (National) 2019]**

(a) 2 electrons, 2 protons and 2 neutrons
(b) 2 electrons and 4 protons only
(c) 2 protons only
(d) 2 protons and 2 neutrons only

Ans. *(d)*

α-particles are doubly ionised helium nucleus (He^{2+}) which are emitted in any radioactive process. So, they have two protons, 2 neutrons in its nucleus and no electron.

07 For a radioactive material, half-life is 10 minutes. If initially there are 600 number of nuclei, the time taken (in minutes) for the disintegration of 450 nuclei is **[NEET 2018]**

(a) 30 (b) 10 (c) 20 (d) 15

Ans. *(c)*

Key Concept *After n half-life, the number of nuclei left undecayed is given as*

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

where, $n = \dfrac{t}{t_{1/2}}$

Here, initially number of nuclei, $N_0 = 600$

After disintegration, number of nuclei, $N' = 450$

$\therefore$ Number of nuclei left undecayed,

$$N = N_0 - N' = 600 - 450 = 150$$

Half-life, $t_{1/2} = 10$ min

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

Substituting the given values, we get

$$\frac{150}{600} = \left(\frac{1}{2}\right)^{t/20}$$

or $\dfrac{1}{4} = \left(\dfrac{1}{2}\right)^{t/10}$

or $\left(\dfrac{1}{2}\right)^2 = \left(\dfrac{1}{2}\right)^{t/10}$

or $\dfrac{t}{10} = 2 \Rightarrow t = 20$ min

08 Radioactive material A has decay constant 8λ and material B has decay constant λ. Initially, they have same number of nuclei. After what time, the ratio of number of nuclei of material B to that A will be $\dfrac{1}{e}$? **[NEET 2017]**

(a) $\dfrac{1}{\lambda}$ (b) $\dfrac{1}{7\lambda}$
(c) $\dfrac{1}{8\lambda}$ (d) $\dfrac{1}{9\lambda}$

Ans. *(b)*

Let initial number of nuclei in A and B is N_0.

Number of nuclei of A after time t is

$$N_A = N_0 e^{-8\lambda t} \quad \text{...(i)}$$

Similarly, number of nuclei of A after time t is

$$N_B = N_0 e^{-\lambda t} \quad \text{...(ii)}$$

It is given that $\dfrac{N_A}{N_B} = \dfrac{1}{e}$ $\quad [\because N_B > N_A]$

Now, from Eqs. (i) and (ii)

$$\frac{e^{-8\lambda t}}{e^{-\lambda t}} = \frac{1}{e}$$

Rearranging

$\Rightarrow \quad e^{-1} = e^{-7\lambda t} \Rightarrow 7\lambda t = 1$

$\Rightarrow \quad$ Time $t = \dfrac{1}{7\lambda}$

09 The half-life of a radioactive substance is 30 minutes. The time (in minutes) taken between 40% decay and 85% decay of the same radioactive substance is **[NEET 2016]**

(a) 15 (b) 30 (c) 45 (d) 60

Ans. *(d)*

Key Idea Half-life of a radioactive substance is $T_{1/2} \propto \log\left(\dfrac{N_0}{N}\right)$

Given, $N_1 = 0.6N_0$ $\quad (\because 40\%$ decay$)$

$N_2 = 0.15N_0$ $\quad (\because 85\%$ decay$)$

Putting these in the formula,

$$\frac{N_2}{N_1} = \frac{0.15N_0}{0.6N_0} = \frac{1}{4} = \left(\frac{1}{4}\right)^2$$

So, two half-life periods has passed.

Thus, time taken $= 2 \times t_{1/2} = 2 \times 30 = 60$ min

10 If radius of the ${}^{27}_{13}$Al nucleus is taken to be R_{Al}, then the radius of ${}^{125}_{53}$Te nucleus is nearly **[CBSE AIPMT 2015]**

(a) $\left(\dfrac{53}{13}\right)^{\frac{1}{3}} R_{Al}$ (b) $\dfrac{5}{3} R_{Al}$

(c) $\dfrac{3}{5} R_{Al}$ (d) $\left(\dfrac{13}{53}\right)^{\frac{1}{3}} R_{Al}$

Ans. *(b)*

Radius of the nucleus is given by

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

$$\frac{R_{Al}}{R_{Te}} = \left(\frac{A_{Al}}{A_{Te}}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$$

$$R_{Te} = \frac{5}{3} R_{Al}$$

11 A radio isotope X with a half life 1.4×10^9 yr decays of Y which is stable. A sample of the rock from a cave was found to contain X and Y in the ratio 1 : 7. The age of the rock is **[CBSE AIPMT 2014]**

(a) 1.96×10^9 yr (b) 3.92×10^9 yr
(c) 4.20×10^9 yr (d) 8.40×10^9 yr

Ans. *(c)*

Ratio of $X : Y$ is given $= 1 : 7$

$$\frac{m_x}{m_y} = \frac{1}{7} \Rightarrow 7m_x = m_y$$

Let the initial total mass be m.

$\Rightarrow \quad m_x + m_y = m \Rightarrow \dfrac{m_y}{7} + m_y = m$

$\Rightarrow \quad \dfrac{8m_y}{7} = m \Rightarrow m_y = \dfrac{7}{8}m$

only $\dfrac{1}{8}$ part remains

$\Rightarrow \quad 1 \xrightarrow{T_{1/2}} \dfrac{1}{2} \xrightarrow{T_{1/2}} \dfrac{1}{4} \xrightarrow{T_{1/2}} \dfrac{1}{8}$

So, time taken to become $\dfrac{1}{8}$ unstable part

$$= 3 \times T_{1/2} = 3 \times 1.4 \times 10^9 = 4.2 \times 10^9 \text{ y}$$

Alternative

$$\underset{\text{Active}}{X} \rightarrow \underset{\text{Stable}}{Y}$$

As we know that

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

$$\frac{1}{1+7} = \frac{1}{8} = \left(\frac{1}{2}\right)^3 \Rightarrow n = 3$$

As $T_{1/2} = \dfrac{t}{n}$

$\therefore \quad t = T_{1/2} \times n$

$= 1.4 \times 10^9 \times 3 = 4.2 \times 10^9$ y

12 The half-life of a radioactive isotope X is 20 yr. It decays to another element Y which is stable. The two elements X and Y were found to be in the ratio 1 : 7 in a sample of a given rock. The age of the rock is estimated to be **[NEET 2013]**

(a) 40 yr (b) 60 yr (c) 80 yr (d) 100 yr

Ans. *(b)*

As we know that

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

$$\frac{N}{N_0}=\left(\frac{1}{2}\right)^3=\frac{1}{1+7}=\frac{1}{8}$$

So, number of half lifes = 3

$\Rightarrow \quad T=20$ yr

$\therefore \quad T=\frac{t}{n}$

$\Rightarrow \quad t=T\ n=20\times 3\text{ yr}=60\text{yr}$

13 A mixture consists of two radioactive materials A_1 and A_2 with half lives of 20 s and 10 s respectively. Initially the mixture has 40 g of A_1 and 160 g of A_2. The amount of the two in the mixture will become equal after **[CBSE AIPMT 2012]**

(a) 60 s (b) 80 s
(c) 20 s (d) 40 s

Ans. *(d)*

For 40 g amount,

$$40\text{ g}\xrightarrow[\text{half-life}]{20\text{ s}}20\text{ g}\xrightarrow{20\text{ s}}10\text{ g}$$

For 160 g amount,

$$160\text{ g}\xrightarrow{10\text{ s}}80\text{ g}\xrightarrow{10\text{ s}}40\text{ g}$$
$$\xrightarrow{10\text{ s}}20\text{ g}\xrightarrow{10\text{ s}}10\text{ g}$$

So, after 40 s A_1 and A_2 will become equal.

14 A radioactive nucleus of mass M emits a photon of frequency ν and the nucleus recoils. The recoil energy will be **[CBSE AIPMT 2011]**

(a) $h^2\nu^2/2Mc^2$ (b) zero
(c) $h\nu$ (d) $Mc^2-h\nu$

Ans. *(a)*

Momentum of a photon

$$p=\frac{h\nu}{c}$$

Hence, recoil energy, $E=\frac{p^2}{2M}$

$$\therefore \quad E=\frac{\left(\frac{h\nu}{c}\right)^2}{2M}\text{ or }E=\frac{h^2\nu^2}{2Mc^2}$$

15 The half-life of a radioactive isotope X is 50 yr. It decays to another element Y which is stable. The two elements X and Y were found to be in the ratio of 1 : 15 in a sample of a given rock. The age of the rock was estimated to be **[CBSE AIPMT 2011]**

(a) 200 yr (b) 250 yr
(c) 100 yr (d) 150 yr

Ans. *(a)*

We know that

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

$$\Rightarrow \frac{1}{1+15}=\frac{1}{16}=\left(\frac{1}{2}\right)^4=\left(\frac{1}{2}\right)^{t/50}$$

$t=4\times 50$

$t=200$ yr

16 A nucleus ^m_nX emits one α-particle and two β^- particles. The resulting nucleus is **[CBSE AIPMT 2011]**

(a) $^{m-6}_{n}Z$ (b) $^{m-4}_{n}X$ (c) $^{m-4}_{n-2}Y$ (d) $^{m-6}_{n-4}Z$

Ans. *(b)*

$$^m_nX\xrightarrow{\alpha}{}_{n-2}X^{m-4}\xrightarrow{2\beta}{}_nX^{m-4}$$

17 The activity of a radioactive sample is measured as N_0 counts per minute at $t=0$ and N_0/e counts per minute at $t=5$ min. The time (in minute) at which the activity reduces to half its value is **[CBSE AIPMT 2010]**

(a) $\log_e 2/5$ (b) $\frac{5}{\log_e 2}$
(c) $5\log_{10}2$ (d) $5\log_e 2$

Ans. *(d)*

Fraction remains after n half lives

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

Given $\quad N=\frac{N_0}{e}\Rightarrow\frac{N_0}{eN_0}=\left(\frac{1}{2}\right)^{5/T}$

or $\quad \frac{1}{e}=\left(\frac{1}{2}\right)^{5/T}$

Taking log on both sides, we get

$$\log 1-\log e=\frac{5}{T}\log\frac{1}{2}$$
$$-1=\frac{5}{T}(-\log 2)$$

$\Rightarrow \quad T=5\log_e 2$

Now, let t' be the time after which activity reduces to half

$$\left(\frac{1}{2}\right)=\left(\frac{1}{2}\right)^{t'/5\log_e 2}\Rightarrow t'=5\log_e 2$$

18 The number of beta particles emitted by a radioactive substance is twice the number of alpha particles emitted by it. The resulting daughter is an **[CBSE AIPMT 2009]**

(a) isobar of parent
(b) isomer of parent
(c) isotone of parent
(d) isotope of parent

Ans. *(d)*

Let the radioactive substance be ^A_ZX.
Radioactive transition is given by

$$^A_ZX\xrightarrow{-\alpha}{}^{A-4}_{Z-2}X\xrightarrow{-2\beta}{}^{A-4}_{Z}X$$

The atoms of element having same atomic number but different mass numbers are called isotopes.

So, ^A_ZX and $^{A-4}_{Z}X$ are isotopes.

19 In the nuclear decay given below

$$^A_ZX\longrightarrow{}^A_{Z+1}Y\longrightarrow{}^{A-4}_{Z-1}B^*\longrightarrow{}^{A-4}_{Z-1}B$$,

the particles emitted in the sequence are **[CBSE AIPMT 2009]**

(a) β,α,γ (b) γ,β,α
(c) β,γ,α (d) α,β,γ

Ans. *(a)*

Alpha particles are positively charged particles with charge +2e and mass 4 m. Emission of an α-particle reduces the mass of the radionuclide by 4 and its atomic number by 2. β-particles are negatively charged particles with rest mass as well as charge same as that of electrons. γ-particles carry no charge and mass.

Radioactive transition will be as follows

$$^A_ZX\longrightarrow{}^A_{Z+1}Y+\beta^0_{-1}$$
$$^A_{Z+1}Y\longrightarrow{}^{A-4}_{Z-1}\beta+\alpha^4_2$$
$$^{A-4}_{Z+1}\beta\longrightarrow{}^{A-4}_{Z-1}\beta+\gamma^0_0$$

20 Two radioactive materials X_1 and X_2 have decay constants 5λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that of X_2 will be $\frac{1}{e}$ after a time **[CBSE AIPMT 2008]**

(a) λ (b) $\frac{1}{2}\lambda$ (c) $\frac{1}{4\lambda}$ (d) $\frac{e}{\lambda}$

Ans. *(c)*

$$N_1=N_0e^{-5\lambda t}\quad\text{...(i)}$$
$$N_2=N_0e^{-\lambda t}\quad\text{...(ii)}$$

Dividing Eq. (i) by Eq. (ii), we obtain

$$\frac{N_1}{N_2}=\frac{1}{e}$$

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

$\therefore \quad e^{-1}=e^{-4\lambda t}$

$1=4\lambda t$

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

21 Two radioactive substances A and B have decay constants 5λ and λ respectively. At $t=0$ they have the same number of nuclei. The ratio of number of nuclei of A to those of B will be $\left(\frac{1}{e}\right)^2$ after a time interval **[CBSE AIPMT 2007]**

(a) $\frac{1}{4\lambda}$ (b) 4λ (c) 2λ (d) $\frac{1}{2\lambda}$

Ans. ***(d)***

Number of nuclei remained after time t can be written as

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

where, N_0 is initial number of nuclei of both the substances.

$$N_1 = N_0 e^{-5\lambda t} \quad ...(i)$$

and $$N_2 = N_0 e^{-\lambda t} \quad ...(ii)$$

Dividing Eq. (i) by Eq. (ii), we obtain

$$\frac{N_1}{N_2} = e^{(-5\lambda+\lambda)t} = e^{-4\lambda t} = \frac{1}{e^{4\lambda t}}$$

But, we have given

$$\frac{N_1}{N_2} = \left(\frac{1}{e}\right)^2 = \frac{1}{e^2}$$

Hence, $$\frac{1}{e^2} = \frac{1}{e^{4\lambda t}}$$

Comparing the powers, we get

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

22 If the nucleus $^{27}_{13}Al$ has a nuclear radius of about 3.6 fm, then $^{125}_{52}Te$ would have its radius approximately as **[CBSE AIPMT 2007]**

(a) 6.0 fm (b) 9.6 fm
(c) 12.0 fm (d) 4.8 fm

Ans. ***(a)***

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 form as

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

The value of R_0 is 1.2×10^{-15} m, i.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 $$R_{Te} = \frac{5}{3} \times R_{Al}$$

$$= \frac{5}{3} \times 3.6 = 6 \text{ fm}$$

23 In radioactive decay process, the negatively charged emitted β-particles are **[CBSE AIPMT 2007]**

(a) the electrons present inside the nucleus
(b) the electrons produced as a result of the decay of neutrons inside the nucleus
(c) the electrons produced as a result of collisionsbetween atoms
(d) the electrons orbiting around the nucleus

Ans. ***(b)***

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

In negative β-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 present inside the nucleus.

24 The radius of germanium (Ge) nuclide is measured to be twice the radius of ^9_4Be. The number of nucleons in Ge are **[CBSE AIPMT 2006]**

(a) 73 (b) 74
(c) 75 (d) 72

Ans. ***(d)***

According to question, radius of ^9_4Be nucleus be r, and radius of germanium (Ge) nucleus will be $2r$.

Radius of a nucleus is given by

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

R = Radius of atom having mass number. A

$$R \propto A^{1/3}$$

So, $$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

$$\Rightarrow \frac{r}{2r} = \left(\frac{9}{A_2}\right)^{1/3} \quad (\because A_1 = 9)$$

or $$\left(\frac{1}{2}\right)^3 = \frac{9}{A_2}$$

Hence, $$A_2 = 9 \times (2)^3 = 9 \times 8 = 72$$

Thus, in germanium (Ge) nucleus number of nucleons is 72.

25 In a radioactive material the activity at time t_1 is R_1 and at a later time t_2, it is R_2. If the decay constant of the material is λ, then **[CBSE AIPMT 2006]**

(a) $R_1 = R_2\ e^{-\lambda(t_1 - t_2)}$

(b) $R_1 = R_2\ e^{\lambda(t_1 - t_2)}$

(c) $R_1 = R_2 \left(\frac{t_2}{t_1}\right)$

(d) $R_1 = R_2$

Ans. ***(a)***

The decay rate R of a radioactive material is the number of decays per second.

From radioactive decay law,

$$-\frac{dN}{dt} \propto N$$

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

i.e. Rate of reaction is directly proportional to the initial concentration of reactants.

Thus, $$R = -\frac{dN}{dt} \quad \text{or} \quad R \propto N$$

or $$R = \lambda N \quad \text{or} \quad R = \lambda N_0\ e^{-\lambda t} \quad ...(i)$$

where $R_0 = \lambda N_0$ is the activity of the radioactive material at time $t=0$.

At time t_1, $R_1 = R_0\ e^{-\lambda t_1}$ ...(ii)

At time t_2, $R_2 = R_0\ e^{-\lambda t_2}$ ...(iii)

Dividing Eq. (ii) by Eq. (iii), we have

$$\frac{R_1}{R_2} = \frac{e^{-\lambda t_1}}{e^{-\lambda t_2}} = e^{-\lambda(t_1 - t_2)}$$

or $$R_1 = R_2\ e^{-\lambda(t_1 - t_2)}$$

26 The nuclei of which one of the following pairs of nuclei are isotones ? **[CBSE AIPMT 2005]**

(a) $_{34}Se^{74}$, $_{31}Ga^{71}$ (b) $_{42}Mo^{92}$, $_{40}Zr^{92}$
(c) $_{38}Sr^{84}$, $_{38}Sr^{86}$ (d) $_{20}Ca^{40}$, $_{16}S^{32}$

Ans. ***(a)***

The nuclei which have same number of neutrons but different atomic number and mass number are known as isotones. In choice (a) nuclei of $_{34}Se^{74}$ and $_{31}Ga^{71}$ are isotones as

$$A - Z = 74 - 34 = 71 - 31 = 40$$

27 The half-life of radium is about 1600 yr. Of 100 g of radium existing now, 25 g will remain unchanged after **[CBSE AIPMT 2004]**

(a) 4800 yr (b) 6400 yr
(c) 2400 yr (d) 3200 yr

Ans. *(d)*

Amount of substance remained is

$$M = M_0 \left(\frac{1}{2}\right)^n$$

$$\begin{bmatrix} M = \text{substance remained} \\ M_0 = \text{initial amount} \end{bmatrix}$$

Given, $M_0 = 100\text{g}, M = 25\text{g}$,

Half-life of radioactive substance

$T_{1/2} = 1600$ yr

So, $25 = 100\left(\frac{1}{2}\right)^n$

or $\frac{25}{100} = \left(\frac{1}{2}\right)^n$ or $\left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^n$

Comparing the power, we have

$n = 2$

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

or $t = 2T_{1/2} = 2 \times 1600 = 3200$ yr

28 A sample of radioactive element has a mass of 10g at an instant $t = 0$. The approximate mass of this element in the sample after two mean lives is **[CBSE AIPMT 2003]**

(a) 3.70 g (b) 6.30 g
(c) 1.35 g (d) 2.50 g

Ans. *(c)*

Mean life of radioactive substance is given by

$\tau = \frac{1}{\lambda}$, (λ is decay constant)

Also, it is given that $t = 2\tau$

So, $t = 2 \times \frac{1}{\lambda} = \frac{2}{\lambda}$

Thus, mass remained after time t is

$$M = M_0 \, e^{-\lambda t}$$

$$\begin{bmatrix} M = \text{Final mass} \\ M_0 = \text{Inital mass} \\ \lambda = \text{Decay constant} \end{bmatrix}$$

$= 10\, e^{-\lambda \times \frac{2}{\lambda}}$ $(\because M_0 = 10\text{g})$

$= 10\, e^{-2}$

$= \frac{10}{e^2}$

$= 1.35$ g

29 A nuclear reaction given by

$_Z X^A \rightarrow {}_{Z+1}Y^A + {}_{-1}e^0 + \overline{\nu}$

represents **[CBSE AIPMT 2003]**

(a) fusion (b) fission
(c) β-decay (d) γ-decay

Ans. *(c)*

Since in the given reaction $_{-1}e^0$ and antineutrino $(\overline{\nu})$ are released, so it can be considered β-decay.

30 The mass number of a nucleus is **[CBSE AIPMT 2003]**

(a) sometimes equal to its atomic number
(b) sometimes less than and sometimes more than its atomic number
(c) always less than its atomic number
(d) always more than its atomic number

Ans. *(a)*

Mass number

= No. of protons + No. of neutrons

For example, in case of hydrogen

Number of neutrons = 0

Thus, mass number = atomic number

Hence, sometimes the atomic number is equal to the mass number.

31 The volume occupied by an atom is greater than the volume of the nucleus by factor of about **[CBSE AIPMT 2003]**

(a) 10^{10} (b) 10^{15} (c) 10^1 (d) 10^5

Ans. *(b)*

Order of Radius of atom $\approx 10^{-10}$ m

Order of Radius of nucleus $\approx 10^{-15}$ m

Ratio of volume of atom to volume of nucleus

$$= \frac{\text{volume of atom}}{\text{volume of nucleus}} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3}$$

$$= \left(\frac{10^{-10}}{10^{-15}}\right)^3 = 10^{15}$$

32 A sample of radioactive elements contains 4×10^{10} active nuclei. If half-life of element is 10 days, then the number of decayed nuclei after 30 days is **[CBSE AIPMT 2002]**

(a) 0.5×10^{10} (b) 2×10^{10}
(c) 3.5×10^{10} (d) 1×10^{10}

Ans. *(c)*

Number of half-lives

$$n = \frac{t}{T_{1/2}} = \frac{30 \text{ days}}{10 \text{ days}} = 3$$

$[T_{1/2} = \text{half life period}]$

So, number of undecayed radioactive nuclei is given by

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \quad \begin{bmatrix} N = \text{Final number} \\ N_0 = \text{Initial number} \end{bmatrix}$$

or $N = N_0 \left(\frac{1}{2}\right)^n = 4 \times 10^{10} \left(\frac{1}{2}\right)^3$

$= 4 \times 10^{10} \times \frac{1}{8} = 0.5 \times 10^{10}$

Thus, number of nuclei decayed after 30 days

$= N_0 - N$

$= 4 \times 10^{10} - 0.5 \times 10^{10} = 3.5 \times 10^{10}$

33 In compound $X(n, \alpha) \rightarrow {}_3\text{Li}^7$, the element X is **[CBSE AIPMT 2001]**

(a) $_2\text{He}^4$ (b) $_5\text{B}^{10}$ (c) $_5\text{B}^9$ (d) $_4\text{Be}^{11}$

Ans. *(b)*

The given nuclear reaction can be written as

$$_Z X^A + {}_0n^1 \longrightarrow {}_3\text{Li}^7 + {}_2\text{He}^4$$

Conservation of mass number gives,

$A + 1 = 7 + 4 \Rightarrow A = 10$

Conservation of charge number/Atomic No. gives,

$Z + 0 = 2 + 3 \Rightarrow Z = 5$

Hence, $Z = 5$, $A = 10$ corresponds to boron ($_5\text{B}^{10}$).

34 Half-life of a radioactive substance is 12.5 h and its mass is 256 g. After what time, the amount of remaining substance is 1g ? **[CBSE AIPMT 2001]**

(a) 75 h (b) 100 h (c) 125 h (d) 150 h

Ans. *(b)*

The mass of radioactive substance remained is,

$$M = M_0 \left(\frac{1}{2}\right)^n$$

Here, final mass, $M = 1$ g, initial mass, $M_0 = 256$ g, half life period, $T_{1/2} = 12.5$ h

So, $1 = 256\left(\frac{1}{2}\right)^n$ or $\frac{1}{256} = \left(\frac{1}{2}\right)^n$

or $\left(\frac{1}{2}\right)^8 = \left(\frac{1}{2}\right)^n$

Comparing the powers on both the sides, we get

$n = 8 = \frac{t}{T_{1/2}}$

$\therefore$ $t = 8T_{1/2} = 8 \times 12.5 = 100$ h

35 Half-life period of a radioactive substance is 6 h. After 24 h activity is 0.01 μC, what was the initial activity ? **[CBSE AIPMT 2001]**

(a) 0.04 μC (b) 0.08 μC (c) 0.24 μC (d) 0.16 μC

Ans. *(d)*

The activity of a radioactive substance is

$$R = R_0 \left(\frac{1}{2}\right)^n \quad \begin{bmatrix} R = \text{Final number} \\ R_0 = \text{Initial number} \end{bmatrix}$$

Here, n = number of half-lives

$= \frac{t}{T_{1/2}} = \frac{24}{6} = 4$ $[T_{1/2} = \text{Half life period}]$

and $R = 0.01 \mu$C

So, $0.01 = R_0 \left(\frac{1}{2}\right)^4$

or $R_0 = 0.01 \times (2)^4$

$= 0.01 \times 16 = 0.16 \mu$C

36 Which of the following is positively charged ? **[CBSE AIPMT 2001]**

(a) α-particle (b) β-particle

(c) γ-rays (d) X-rays

Ans. *(a)*

Out of the given choices, X-rays and γ-rays are electromagnetic waves, so they have no charge. β-particles are negatively charged particles and are fast moving electrons. Alpha (α) particles have positive charge and is a nucleus of helium.

37 A nuclear decay is expressed as

$$_6C^{11} \longrightarrow {}_5B^{11} + \beta^+ + X$$

Then the unknown particle X is **[CBSE AIPMT 2000]**

(a) neutron (b) antineutrino

(c) proton (d) neutrino

Ans. *(d)*

Let Z be the charge number and A be the mass number of particle X, then conservation of charge number gives

$$6 = 5 + 1 + Z \Rightarrow Z = 0$$

Conservation of mass number gives,

$$11 = 11 + 0 + A \Rightarrow A = 0$$

X is a particle of zero charge and zero mass. This particle may be neutrino or antineutrino. As we know that for positive β-particle, neutrino is emitted and with negative β-particle, antineutrino is emitted.

Thus, in this case neutrino will be emitted.

38 The half-life of a radioactive material is 3 h. If the initial amount is 300 g, then after 18 h, it will remain **[CBSE AIPMT 2000]**

(a) 4.68 g (b) 46.8 g

(c) 9.375 g (d) 93.75 g

Ans. *(a)*

Number of half-lives

$$n = \frac{t}{T_{1/2}} = \frac{18}{3} = 6 \quad [T_{1/2} = \text{half life period}]$$

Amount remained after n half-lives

$$N = N_0\left(\frac{1}{2}\right)^n \quad \begin{bmatrix} N_0 = \text{initial count} \\ N = \text{final count} \end{bmatrix}$$

Given, $N_0 = 300$ g

$$\therefore \quad N = 300\left(\frac{1}{2}\right)^6 = 300 \times \frac{1}{64} = 4.68 \text{ g}$$

Alternative

Total time of decay given

$$t = \frac{2.303}{\lambda}\log_{10}\left(\frac{300}{N}\right)$$

but $\lambda = \frac{0.693}{T} = \frac{0.693}{3} = 0.231/\text{h}$

$$\therefore \quad t = \frac{2.303}{0.231}\log_{10}\left(\frac{300}{N}\right)$$

Given, $t = 18$ h

So, $18 = \frac{2.303}{0.231}\log_{10}\left(\frac{300}{N}\right)$

or $\log_{10}\left(\frac{300}{N}\right) = \frac{0.231}{2.303} \times 18$

or $\frac{300}{N} = (10)^{1.8}$

or $N = \frac{300}{(10)^{1.8}} = 4.68$ g

39 The relationship between disintegration constant (λ) and half-life (T) will be **[CBSE AIPMT 2000]**

(a) $\lambda = \frac{\log_{10} 2}{T}$ (b) $\lambda = \frac{\log_e 2}{T}$

(c) $\lambda = \frac{T}{\log_e 2}$ (d) $\lambda = \frac{\log_2 e}{T}$

Ans. *(b)*

The time required for the number of parent nuclei to fall to 50% is called half-life T and may be related to disintegration constant λ as follows. Since,

$$0.5 N_0 = N_0 e^{-\lambda T} \quad \begin{bmatrix} N = \text{Final No. of nuclei} \\ = 0.5 N_0 \\ \lambda = \text{decay constant} \end{bmatrix}$$

N_0 = Initial No. of nuclei

λ = decay constant

we have, $\lambda T = \log_e 2$

$$\therefore \quad \lambda = \frac{\log_e 2}{T}$$

40 In one α and 2 β-emissions **[CBSE AIPMT 1999]**

(a) mass number reduces by 2

(b) mass number reduces by 6

(c) atomic number reduces by 2

(d) atomic number remains unchanged

Ans. *(d)*

The α-particle can be represented as $_2\text{He}^4$ and β-particle as $_{-1}\beta^0$. So, after emission of one

α-particle the mass number of resultant nucleus decreases by 4 unit and atomic number by 2 unit. Similarly, after emission of one β-particle the atomic number increases by 1 unit keeping its mass number same. So, according to reaction (assuming $_ZX^A$ the initial nucleus)

$$_ZX^A \rightarrow {}_{Z-2}Y^{A-4} + {}_2\text{He}^4 \quad (\alpha\text{-particle})$$

and $$_{Z-2}Y^{A-4} \rightarrow {}_ZX^{A-4} + 2({}_{-1}\beta^0) \quad (2\beta\text{-particles})$$

So, by one α and two β-emissions the atomic number remains unchanged. i.e. formation of isotopes takes place.

41 Alpha particles are **[CBSE AIPMT 1999]**

(a) 2 free protons

(b) helium atoms

(c) singly ionised helium atoms

(d) doubly ionised helium atoms

Ans. *(d)*

Alpha particle is a positive particle. An alpha particle has 3.2×10^{-19} C charge twice the negative charge of an electron. The mass of an α-particle is 6.645×10^{-27} kg which is equal to mass of helium nucleus. When two electrons are emitted by a helium atom, a nucleus of helium remains which has charge equal to that of two electrons. Actually alpha (α) particle is a nucleus of helium. Hence, it is also called as doubly-ionised helium atom.

42 A nucleus $_nX^m$ emits one α and two β-particles. The resulting nucleus is **[CBSE AIPMT 1998]**

(a) $_nX^{m-4}$ (b) $_{n-2}Y^{m-4}$

(c) $_{n-4}Z^{m-4}$ (d) None of these

Ans. *(a)*

The reaction can be shown as

$$_nX^m \xrightarrow{\alpha\ (_2\text{He}^4)} {}_{n-2}Y^{m-4}$$

$$_{n-2}Y^{m-4} \xrightarrow{2\ (_{-1}\beta^0)} {}_nX^{m-4}$$

Thus, the resulting nucleus is the isotope of parent nucleus and is $_nX^{m-4}$.

43 Atomic weight of boron is 10.81 and it has two isotopes $^{10}_5$B and $^{11}_5$B. Then, the ratio of atoms of $^{10}_5$B and $^{11}_5$B in nature would be **[CBSE AIPMT 1998]**

(a) 19 : 81 (b) 10 : 11 (c) 15 : 16 (d) 81 : 19

Ans. *(a)*

Let n_1 and n_2 be the number of atoms in $^{10}_5$B and $^{11}_5$B isotopes.

Atomic weight

$$= \frac{n_1 \times (\text{At. wt. of } ^{10}_5\text{B}) + n_2 \times (\text{At. wt. of } ^{11}_5\text{B})}{n_1 + n_2}$$

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 $$\frac{n_1}{n_2} = \frac{0.19}{0.81} = \frac{19}{81}$$

Note

Atomic weight of an atom having two or more isotopes is the average of the total weight of two of more isotopes

44 Half-lives of two radioactive substances A and B are respectively 20 min and 40 min. Initially, the samples of A and B have equal number of nuclei. After 80 min the ratio of remaining number of A and B nuclei is **[CBSE AIPMT 1998]**

(a) 1 : 16 (b) 4 : 1 (c) 1 : 4 (d) 1 : 1

Ans. *(c)*

Total time given = 80 min

Number of half-lives of

$$A,\ n_A = \frac{80\text{ min}}{20\text{ min}} = 4$$

Number of half-lives of

$$B,\ n_B = \frac{80\text{ min}}{40\text{ min}} = 2$$

Number of nuclei remained undecayed

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

where N_0 is initial number of nuclei and N is final number of nuclei

So for two different cases (A) and (B),

$$\frac{N_A}{N_B} = \frac{\left(\frac{1}{2}\right)^{n_A}}{\left(\frac{1}{2}\right)^{n_B}} \text{ or } \frac{N_A}{N_B} = \frac{\left(\frac{1}{2}\right)^4}{\left(\frac{1}{2}\right)^2} = \frac{\left(\frac{1}{16}\right)}{\left(\frac{1}{4}\right)}$$

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

45 A free neutron decays into a proton, an electron and **[CBSE AIPMT 1997]**

(a) a beta particle (b) an alpha particle
(c) an antineutrino (d) a neutrino

Ans. *(c)*

Pauli suggested that after emission of β-particle (electron) a neutron is converted into a proton in a nucleus and in this reaction an electron and an antineutrino $(\bar{\nu})$ will be formed. This reaction is represented as

$$\underset{\text{(Neutron)}}{{}_0n^1} \rightarrow \underset{\text{(Proton)}}{{}_1H^1} + \underset{\text{(Electron)}}{{}_{-1}\beta^0} + \underset{\text{(Antineutrino)}}{\bar{\nu}}$$

Antineutrino is a particle whose mass is negligible and on which no charge is present.

After emission of β-particle, the total number of particles (mass-number) in a nucleus remains unchanged but no. of neutrons reduces by 1 making the no. of protons (i.e. charge-number) to increase by 1.

46 The stable nucleus that has a radius half that of Fe^{56} is **[CBSE AIPMT 1997]**

(a) Li^7 (b) Na^{21} (c) S^{16} (d) Ca^{40}

Ans. *(a)*

The relation between nuclei radius (R) and mass number (A) is given by

$$R \propto A^{1/3} \quad \text{...(i)}$$

or $A \propto R^3$

or $\frac{A_1}{A_2} = \left(\frac{R_1}{R_2}\right)^3$

Given, $R_1 = R,\ R_2 = \frac{R}{2},\ A_1 = 56$

$\therefore \quad \frac{56}{A_2} = \left(\frac{R}{R/2}\right)^3 = 2^3 = 8$

or $A_2 = \frac{56}{8} = 7$

Thus, required stable nucleus will be Li^7.

47 The activity of a radioactive sample is measured as 9750 counts/min at $t = 0$ and as 975 counts/min at $t = 5$ min. The decay constant is approximately **[CBSE AIPMT 1997]**

(a) 0.922/min (b) 0.691/min
(c) 0.461/min (d) 0.230/min

Ans. *(c)*

According to law of radioactivity

$$\frac{N}{N_0} = e^{-\lambda t} \quad \text{...(i)}$$

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

$\begin{bmatrix} N = \text{final concentration} \\ N_0 = \text{initial concentration} \\ \lambda = \text{decay constant} \end{bmatrix}$

Taking logarithm on both sides of Eq. (i), we have

$$\log_e\left(\frac{N_0}{N}\right) = \log_e(e^{\lambda t})$$

$$= \lambda t \log_e e = \lambda t$$

As we know that, $\log_e x = 2.3026 \log_{10} x$

Making substitution, we get

$$\lambda = \frac{2.3026 \log_{10}\left(\frac{9750}{975}\right)}{5}$$

$[\because N_0 = 9750 \text{ counts/min and } N = 975 \text{ counts/min}]$

$$= \frac{2.3026}{5}\log_{10} 10 = \frac{2.3026}{5}\text{ min}^{-1}$$

$$= 0.461\text{ min}^{-1}$$

48 The most penetrating radiation out of the following is **[CBSE AIPMT 1997]**

(a) γ-rays (b) α-particles
(c) β-rays (d) X-rays

Ans. *(a)*

The penetrating power of radiation is directly proportional to the energy of its photon.

Energy of photon $= \frac{hc}{\lambda} \propto \frac{1}{\lambda}$ (wavelength)

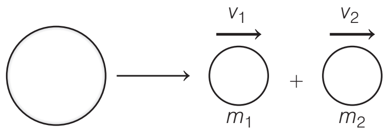
$\therefore$ Penetrating power $\propto \frac{1}{\lambda}$ (wavelength)

Since, λ is minimum for γ-rays, so penetrating power is maximum for γ-rays.

49 A nucleus ruptures into two nuclear parts, which have their velocity ratio equal to 2 : 1. What will be the ratio of their nuclear size (nuclear radius)? **[CBSE AIPMT 1996]**

(a) $2^{1/3}:1$ (b) $1:2^{1/3}$ (c) $3^{1/2}:1$ (d) $1:3^{1/2}$

Ans. *(b)*



From law of conservation of momentum

$0 = m_1v_1 + m_2v_2$

$\therefore \quad m_1v_1 = -m_2v_2$

or $\frac{v_1}{v_2} = -\frac{m_2}{m_1} = \frac{2}{1}$

One sign indicates that velocity is in opposite direction

As nucleus is assumed to be spherical of radius r, density ρ.

$\therefore \quad m = \frac{4}{3}\pi r^3\rho \Rightarrow m \propto r^3$

So for two different parts of nuclei,

$$\frac{m_2}{m_1} = \frac{r_2^3}{r_1^3}$$

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

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

50 The count rate of a Geiger Muller counter for the radiation of a radioactive material of half-life 30 min decreases to 5 s^{-1} after 2 h. The initial count rate was **[CBSE AIPMT 1995]**

(a) 20 s^{-1} (b) 25 s^{-1} (c) 80 s^{-1} (d) 625 s^{-1}

Ans. *(c)*

The equation for initial and final count rate is

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

$\begin{bmatrix} N = \text{final count rate} \\ N_0 = \text{initial rate of radio-active atom} \end{bmatrix}$

where, $n = \frac{t}{T_{1/2}}$

Here, $n = \frac{120}{30} = 4$

$[\because t = 2h = 2 \times 60 \text{ min} = 120 \text{ min}]$

$\therefore \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$

or $\quad N_0 = 16 \times N = 16 \times 5 = 80 \ s^{-1}$

51 What is the respective number of α and β-particles emitted in the following radioactive decay

$^{200}X_{90} \longrightarrow {}^{168}Y_{80}$?

[CBSE AIPMT 1995]

(a) 6 and 8 (b) 6 and 6
(c) 8 and 8 (d) 8 and 6

Ans. *(d)*

Suppose x α-particles and y β-particles are emitted

So, change in mass no. is given by

$$4x = 200 - 168 = 32$$
$$x = 8$$

and change in atomic no. is given by

$$2x - y = 90 - 80 = 10$$

putting value of x

or $\quad 2 \times 8 - y = 10$

So, no. of β-particles $\quad y = 6$

No. of α-particles $\quad x = 8$

Alternative

$$^{200}X_{90} \longrightarrow {}^{168}Y_{80}$$

As,

$$^{200}X_{90} \longrightarrow (n\,{}_2He^4) + m({}_{-1}\beta^0) + {}^{168}Y_{80}$$

Therefore, in this reaction

$$200 = 4n + 168 \quad \text{or} \quad n = \frac{200 - 168}{4} = 8$$

Also, $\quad 90 = 2n - m + 80$

or $\quad m = 2n + 80 - 90$

$$= 2 \times 8 + 80 - 90 = 6$$

Thus, respective number of α and β-particles will be 8 and 6.

52 The mass number of He is 4 and that for sulphur is 32. The radius of sulphur nuclei is larger than that of helium by **[CBSE AIPMT 1994]**

(a) $\sqrt{8}$ (b) 4 (c) 2 (d) 8

Ans. *(c)*

Volume of a nucleus is proportional to its mass number A. If R is the radius of the nucleus assumed to be spherical, then its volume $(v) \propto A$ (mass No.)

So, $\left(\frac{4}{3}\pi R^3\right) \propto A \quad$ or $\quad R \propto A^{1/3}$

$$\therefore \quad \frac{R_S}{R_{He}} = \left(\frac{A_S}{A_{He}}\right)^{1/3} = \left(\frac{32}{4}\right)^{1/3} = 2$$

or $\quad R_S = 2R_{He}$

53 In a given reaction,

$${}_ZX^A \rightarrow {}_{Z+1}Y^A \rightarrow {}_{Z-1}K^{A-4} \rightarrow {}_{Z-1}K^{A-4}$$

Radioactive radiations are emitted in the sequence of

[CBSE AIPMT 1993]

(a) α, β, γ (b) γ, α, β (c) β, α, γ (d) γ, β, α

Ans. *(c)*

When a nucleus emits an alpha particle, its mass number decreases by 4 and charge/atomic no. decreases by 2. In β-particle emission, mass remains same but atomic number is increased by one. In γ-decay, daughter nucleus has the same charge number and same mass number as those of parent nucleus. Hence, sequence is

$${}_ZX^A \xrightarrow{\beta} {}_{Z+1}Y^A \xrightarrow{\alpha} {}_{Z-1}K^{A-4} \xrightarrow{\gamma} {}_{Z-1}K^{A-4}$$

54 The mass density of a nucleus varies with mass number A as

[CBSE AIPMT 1992]

(a) A^2 (b) A
(c) constant (d) $\frac{1}{A}$

Ans. *(c)*

Density of nuclear matter is the ratio of mass of nucleus and its volume.

If m is average mass of a nucleon and R is the nuclear radius, then mass of nucleus $= mA$, where A is the mass number of the element.

Volume of nucleus $= \frac{4}{3}\pi R^3$

$$= \frac{4}{3}\pi (R_0 A^{1/3})^3 = \frac{4}{3}\pi R_0^3 A$$

As density of nuclear matter

$$= \frac{\text{mass of nucleus}}{\text{volume of nucleus}}$$

$$\rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$\therefore \quad \rho = \frac{3m}{4\pi R_0^3}$$

As m and R_0 are constants, therefore density ρ of nuclear matter is constant.

55 If the nuclear force between two protons, two neutrons and between proton and neutron is denoted by F_{pp}, F_{nn} and F_{pn} respectively, then

[CBSE AIPMT 1991]

(a) $F_{pp} \approx F_{nn} \approx F_{pn}$
(b) $F_{pp} \neq F_{nn}$ and $F_{pp} = F_{nn}$
(c) $F_{pp} = F_{nn} = F_{pn}$
(d) $F_{pp} \neq F_{nn} \neq F_{pn}$

Ans. *(c)*

Nuclear forces act between a pair of neutrons, a pair of protons and also between a neutron-proton pair, with the same strength. This shows that nuclear forces are independent of charge.

56 In the nucleus of ${}_{11}Na^{23}$, the number of protons, neutrons and electrons are **[CBSE AIPMT 1991]**

(a) 11, 12, 0 (b) 23, 12, 11
(c) 12, 11, 0 (d) 23, 11, 12

Ans. *(a)*

A nucleus of mass number A and atomic number Z contains Z protons and $(A - Z)$ neutrons. As an atom is electrically neutral, therefore number of peripheral electrons must be equal to Z, the number of protons inside the nucleus. In ${}_{11}Na^{23}$, $Z = 11$ i.e. number of protons $= 11$,

Mass number $A = 23$

Number of neutrons $= A - Z = 23 - 11 = 12$

There is no electron in the nucleus.

So, number of protons, neutrons and electrons are 11, 12, 0.

57 The half-life of radium is 1600 yr. The fraction of a sample of radium that would remain after 6400 yr

[CBSE AIPMT 1991]

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) $\frac{1}{8}$ (d) $\frac{1}{16}$

Ans. *(d)*

Number of atoms left after n half-lives is given by

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

$$\begin{bmatrix} N_0 = \text{initial count} \\ N = \text{final count rate of the n half life} \end{bmatrix}$$

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

where $\quad n = \frac{t}{T_{1/2}}$

$$\therefore \quad n = \frac{6400}{1600} = 4 \quad \begin{bmatrix} t = 6400 \\ T_{1/2} = 1600 \end{bmatrix}$$

$$\therefore \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$$

58 The constituents of atomic nuclei are believed to be

[CBSE AIPMT 1991]

(a) neutrons and protons
(b) protons only
(c) electrons and protons
(d) electrons, protons and neutrons

Ans. ***(a)***

According to proton-neutron hypothesis, a nucleus of mass number A and atomic number Z contains Z protons and $(A-Z)$ neutrons. Constituents of atomic nucleus are Nucleons i.e. neutron and proton.

59 The nucleus $_6C^{12}$ absorbs an energetic neutron and emits a beta particle (β). The resulting nucleus is **[CBSE AIPMT 1990]**

(a) $_7N^{14}$ (b) $_7N^{13}$ (c) $_5B^{13}$ (d) $_6C^{13}$

Ans. ***(b)***

A nuclear reaction represents the transformation of one stable nucleus into another nucleus by bombarding the former with suitable high energy particles.

$$_6C^{12} + {_0n^1} \rightarrow {_6C^{13}} \rightarrow {_7N^{13}} + {_{-1}\beta^0} + Q \text{ (Energy)}$$

Resulting nucleus is of nitrogen having mass no. 13 and atomic no. 7

60 The ratio of the radii of the nuclei $_{13}Al^{27}$ and $_{52}Te^{125}$ is approximately **[CBSE AIPMT 1990]**

(a) 6 : 10 (b) 13 : 52
(c) 40 : 177 (d) 14 : 73

Ans. ***(a)***

Experimental measurements show that volume of a nucleus is proportional to its mass number A. If R is the radius of the nucleus assumed to be spherical, then its volume and mass no. relation is given by

Volume $(V) \propto$ mass no. (A)

or $\left(\frac{4}{3}\pi R^3\right) \propto A$

or $R \propto A^{1/3}$

$\therefore \frac{R_{Al}}{R_{Te}} = \frac{(27)^{1/3}}{(125)^{1/3}} = \frac{3}{5} = \frac{6}{10}$

61 Which of the following statements is true for nuclear forces? **[CBSE AIPMT 1990]**

(a) They obey the inverse square law of distance.
(b) They obey the inverse third power law of distance
(c) They are short range forces
(d) They are equal in strength to electromagnetic forces

Ans. ***(c)***

Nuclear forces are the short range forces of attraction which hold together the nucleons (neutrons and protons) in the tiny nucleus of an atom, inspite of strong electrostatic forces of repulsion between protons. Nuclear forces are charge independent forces. They are the strongest forces in nature. The magnitude of nuclear forces is 100 times that of electrostatic forces and 10^{38} times that of gravitational forces between nucleons. They are operative upto distances of the order of a few fermi. They are non-central forces.

62 The nuclei $_6C^{13}$ and $_7N^{14}$ can be described as **[CBSE AIPMT 1990]**

(a) isotones
(b) isobars
(c) isotopes of carbon
(d) isotopes of nitrogen

Ans. ***(a)***

Isotones are the nuclides which contain the same number of neutrons. In $_6C^{13}$ and $_7N^{14}$, number of neutrons in carbon $= 13-6=7$ and number of neutrons in nitrogen $= 14-7=7$.

No. of neutrons is given by mass no. (A) – atomic no. (Z)

63 An element A decays into element C by a two step process

$$A \rightarrow B + {_2He^4}$$
$$B \rightarrow C + 2e^-$$

then **[CBSE AIPMT 1989]**

(a) A and C are isotopes
(b) A and C are isobars
(c) A and B are isotopes
(d) A and B are isobars

Ans. ***(a)***

From equation (Ist) there is $1\propto$-decay in which B has atomic no. 2 less than A. In IInd case there is 2-β-decay in which C has atomic no. 2 greater than B, Since A and C have same atomic no. so they are called isotopes.

64 A radioactive element has half-life period 800 yr. After 6400 yr, what amount will remain? **[CBSE AIPMT 1989]**

(a) $\frac{1}{2}$ (b) $\frac{1}{16}$
(c) $\frac{1}{8}$ (d) $\frac{1}{256}$

Ans. ***(d)***

Number of atoms left after n half-lives is given by

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

Number of half-lives,

$$n = \frac{t}{T} = \frac{6400}{800} = 8$$

$$\therefore \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^8 = \frac{1}{256}$$

Alternative

Let the initial part be unity

So, after 800 years, it will remain $= \frac{1}{2}$

after 1600 years, it will remain $= \frac{1}{4}$

after 2400 years, it will remain $= \frac{1}{8}$

after 3200 years, it will remain $= \frac{1}{16}$

after 4000 years, it will remain $= \frac{1}{32}$

after 4800 years, it will remain $= \frac{1}{64}$

after 5600 years, it will remain $= \frac{1}{128}$

after 6400 years, it will remain $= \frac{1}{256}$

65 The nucleus $_{48}Cd^{115}$, after two successive β-decay will give **[CBSE AIPMT 1988]**

(a) $_{46}Pa^{115}$ (b) $_{49}In^{114}$
(c) $_{50}Sn^{113}$ (d) $_{50}Sn^{115}$

Ans. ***(d)***

When a parent nucleus emits a β-particle (i.e, an electron) mass number remains same because mass of electron is negligibly low. Atomic number is increased by one. The nucleus $_{48}Cd^{115}$ after two successive β-decays will give $_{50}Sn^{115}$.

66 A radioactive sample with a half-life of 1 month has the label : 'Activity = 2 microcurie on 1-8-1991'. What would be its activity two months earlier? **[CBSE AIPMT 1988]**

(a) 1.0 microcurie (b) 0.5 microcurie
(c) 4 microcurie (d) 8 microcurie

Ans. ***(d)***

The activity of a radioactive substance is defined as the rate at which the nuclei of its atoms in the sample disintegrate. In two half-lives, the activity becomes one-fourth. Two months is 2 half-life period. The activity, two months earlier was $2 \times 2^2 = 8$ microcurie.

Note

The activity of a radioactive sample is called one curie, if it undergoes 3.7×10^{10} disintegrations per second.

TOPIC 2

Nuclear Fission & Fusion and Binding Energy

67 A nucleus with mass number 240 breaks into two fragments each of mass number 120, the binding energy per nucleon of unfragmented nuclei is 7.6 MeV while that of fragments is 8.5 MeV. The total gain in the binding energy in the process is **[NEET 2021]**

(a) 0.9 MeV (b) 9.4 MeV
(c) 804 MeV (d) 216 MeV

Ans. ***(d)***

A nucleus with mass number 240 breaks into two fragment each of mass number 120.

$$X^{240} \longrightarrow Y^{120} + Z^{120}$$

Given, the binding energy per nucleon of unfragmented nuclei, $X = 7.6$ MeV

The binding energy per nucleon of fragmented nuclei, $Y = Z = 8.5$ MeV

Now, we shall determine the total gain in binding energy.

Gain in binding energy = Binding energy of products – Binding energy of reactants

Gain in binding energy

$= 2 \times 120 \times 8.5 - 240 \times 7.6$

$= 216$ MeV

68 The energy equivalent of 0.5 g of a substance is **[NEET (Sep.) 2020]**

(a) 4.5×10^{13} J (b) 1.5×10^{13} J
(c) 0.5×10^{13} J (d) 4.5×10^{16} J

Ans. ***(a)***

Given, $m = 0.5\,g = 0.5 \times 10^{-3}$ kg

Relation for energy equivalent of mass is

$$E = mc^2$$

where, c is speed of light.

$$= 0.5 \times 10^{-3} \times (3 \times 10^8)^2 \quad (\because c = 3 \times 10^8)$$

$$= 4.5 \times 10^{13} \text{ J}$$

Hence, correct option is (a).

69 When a uranium isotope $^{235}_{92}U$ is bombarded with a neutron, it generates $^{89}_{36}Kr$, three neutrons and **[NEET (Sep.) 2020]**

(a) $^{91}_{40}Zr$ (b) $^{101}_{36}Kr$ (c) $^{103}_{36}Kr$ (d) $^{144}_{56}Ba$

Ans. ***(d)***

Here,

$$^{235}_{92}U + ^1_0n \longrightarrow ^{89}_{36}Kr + ^A_ZX + 3(^1_0n)$$

According to the law of conservation,

(Atomic number)$_{Reactant}$ = (Atomic number)$_{Product}$

$$92 + 0 = 36 + Z$$

$\Rightarrow \quad Z = 92 - 36 = 56$

Similarly,

(Atomic masses)$_{Reactant}$ = (Atomic masses)$_{Product}$

$$235 + 1 = 89 + A + 3 \times 1$$

$\Rightarrow \quad A = 144$

$\therefore$ Other element is $^{144}_{56}Ba$.

Hence, correct option is (d).

70 A nucleus of uranium decays at rest into nuclei of thorium and helium. Then, **[CBSE AIPMT 2015]**

(a) the helium nucleus has more kinetic energy than the thorium nucleus
(b) the helium nucleus has less momentum than the thorium nucleus
(c) the helium nucleus has more momentum than the thorium nucleus
(d) the helium nucleus has less kinetic energy than the thorium nucleus

Ans. ***(a)***

$$_{92}U^{238} \longrightarrow {}_{92}Th^{238} + {}_2He^4$$

According to law of conservation of linear momentum, we have.

$$|P_{Th}| = |P_{He}| = P$$

$\Rightarrow$ As, kinetic energy of an element,

$$KE = \frac{P^2}{2m}$$

where, m is mass of an element.

Thus, $KE \propto \frac{1}{M}$

So, $M_{He} < M_{Th} \Rightarrow K_{He} > K_{Th}$

71 The binding energy per nucleon of ^7_3Li and ^4_2He nuclei are 5.60 MeV and 7.06 MeV, respectively. In the nuclear reaction $^7_3Li + ^1_1H \rightarrow ^4_2He + ^4_2He + Q$, the value of energy Q released is **[CBSE AIPMT 2014]**

(a) 19.6 MeV (b) – 2.4 MeV
(c) 8.4 MeV (d) 17.3 MeV

Ans. ***(d)***

The binding energy for $_1H^1$ is around zero and also not given in the question so we can ignore it

$Q = 2(4 \times 7.06) - (7 \times 5.60)$

$= 2(E_{bn}$ of He$) - (E_{bn}$ of Li$)$

$= (8 \times 7.06) - (7 \times 5.60)$

$= (56.48 - 39.2)$ MeV

$\therefore \quad Q = 17.28$ MeV $\simeq 17.3$ MeV

72 A certain mass of hydrogen is changed to helium by the process of fusion. The mass defect in fusion reaction is 0.02866 u. The energy liberated per u is (given 1 u = 931 MeV) **[NEET 2013]**

(a) 2.67 MeV (b) 26.7 MeV
(c) 6.675 MeV (d) 13.35 MeV

Ans. ***(c)***

Given, $\Delta m = 0.02866$ u

$\therefore$ Energy liberated $= \Delta mc^2$

$\Rightarrow$ Energy liberated per u

$$= \frac{0.02866 \times 931}{4} = \frac{26.7}{4} \text{ MeV}$$

$$= \frac{E_b}{A} = 6.675 \text{ MeV}$$

73 Fusion reaction takes place at high temperature because **[CBSE AIPMT 2011]**

(a) atoms get ionised at high temperature
(b) kinetic energy is high enough to overcome the coulomb repulsion between nuclei
(c) molecules break up at high temperature
(d) nuclei break up at high temperature

Ans. ***(b)***

Fusion reaction takes place at high temperature because kinetic energy is high enough to overcome the couloumb repulsion between nuclei.

74 The mass of a ^7_3Li nucleus is 0.042u less than the sum of the masses of all its nucleons. The binding energy per nucleon of ^7_3Li nucleus is nearly **[CBSE AIPMT 2010]**

(a) 46 MeV (b) 5.6 MeV
(c) 3.9 MeV (d) 23 MeV

Ans. ***(b)***

If $m = 1$ u, $c = 3 \times 10^8 ms^{-1}$, then

$E = 931$ MeV i.e. 1 u = 931 MeV

Binding energy $= 0.042 \times 931 = 39.10$ MeV

$\therefore$ Binding energy per nucleon

$$= \frac{39.10}{7} = 5.58 \approx 5.6 \text{ MeV}$$

75 A nucleus ^A_ZX has mass represented by $m(A, Z)$. If m_p and m_n denote the mass of proton and neutron respectively and BE the binding energy (in MeV), then **[CBSE AIPMT 2007]**

(a) $BE = [m(A, Z) - Zm_p - (A - Z)\, m_n]\, c^2$
(b) $BE = [Zm_p + (A - Z)\, m_n - m(A, Z)]\, c^2$
(c) $BE = [Zm_p + Am_n - m(A, Z)]\, c^2$
(d) $BE = m(A, Z) - Zm_p - (A - Z)\, m_n$

Ans. *(b)*

In the case of formation of a nucleus, the evolution of energy equal 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 nucleus 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.

76 The binding energy of deuteron is 2.2 MeV and that of ${}^4_2He$ is 28 MeV. If two deuterons are fused to form one ${}^4_2He$, then the energy released is **[CBSE AIPMT 2006]**

(a) 25.8 MeV (b) 23.6 MeV
(c) 19.2 MeV (d) 30.2 MeV

Ans. *(b)*

The reaction can be written as

$${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + \text{energy}$$

The energy released in the reaction is the difference of binding energies of daughter and parent nuclei.

Hence, energy released

$$= \text{binding energy of } {}_2He^4 - 2 \times \text{binding energy of } {}_1H^2$$
$$= 28 - 2 \times 2.2 = 23.6 \text{ MeV}$$

77 In any fission process the ratio $\dfrac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is **[CBSE AIPMT 2005]**

(a) less than 1
(b) greater than 1
(c) equal to 1
(d) depends on the mass of parent nucleus

Ans. *(a)*

In fission process, when a parent nucleus breaks into daughter products, then some mass is lost in the form of energy.

Thus,
mass of fission products < mass of parent nucleus

$$\Rightarrow \frac{\text{Mass of fission products}}{\text{Mass of parent nucleus}} < 1$$

78 Fission of nuclei is possible because the binding energy per nucleon in them **[CBSE AIPMT 2005]**

(a) increases with mass number at high mass numbers
(b) decreases with mass number at high mass numbers
(c) increases with mass number at low mass numbers
(d) decreases with mass number at low mass numbers

Ans. *(b)*

The binding energy per nucleon for the middle nuclides (from $A = 20$ to $A = 56$) is maximum. Hence, these are more stable. As the mass number increases, the binding energy per nucleon gradually decreases and ultimately binding energy per nucleon of heavy nuclides (such as uranium etc.) is comparatively low. Hence, these nuclides are relatively unstable. So, they can be fissioned easily.

79 In the reaction ${}^2_1H + {}^3_1H \rightarrow {}^4_2He + {}^1_0n$, if the binding energies of ${}^2_1H$, ${}^3_1H$ and ${}^4_2He$ are respectively a, b and c (in MeV), then the energy (in MeV) released in this reaction is **[CBSE AIPMT 2005]**

(a) $c + a - b$ (b) $c - a - b$
(c) $a + b + c$ (d) $a + b - c$

Ans. *(b)*

Given, Binding energy of $({}^2_1H + {}^3_1H) = a + b$
Binding energy of ${}^4_2He = c$

In a nuclear reaction, the resultant nucleus is more stable than the reactants. Hence, binding energy of ${}^4_2He$ will be more than that of $({}^2_1H + {}^3_1H)$.

Thus, energy released per nucleon
= resultant binding energy
Binding energy of product – Binding energy of reactants

$$= c - (a + b) = c - a - b$$

80 m_p denotes the mass of a proton and m_n that of a neutron. A given nucleus of binding energy BE, contains Z protons and N neutrons. The mass $m(N, Z)$ of the nucleus is given by **[CBSE AIPMT 2004]**

(a) $m(N, Z) = Nm_n + ZM_p - BEc^2$
(b) $m(N, Z) = Nm_n + Zm_p + BEc^2$
(c) $m(N, Z) = Nm_n + Zm_p - BE/c^2$
(d) $m(N, Z) = Nm_n + Zm_p + BE/c^2$

Ans. *(c)*

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

$$BE = [Nm_n + Zm_p - m(N, Z)]\, c^2$$
$$\Rightarrow \frac{BE}{c^2} = Nm_n + Zm_p - m(N, Z)$$
$$\Rightarrow m(N, Z) = Nm_n + Zm_p - BE/c^2$$

81 If in a nuclear fusion process, the masses of the fusing nuclei be m_1 and m_2 and the mass of the resultant nucleus be m_3, then **[CBSE AIPMT 2004]**

(a) $m_3 = m_1 + m_2$
(b) $m_3 = |m_1 - m_2|$
(c) $m_3 < (m_1 + m_2)$
(d) $m_3 > (m_1 + m_2)$

Ans. *(c)*

In a nuclear fusion, when two light nuclei of different masses are combined to form a stable nucleus, then some mass is lost and appears in the form of energy, called the mass defect. So, the mass of resultant nucleus is always less than the sum of masses of initial nuclei i.e.,

$$m_3 < (m_1 + m_2)$$

82 Solar energy is mainly caused due to **[CBSE AIPMT 2003]**

(a) fusion of protons during synthesis of heavier elements
(b) gravitational contraction
(c) burning of hydrogen in the oxygen
(d) fission of uranium present in the sun

Ans. *(a)*

In sun, huge amount of energy is produced due to fusion of 4 protons (hydrogen nucleus) into a helium nucleus. According to the reaction

$${}_1H^1 + {}_1H^1 + {}_1H^1 + {}_1H^1 \longrightarrow {}_2He^4 + 2\,{}_{+1}\beta^0 + \gamma\,(\text{energy}) + 2\upsilon$$

83 The mass of proton is 1.0073 u and that of neutron is 1.0087 u (u = atomic mass unit) The binding energy of ${}_2He^4$ is (mass of helium nucleus = 4.0015 u) **[CBSE AIPMT 2003]**

(a) 28.4 MeV (b) 0.061 u
(c) 0.0305 J (d) 0.0305 erg

Ans. *(a)*

${}_2He^4$ contains 2 neutrons and 2 protons
So, mass of 2 protons

$$= 2 \times 1.0073 = 2.0146\,u$$

So, mass of 2 neutrons

$= 2 \times 1.0087 = 2.0174$ u

Total mass of 2 protons and 2 neutrons

$= (2.0146 + 2.0174)$ u $= 4.032$ u

Mass of helium nucleus $= 4.0015$ u

Thus, mass defect is lacking of mass in forming the helium nucleus from 2 protons and 2 neutrons.

$\therefore \Delta m =$ mass defect $= (4.032 - 4.0015)$ u

$= 0.0305$ u

As we know that, 1u = 931 MeV

Hence, binding energy

$\Delta E = (\Delta m) \times 931$

$= 0.0305 \times 931 = 28.4$ MeV

84 When a deuterium is bombarded on ${}_8O^{16}$ nucleus, an α-particle is emitted, then the product nucleus is **[CBSE AIPMT 2002]**

(a) ${}_7N^{13}$ (b) ${}_5B^{10}$ (c) ${}_4Be^9$ (d) ${}_7N^{14}$

Ans. *(d)*

Let the unknown product nucleus be ${}_ZX^A$.

The reaction can be written as

$$\underset{\text{(Oxygen)}}{{}_8O^{16}} + \underset{\text{(deuterium)}}{{}_1H^2} \longrightarrow \underset{\text{(unknown nucleus)}}{{}_ZX^A} + \underset{\alpha-\text{particle}}{{}_2He^4}$$

Conservation of mass number between product and reactant of above reaction gives,

$16 + 2 = A + 4 \Rightarrow A = 14$

Conservation of atomic number between reactant and product of above reaction gives

$8 + 1 = Z + 2 \Rightarrow Z = 7$

Thus, the unknown product nucleus is nitrogen (${}_7N^{14}$).

Note

Fusion reaction can take place at very high temperature ($\approx 10^8$ K) and very high pressure which can be provided at sun or by fission of atom bomb.

85 Which of the following are suitable for the fusion process ? **[CBSE AIPMT 2002]**

(a) Light nuclei
(b) Heavy nuclei
(c) Elements lying in the middle of periodic table
(d) Elements lying in the middle of binding energy curve

Ans. *(a)*

Binding energy for light nuclei ($A < 20$) is much smaller than the binding energy for heavier nuclei. This suggests a process that is reverse of fission. When two light nuclei combine to form a heavier nucleus, the process is called nuclear fusion. The union of two light nuclei into heavier nuclei also lead to a transfer of mass and a consequent liberation of large amount energy.

86 In nuclear fission process, energy is released because **[CBSE AIPMT 2001]**

(a) mass of products is more than mass of nucleus
(b) total binding energy of products formed due to nuclear fission is more than the parent fissionable material
(c) total binding energy of products formed due to nuclear fission is less than parent fissionable material
(d) mass of some particles is converted into energy

Ans. *(b)*

In a nuclear process, energy is released if binding energy per nucleon of the daughter products gets increased. In nuclear fission reaction, total binding energy of products formed due to nuclear fission is more than the parent fissionable material.

87 m_p and m_n are masses of proton and neutron respectively. An element of mass m has Z protons and N neutrons, then **[CBSE AIPMT 2001]**

(a) $m > Zm_p + Nm_n$
(b) $m = Zm_p + Nm_n$
(c) $m < Zm_p + Nm_n$
(d) m may be greater than, less than or equal to $Zm_p + Nm_n$, depending on nature of element

Ans. *(c)*

When a nucleus is formed, then the mass of nucleus is slightly less than the sum of masses of Z protons and N neutrons.

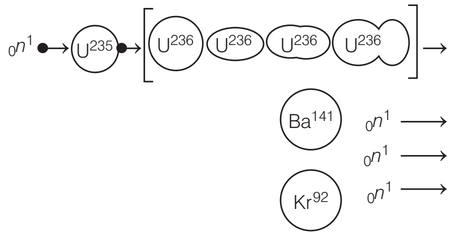
i.e., $m < (Zm_p + Nm_n)$

88 Nuclear fission can be explained by **[CBSE AIPMT 2000]**

(a) proton-proton cycle
(b) liquid drop model of nucleus
(c) independent of nuclear particle model
(d) nuclear shell model

Ans. *(b)*

Neil Bohr and J.A. Wheeler explained the nuclear fission on the basis of liquid drop model of the nucleus. The ${}_{92}U^{235}$ nucleus behaves like a liquid drop and owing to surface tension is perfectly spherical in shape. When the neutron strikes the nucleus, some energy called the excitation energy is imparted to the nucleus.



The phenomenon of surface tension tries to keep the nucleus spherical in shape, whereas the excitation energy tries to deform it. Due to the struggle between the surface tension and the excitation energy, the oscillations are set up inside the compound nucleus.

As a result, the nucleus gets deformed from spherical shape to ellipsoidal and then to a dumb bell as shown, till the Coulomb's repulsive force between protons succeeds in tearing the two bells apart.

89 Complete the equation for the following fission process

${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{38}Sr^{90} + \ldots\ldots$ **[CBSE AIPMT 1998]**

(a) ${}_{54}Xe^{143} + 3\,{}_0n^1$
(b) ${}_{54}Xe^{145}$
(c) ${}_{57}Xe^{142}$
(d) ${}_{54}Xe^{142} + {}_0n^1$

Ans. *(a)*

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

If total atomic number on LHS

$= 92 + 0 = 92$

Total atomic number on RHS

$= 38 + 54 + 0 = 92$

Total mass number on LHS

$= 235 + 1 = 236$

Total mass number on RHS

$= 90 + 143 + 3 \times 1 = 236$

So, option (a) is correct.

Note

For a nuclear reaction to be completed, the mass number and charge number on both sides should be same.

90 In a fission reaction,

$${}^{236}_{92}U \rightarrow {}^{117}X + {}^{117}Y + n + n$$

the binding energy per nucleon of X and Y is 8.5 MeV whereas of ${}^{236}U$ is 7.6 MeV. The total energy liberated will be about **[CBSE AIPMT 1997]**

(a) 2000 MeV (b) 200 MeV
(c) 2 MeV (d) 1 keV

Ans. *(b)*

Binding energy of fissioned nucleus

$= 236 \times 7.6$ MeV

Binding energy of products

$= 117 \times 8.5 + 117 \times 8.5$

$= 2 \times 117 \times 8.5$

Hence, net binding energy = binding energy of products – binding energy of fissioned nucleus

$= 234 \times 8.5 - 236 \times 7.6$

$= 1989 - 1793.6 = 195.4$ MeV

≈ 200 MeV

Thus, in per fission of uranium nearly 200 MeV energy is released.

91 Which of the following is used as a moderator in nuclear reactors ? **[CBSE AIPMT 1997]**

(a) Plutonium (b) Cadmium

(c) Heavy water (d) Uranium

Ans. *(c)*

Moderator in a nuclear reactor is used to slow down the fast moving neutrons. Heavy water, graphite or beryllium oxide are used as moderators. Heavy water is best moderator.

Note

In an ordinary uranium reactor, plutonium (Pu^{239}) is produced which is a better fissionable material than uranium (U^{235}). It is a heavy isotope of uranium.

92 Heavy water is used as a moderator in a nuclear reactor. The function of the moderator is **[CBSE AIPMT 1994]**

(a) to control energy released in the reactor

(b) to absorb neutrons and stop chain reaction

(c) to cool the reactor

(d) to slow down the neutrons to thermal energies

Ans. *(d)*

The function of a moderator is to slow down the fast moving secondary neutrons produced during the fission as fission reaction can only be initiated by slow moving neutrons.

The material of moderator should be light and it should not absorb neutrons. Usually, heavy water, graphite, deuterium, paraffin etc. can act as moderators. These moderators are rich in protons.

93 If the binding energy per nucleon in $_3Li^7$ and $_2He^4$ nuclei are respectively 5.60 MeV and 7·06 MeV, then the energy of proton in the reaction

$_3Li^7 + p \longrightarrow 2\,_2He^4$ is **[CBSE AIPMT 1994]**

(a) 19.6 MeV

(b) 2.4 MeV

(c) 8.4 MeV

(d) 17.3 MeV

Ans. *(d)*

Total BE of nucleons in $_3Li^7$

$= 7 \times 5.60 = 39.20$ MeV

Total BE of nucleons in $2(_2He^4)$

$= (4 \times 7.06) \times 2 = 56.48$ MeV

Therefore, energy of protons in the reaction

= difference of BE's

$= 56.48 - 39.20 = 17.3$ MeV

94 Energy released in the fission of a single $_{92}U^{235}$ nucleus is 200 MeV. The fission rate of a $_{92}U^{235}$ filled reactor operating at a power level of 5 W is **[CBSE AIPMT 1993]**

(a) $1.56 \times 10^{-10}\ s^{-1}$ (b) $1.56 \times 10^{11}\ s^{-1}$

(c) $1.56 \times 10^{-16}\ s^{-1}$ (d) $1.56 \times 10^{-17}\ s^{-1}$

Ans. *(b)*

$$\text{Fission rate} = \frac{\text{total nuclear power}}{\text{energy produced / fission}}$$

Here, total nuclear power = 5 W

Energy released per fission = 200 MeV

$$\therefore \text{Fission rate} = \frac{5}{200\ \text{MeV}}$$

$$= \frac{5}{200 \times 1.6 \times 10^{-13}}$$

[∵1 Mev J]

$= 1.56 \times 10^{11}\ s^{-1}$

95 The binding energy per nucleon is maximum in case of **[CBSE AIPMT 1993]**

(a) $_2He^4$ (b) $_{26}Fe^{56}$

(c) $_{56}Ba^{141}$ (d) $_{92}U^{235}$

Ans. *(b)*

The binding energy curve has a broad maximum in the range $A = 30$ to $A = 120$ corresponding to average binding energy per nucleon = 8 MeV. The peak value of the maximum is 8.8 MeV/N for $_{26}Fe^{56}$.

96 The energy equivalent of one atomic mass unit is **[CBSE AIPMT 1992]**

(a) 1.6×10^{-19} J (b) 6.02×10^{23} J

(c) 931 MeV (d) 9.31 MeV

Ans. *(c)*

According to Einstein, mass-energy equivalence is represented by $E = mc^2$.

Taking, mass, $m = 1$ amu

$= 1.66 \times 10^{-27}$ kg,

and velocity of light in vacuum,

$c = 3.0 \times 10^8$ m/s

We get, $E = (1.66 \times 10^{-27}) \times (3 \times 10^8)^2$ J

$$= 1.49 \times 10^{-10}\ \text{J} = \frac{1.49 \times 10^{-10}}{1.6 \times 10^{-13}}\ \text{MeV}$$

$(\because 1\ \text{MeV} = 1.6 \times 10^{-13}\ \text{J})$

$= 931.25$ MeV

Hence, 1 amu ≈ 931 MeV

97 Solar energy is due to **[CBSE AIPMT 1992]**

(a) fusion reaction

(b) fission reaction

(c) combustion reaction

(d) chemical reaction

Ans. *(a)*

Stellar energy is the energy obtained continuously from the sun and the stars. It is estimated that the sun has been radiating 3.8×10^{26} J of energy per second for billions of years. Bethe postulated that the interior of the sun and stars provide conditions for the fusion of hydrogen nuclei to form helium nuclei with the release of heavy amount of energy. Hence, solar energy is due to fusion reaction.

98. The average binding energy of a nucleon inside an atomic nucleus is about **[CBSE AIPMT 1989]**

(a) 8 MeV (b) 8 eV

(c) 8 J (d) 8 erg

Ans. *(a)*

Average binding energy per nucleon of a nucleus is the average energy we have to spend to remove a nucleon from the nucleus to infinite distance. It is given by total binding energy divided by the mass number of the nucleus. The BE curve has a broad maximum in the range $A = 30$ to $A = 120$ corresponding to average binding energy per nucleon = 8 MeV. The peak value of the maximum is 8 MeV/N for $_{26}Fe^{56}$.