PHYSICS

Class XII

Chapter 13- Nuclei

1 Mark Questions

Question 1.
Two nuclei have mass number in the ratio 1 : 3. What is the ratio of their nuclear densities?
Answer:
Since nuclear density is independent of the mass number, the ratio of nuclear densities will be 1:1.

Question 2.
Two nuclei have mass numbers in the ratio 2 : 5. What is the ratio of their nuclear densities?
Answer:
Nuclear density is independent of mass number, so the ratio will be 1 : 1.

Question 3.
Two nuclei have mass numbers in the ratio 1: 8. What is the ratio of their nuclear radii?
Answer:

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

$$\Rightarrow \quad R_1 : R_2 = (1^{1/3} : 8^{1/3}) = \left(\frac{1}{8}\right)^{1/3} = \mathbf{1 : 2}$$

Question 4.
Two nuclei have mass numbers in the ratio 8:125. What is the ratio of their nuclear radii?
Answer:

$$A_1 : A_2 = 8 : 125 \quad \Rightarrow \frac{A_1}{A_2} = \frac{8}{125}$$

$$\text{Since } R = R_0 A^{1/3} \quad \therefore \frac{R_1}{R_2} = \frac{A_1^{1/3}}{A_2^{1/3}} = \frac{8^{1/3}}{125^{1/3}} = \frac{\mathbf{2}}{\mathbf{5}}$$

Question 5.
Two nuclei have mass numbers in the ratio 27:125. What is the ratio of their nuclear radii?
Answer:

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$$

$\therefore$ Ratio of their nuclear radii = **3 : 5**

Question 6.
Write any two characteristic properties of nuclear force.
Answer:
1. Nuclear forces are strongest forces in nature.
2. Nuclear forces are charge independent.

Question 7.
State the reason, why heavy water is generally used as a moderator in a nuclear reactor.
Answer:
Neutrons produced during fission get slowed if they collide with a nucleus of the same mass. As ordinary water contains hydrogen atoms (of mass nearly that of neutrons), so it can be used as a moderator. But it absorbs neutrons at a fast rate via reaction :

$$n + p \longrightarrow d + \gamma$$

Here d is deutron. To overcome this difficulty, heavy water is used as a moderator which has negligible cross-section for neutron absorption.

Question 8.
Name the absorbing material used to control the reaction rate of neutrons in a nuclear reactor.
Answer:
Control rod or cadmium rod.

Question 9.
State tzvo characteristic properties of nuclear force.
Answer:
(i) Nuclear forces are the strongest force in nature.
(ii) They are saturated forces.
(iii) They are charge independent.

2 Mark Question

Question 1.
Calculate the energy released in MeV in the following nuclear reaction:

$$^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He} + Q$$

[Mass of $^{238}_{92}U = 238.05079$ u,

Mass of $^{234}_{90}Th = 234.043630$ u,

Mass of $^{4}_{2}He = 4.002600$ u, $\quad$ 1u = 931.5 MeV/c²]

Answer:
Nuclear reaction

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He} + Q$$

$$\begin{aligned}\text{Energy released, } Q &= \Delta m C^2 \\ &= (M_U - M_{Th} - M_{He})C^2 \\ &= 0.00456 \times 931.5 \text{ MeV} \\ &= \mathbf{4.25\ MeV}\end{aligned}$$

Question 2.
A radioactive nucleus ‘A’ undergoes a series of decays according to the following scheme:

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

The mass number and atomic number of A are 190 and 75 respectively. What are these numbers for A_4?
Answer:
The series can be shown as below :

$$^{180}_{72}A \xrightarrow{\alpha} {}^{176}_{70}A_1 \xrightarrow{\beta} {}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$$

So, the Mass number of $A_4 \rightarrow 69$
and Atomic number of $A_4 \rightarrow 172$

Question 3.
A radio active nucleus ‘A’ undergoes a series of decays according to the following scheme:

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

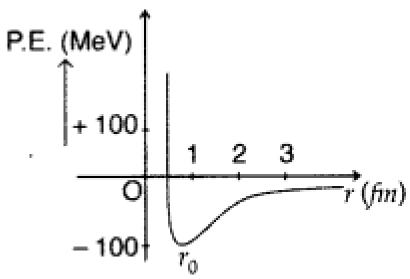
The mass number and atomic number of A are 180 and 72 respectively. What are these numbers for A_4?
Answer:
The series can be shown as below:

$$^{190}_{75}A \xrightarrow{\alpha} {}^{186}_{73}A_1 \xrightarrow{\beta} {}^{186}_{74}A_2 \xrightarrow{\alpha} {}^{182}_{72}A_3 \xrightarrow{\gamma} {}^{182}_{72}A_4$$

So, the Mass number of A_4 is 182
and Atomic number of A_4 is 72

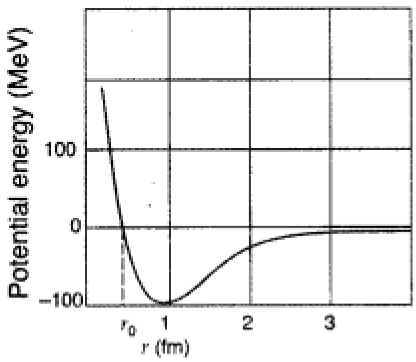
Question 4.
(a) The mass of a nucleus in its ground state is always less than the total mass of its constituents – neutrons and protons. Explain.
(b) Plot a graph showing the variation of potential energy of a pair of nucleons as a function of their separation.
Answer:
(a) When nucleons approach each other to form a nucleus, they strongly attract each other. Their potential energy decreases and becomes negative. It is this potential energy which holds the nucleons together in the nucleus. The decrease in’ potential energy results in the decrease in the mass of the nucleons inside the nucleus.

(b)



Question 5.
A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV.
Answer:
Given : $^{240}X = {}^{110}Y + {}^{130}Z$
∴ Gain in binding energy for nucleon = 8.5 – 7.6 = 0.9 MeV
Hence total gain in binding energy per nucleus fission = 240 × 0.9 = 216 MeV

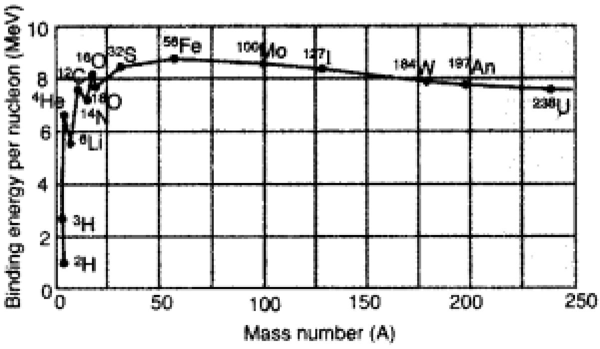
Question 6.
Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions which you can draw regarding the nature of nuclear forces.
Answer:
Two important conclusions :
(i) Nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometres. This explains constancy of the binding energy per nucleon for large-size nucleus.



(ii) Graph explains that force is attractive for distances larger than 0.8 fin and repulsive for distances less than 0.8 fm.

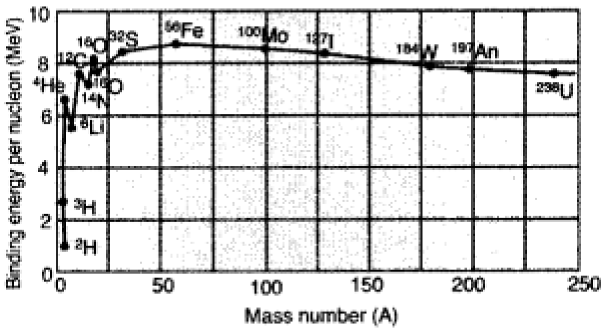
Question 7.
Draw a plot of the binding energy per nucleon as a function of mass number for a large number of nuclei, 2 ≤ A ≤ 240. How do you explain the constancy of binding energy per nucleon in the range 30 < A < 170 using the property that nuclear force is short-ranged?
Answer:
(a) The constancy of the binding energy in the range 30 < A < 170 is a consequence of the fact that the nuclear force is short ranged.
If a nucleon can have a maximum of p neighbours within the range of nuclear force, its binding energy would be proportional to p. Since most of the nucleons in a large nucleus reside inside it and not on the surface, the change in binding energy per nucleon would be small. The binding energy per nucleon is a constant and is approximately equal to pk. The property that a given nucleon influences only nucleons close

to it, is referred to as saturation property of the nuclear force.



(b) Nuclear force is short-ranged for a sufficiently large nucleus. A nucleon is under the influence of only some of its neighbours, which come within the range of the nuclear force. If a nucleon can have maximum of P neighbours within the range of nuclear force, its binding energy would be proportional to 'P' Thus on increasing 'A' by adding nucleons binding energy will remain constant.

Question 8.
Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release of energy in the processes of nuclear fission and nuclear fusion can be explained.
Answer:
1. Nuclear fission : Binding energy per nucleon is smaller for heavier nuclei than the middle ones i.e. heavier nuclei are less stable. When a heavier nucleus splits into the lighter nuclei, the B.E./nucleon changes (increases) from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei results in the liberation of energy. This is what happens in nuclear fission which is the basis of the atom bomb.



2. Nuclear fusion : The binding energy per nucleon is small for light nuclei, i.e., they are less stable. So when two light nuclei combine to form a heavier nucleus, the higher binding energy per nucleon of the latter results in the release of energy.

Question 9.
Complete the following nuclear reactions :

(a) ${}^{10}_{5}\mathrm{B} + {}^{1}_{0}n \longrightarrow {}^{4}_{2}\mathrm{He} + \ldots$

(b) ${}^{94}_{42}\mathrm{Mo} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{95}_{43}\mathrm{Te} + \ldots$

Answer:

(a) $^{10}_{5}\text{B} + ^{1}_{0}n \longrightarrow ^{4}_{2}\text{He} + ^{7}_{3}\text{Li}$

(b) $^{94}_{42}\text{Mo} + ^{2}_{1}\text{H} \longrightarrow ^{95}_{43}\text{Te} + ^{1}_{0}n$

Question 10.
If both the number of protons and neutrons in a nuclear reaction is conserved, in what way is mass converted into energy (or vice verse)? Explain giving one example.
Answer:
Explanation for release of energy in a nuclear reaction : Since proton number and neutron number are conserved in a nuclear reaction, the total rest mass of neutrons and protons is the same on either side of the nuclear reaction.
But total binding energy of nuclei on the left side need not be the same as that on the right hand side. The difference in binding energy causes a release of energy in the reaction.
Examples :

(i) $^{2}_{1}\text{H} + ^{2}_{1}\text{H} \longrightarrow ^{3}_{2}\text{He} + ^{1}_{0}n + \text{energy}$

(ii) $^{235}_{92}\text{U} + ^{1}_{0}n \longrightarrow ^{144}_{56}\text{Ba} + ^{89}_{36}\text{Kr} + 3^{1}_{0}n + \text{energy}$

Question 11.
A nucleus with mass number A = 240 and $\frac{\text{BE}}{\text{A}}$ = 7.6 MeV breaks into two fragments each of A = 120 with $\frac{\text{BE}}{\text{A}}$ = 8.5 MeV. Calculate the released energy.
Answer:
Binding energy of nucleus with mass number 240,

$$(E_{BN})_1 = 240 \times 7.6 \text{ MeV} \quad \ldots(i)$$

Binding energy of two fragments

$$(E_{BN})_2 = 2 \times 120 \times 8.5 \text{ MeV} \quad \ldots(ii)$$

$$\begin{aligned}\text{Energy released} &= (E_{BN})_2 - (E_{BN})_1 \\ &= (2 \times 120 \times 8.5) - (240 \times 7.6) \\ &= 240(8.5 - 7.6) = 240 \times 0.9 \\ &= 216 \text{ MeV}\end{aligned}$$

Question 12.
Calculate the energy in fusion reaction :

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + n,$$

where BE of $^{2}_{1}H$ = 2.23 MeV and of

$^{3}_{2}He$ = 7.73 MeV

Answer:
Total binding energy of initial system (E_i)

$$= ^{2}_{1}H + ^{2}_{1}H = (2.23 + 2.23)\text{ MeV} = 4.46\text{ MeV}$$

Binding energy of final system

i.e. $^{3}_{2}He(E_f) = 7.73$ MeV

Hence, energy released $= E_f - E_i$
$= 7.73\text{ MeV} - 4.46\text{ MeV}$
$= \mathbf{3.27\ MeV}$

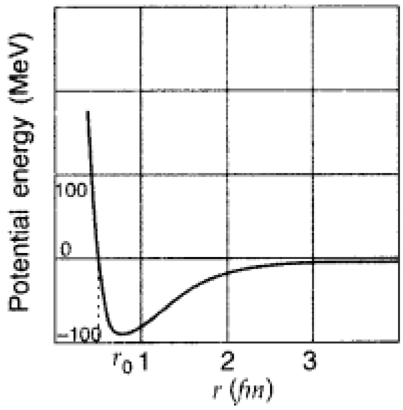
Question 13.
If both the number of protons and the number of neutrons are conserved in each nuclear reaction, in what way is mass converted into energy (or vice-versa) in a nuclear reaction? Explain.
Answer:
The number of protons and neutrons in a nuclear reaction are conserved but the total mass is not conserved. The total mass of the free protons and neutrons is more than their total mass within the nucleus. The lost mass (= Δm) known as 'mass defect', gets converted into energy as per the relation $E = (\Delta m)c^2$ (c is the velocity of light)

4 Marks Questions

Question 1.
Write two characteristic features of nuclear force.
(b) Draw a plot of potential energy of a pair of nucleons as a function of their separation.
Answer:

(a) Nuclear forces. The strong forces of attraction which hold together the nucleons (neutrons and protons) in the tiny nucleus of an atom are called nuclear forces.
Important properties (characteristics):
1. Nuclear forces are independent of charge (These act between a pair of neutrons, between a pair of protons and between a proton and a neutron).
2. Nuclear forces are the strongest forces in nature.
3. Nuclear forces are very short range forces.
4. Nuclear forces are non-central forces.
5. Nuclear forces are dependent on spin.

(b) A plot of the potential energy between two nucleons as a function of distance is shown in the diagram.



Important conclusions from the graph :

(i) The nuclear force is much stronger than the Coulomb force acting between charges or the gravitational forces between masses. The nuclear binding force has to dominate over the Coulomb repulsive force between protons inside the nucleus. This happens only because the nuclear force is much stronger than the coulomb force. The gravitational force is much weaker than even Coulomb force.

(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometers. This leads to saturation of forces in a medium or a large-sized nucleus, which is the reason for the constancy of the binding energy per nucleon.

(iii) The nuclear force between neutron- neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

Question 2.
Write the relation between half life and decay constant of a radioactive nucleus.

Answer:

Relation between λ and $T_{\frac{1}{2}}$

After one half life, Number of nuclei becomes

$$\frac{N_0}{2}$$

$$\Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T_{\frac{1}{2}}} \qquad \Rightarrow 2 = e^{\lambda T_{\frac{1}{2}}}$$

$$\Rightarrow \log_e 2 = \lambda T_{\frac{1}{2}} \qquad \Rightarrow \lambda T_{\frac{1}{2}} = 0.6931$$

$$\Rightarrow T_{\frac{1}{2}} = \frac{0.6931}{\lambda}$$

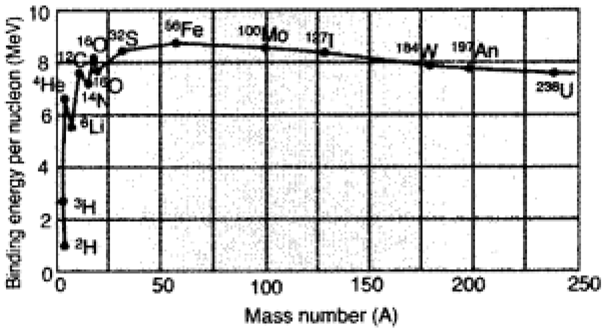
7 Mark Question

Question 1.

Draw a plot showing the variation of binding energy per nucleon versus the mass number (A). Explain with the help of this plot the release of energy in the processes of nuclear fission and fusion.

Answer:

1. Nuclear fission : Binding energy per nucleon is smaller for heavier nuclei than the middle ones i.e. heavier nuclei are less stable. When a heavier nucleus splits into the lighter nuclei, the B.E./nucleon changes (increases) from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei results in the liberation of energy. This is what happens in nuclear fission which is the basis of the atom bomb.



2. Nuclear fusion : The binding energy per nucleon is small for light nuclei, i.e., they are less stable. So when two light nuclei combine to form a heavier nucleus, the higher binding energy per nucleon of the latter results in the release of energy.

the activity of a radionuclide. Write its S.I. unit. Give a plot of the activity of a radioactive species versus time.will a radioactive isotope, whose half life is T years, take for its activity to reduce to 1/8th of its initial value

Activity: It is defined as the total decay rate of a sample of one or more radionuclide.

Its S.I. unit is bequerel

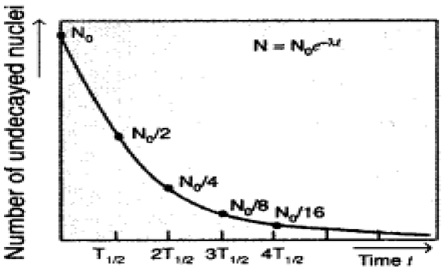
I bequerel = 1 decay per second

Given : $T_{1/2} = T$ years, $\quad N = N_0, \quad t = ?$

Using $N = N_0\left(\frac{1}{2}\right)^n$ $\quad$ ...where $[n = \frac{t}{T}$

$$\frac{\cancel{N}_0}{8} = \cancel{N}_0\left(\frac{1}{2}\right)^{t/T} \quad \Rightarrow \quad \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/T}$$

$$\Rightarrow \frac{t}{T} = 3 \quad \Rightarrow \quad \textbf{Time, } t = 3\textbf{ T years}$$



Question 2.
(i) Define 'activity' of a radioactive material and write its S.I. unit.
(ii) Plot a graph showing variation of activity of a given radioactive sample with time.
(iii) The sequence of stepwise decay of a radioactive nucleus is

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2$$

If the atomic number and mass number of D_2, are 71 and 176 respectively, what are their corresponding values for D?

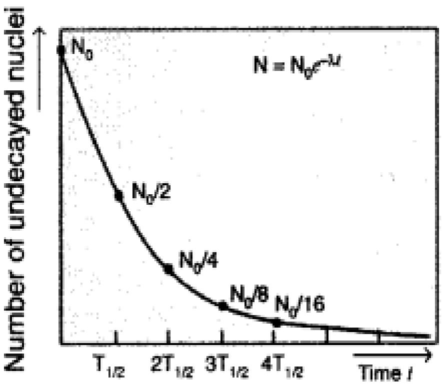
Answer:
Activity: It is defined as the total decay rate of a sample of one or more radionuclide.
Its S.I. unit is bequerel
I bequerel = 1 decay per second

Given : $T_{1/2} = T$ years, $N = N_0$, $t = ?$

Using $N = N_0 \left(\frac{1}{2}\right)^n$ ...**where** $[n = \frac{t}{T}$

$$\frac{\cancel{N}_0}{8} = \cancel{N}_0\left(\frac{1}{2}\right)^{t/T} \Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/T}$$

$$\Rightarrow \frac{t}{T} = 3 \Rightarrow \textbf{Time, } t = 3\,T \textbf{ years}$$



(iii) $${}^{180}_{72}D \xrightarrow[{}^{4}_{2}He]{\alpha} {}^{176}_{70}D_1 \xrightarrow[{}^{0}_{-1}e]{\beta^-} {}^{176}_{71}D_2$$

Atomic number of D = 72, Mass number of D = 180

Question 3.
(a) Write symbolically the P“ decay process of 3215.
(b) Derive an expression for the average life of a radionuclide. Give its relationship with the half-life.
Answer:

(a) $^{32}_{15}P \longrightarrow ^{32}_{16}S + \beta^- + \bar{\nu}$

(b) Suppose a radioactive sample contains N0 nuclei at time t = 0. After time this number reduces to N. Furthermore, suppose dN nuclei disintegrates in time t to t + dt. As dt is small so the life of each of the dN nuclei can be approximately taken equal to t
∴ Total life of dN nuclei = tdN

$$\text{Total life of all the } N_0 \text{ nuclei} = \int_0^{N_0} t\,dN$$

$$\text{Mean life} = \frac{\text{Total life of all } N_0 \text{ nuclei}}{N_0},$$

$$\tau = \frac{1}{N_0}\int_0^{N_0} t\,dN$$

As $N = N_0 e^{-\lambda t}$ $\quad\therefore\ dN = -\lambda N_0 e^{-\lambda t}\,dt$
When $N = N_0$, $t = 0$ and when $N = 0$, $t = \infty$
Changing the limits of integration in terms of time, we get

$$\tau = \frac{1}{N_0}\int_0^{\infty} t\lambda N_0 e^{-\lambda t}\,dt$$

$$\tau = \lambda\int_0^{\infty} te^{-\lambda t}\,dt = \lambda\left[\left\{\frac{te^{-\lambda t}}{-\lambda}\right\}_0^{\infty} - \int_0^{\infty}\frac{e^{-\lambda t}}{\lambda}\,dt\right]$$

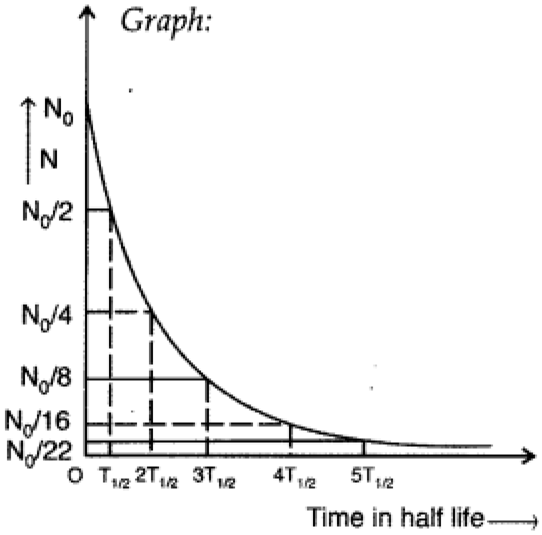
$$= 0 + \frac{\lambda}{\lambda}\int_0^{\infty} e^{-\lambda t}\,dt = \int_0^{\infty} e^{-\lambda t}\,dt = \left[\frac{e^{-\lambda t}}{-\lambda}\right]_0^{\infty}$$

$$= \frac{-1}{\lambda}[e^{-\infty} - e^0] = \frac{-1}{\lambda}[0-1]$$

$$\therefore\ \tau = \frac{1}{\lambda} \qquad \text{Also } \tau_{1/2} = \frac{0.693}{\lambda} = 0.693\,\tau$$

$$\therefore\ \tau = \frac{\tau_{1/2}}{0.693} = \mathbf{1.44\ \tau_{1/2}}$$

Question 4.
State the law of radioactive decay.
Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half life $T_{1/2}$. Depict in the plot the number of undecayed nuclei at
(i) $t = 3 T_{1/2}$ and
(ii) $t = 5_{1/2}$.
Answer:
The number of nuclei undergoing decay per unit time, at any instant is proportional to number of nuclei in the sample at that instant. The given figure shows a graph between the number of undecayed nuclei as a function of time.



Question 5.
(i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number 'A' lying 30 < A < 170?
(ii) Show that the density of nucleus over a wide range of nuclei is constant- independent of mass number A.
Answer:
(i) Saturation is the Short range nature of nuclear forces
(ii) Let A be the mass number and R be the radius of a nucleus
If m is the average mass of a nucleon, then
Mass of nucleus = mA

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

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

$$\therefore \text{Nuclear density} = \frac{\text{mass of nucleus}}{\text{volume of nucleus}}$$

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

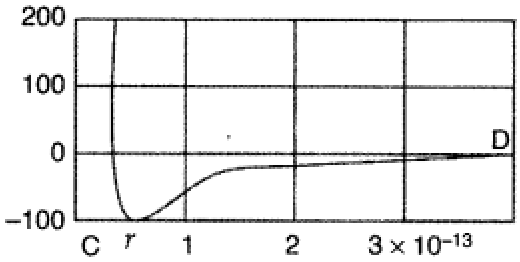
Clearly, nuclear density is independent of mass number A or the size of the nucleus.

Question 6.
Draw a plot of potential energy of a pair of nucleons as a function of their separations. Mark the regions where the nuclear force is
(i) attractive and
(ii) repulsive. Write any two characteristic features of nuclear forces.
(a) In a typical nuclear reaction, e.g.

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + n + 3.27 \text{ MeV}$$

although number of nucleons is conserved, yet energy is released. How? Explain.
(b) Show that nuclear density in a given nucleus is independent of mass number A.

Answer:
The graph indicates that the attractive force between the two nucleons is strongest at a separation r_0 = 1 fm. For a separation greater than the force is attractive and for separation less than r_0, the force is strongly repulsive.



Two characteristic features of nuclear forces :
1. Strongest interaction
2. Short-range force
3. Charge independent character (any two)
(a) In all types of nuclear reactions, the law of conservation of number of nucleons is followed. But during the reaction, the mass of the final product is found to be slightly less than the sum of the masses of the reactant components. This difference in mass of a nucleus and its constituents is called mass defect. So, as per mass energy relation E = $(\Delta M)c^2$, energy is released. In the given reaction the sum of the masses of two deutrons is more than the mass of helium and neutron. Energy equivalent of mass defect is released.

$$(b)\ \text{Nuclear density} = \frac{\text{Mass of nucleus}}{\text{Volum}} = \frac{mA}{\frac{4}{3}\pi R^3}$$

(m = mass of each nucleon)

As $R = R_0 A^{1/3}$ where $R_0 = 1.2 \times 10^{-15}$ m.

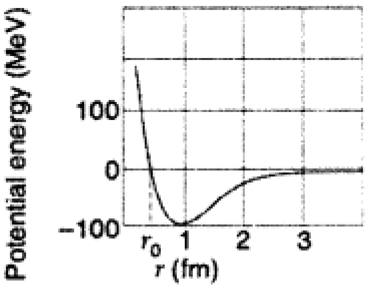
$$\therefore\ \text{Nuclear density} = \frac{3mA}{4\pi R_0^3 A} = \frac{3m}{4\pi R_0^3}$$

i.e. independent of Mass Number A

Question 7.

$${}_{2}^{3}\text{He} + {}_{2}^{3}\text{He} \longrightarrow {}_{2}^{4}\text{He} + {}_{1}^{1}\text{H} + {}_{1}^{1}\text{H} + 12.86 \text{ MeV},$$

though the conserved on both sides of the reaction, yet the energy is released. How? Explain.
(b) Draw a plot of potential energy between a pair of nucleons as a function of their separation. Mark the regions where potential energy is
(i) positive and
(ii) negative.
Answer:
(a) Since the total binding energy of nuclei on the left side of the reaction is not the same as the total binding energy of nucleus on the right hand side, this difference of binding energy appears as the energy released.
(*b*)



For separation (r) ≤ 0.8 fermi
Force is repulsive
For r > 0.8 fermi force will be attractive.

Fill in the blanks

1. Which of the following quantities is not conserved in a nuclear reaction-------------

(Mass)

2. A radioactive nucleus emits a beta particle, then the parent and daughter nuclei are------------
(Isobars)

3. An electron emitted in beta radiation originates from-----------------------

(photon escaping from the nucleus)

Multiple choice questions

1. The light energy emitted by a star is due to

a. Joining of nuclei
b. Burning of nuclei
c. Breaking of nuclei
d. Reflection of solar light

Answer: (a) Joining of nuclei

Explanation: The light energy emitted by a star is due to the joining of nuclei.

2. In nuclear reactions, there is a conservation of

a. Energy only
b. Mass only
c. Mass, energy and momentum
d. Momentum only

Answer: (d) Momentum only

Explanation: In nuclear reactions, there is a conservation of momentum only.

3. Which of the following are not emitted by radioactive substances?

a. Protons
b. Electro

Answer:a

Explanation: Protons are not emitted by radioactive substances.

4. From where are the gamma rays originated?

a. The innermost shell of the nucleus
b. The outermost shell of the nucleus
c. Nucleus
d. The outermost shell of the atom

Answer: (c) Nucleus

Explanation: Gamma rays are originated from the nucleus.

5. Sun's radiant energy is due to

a. Nuclear Fusion
b. Nuclear Fission
c. Photoelectric Effect
d. Radioactive Decay

Answer: (a) Nuclear Fusion

Explanation: Sun's radiant energy is due to Nuclear Fusion.

6. A nucleus undergoes gamma decay due to

a. Excess of neutrons
b. Excess of protons
c. Its excited state
d. Large mass

Answer: (d) Its excited state

Explanation: A nucleus undergoes gamma decay due to its excited state.

7. Isotones have the same number of

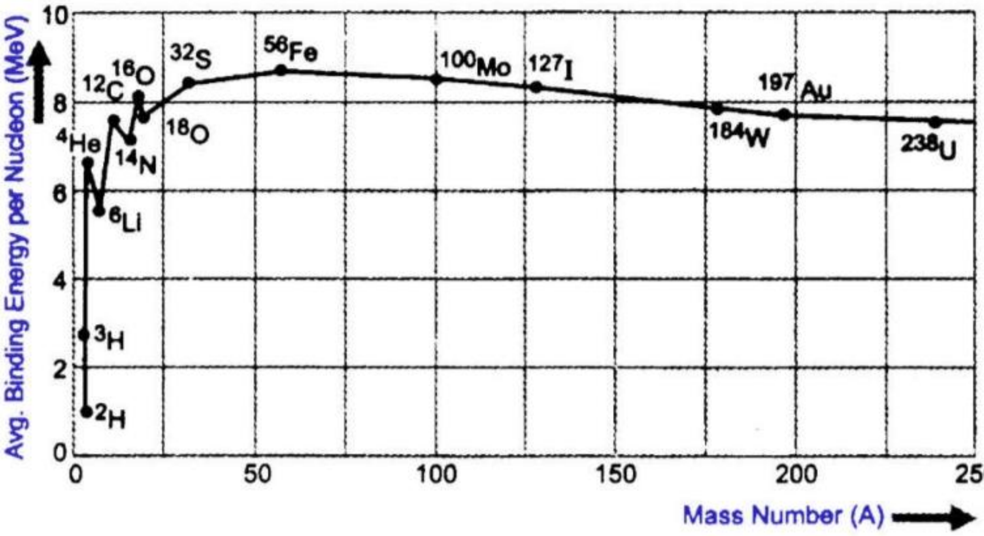
a. Protons
b. Electrons
c. Neutrons
d. All of the above

Answer: (c) Neutrons

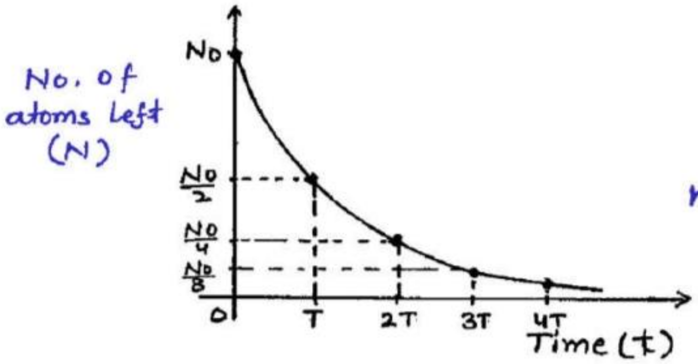
Explanation: Isotones have the same number of neutrons.

Diagrams

Nuclear Binding Energy



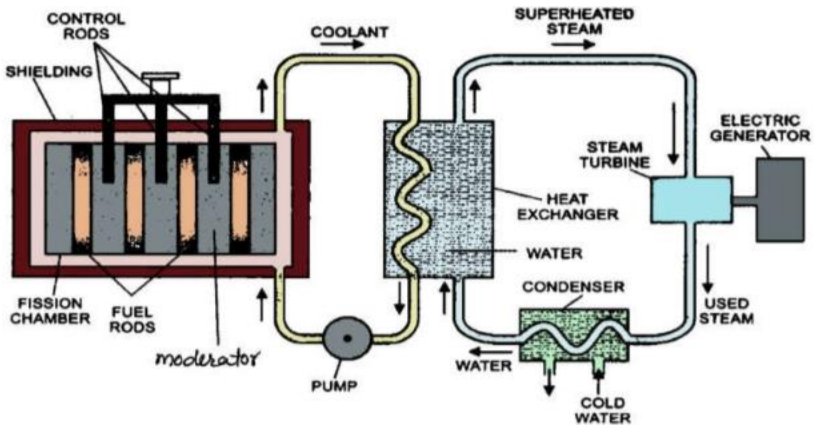
$$B.E. = [Zm_p + (A-Z)m_n - m_N] \times c^2$$



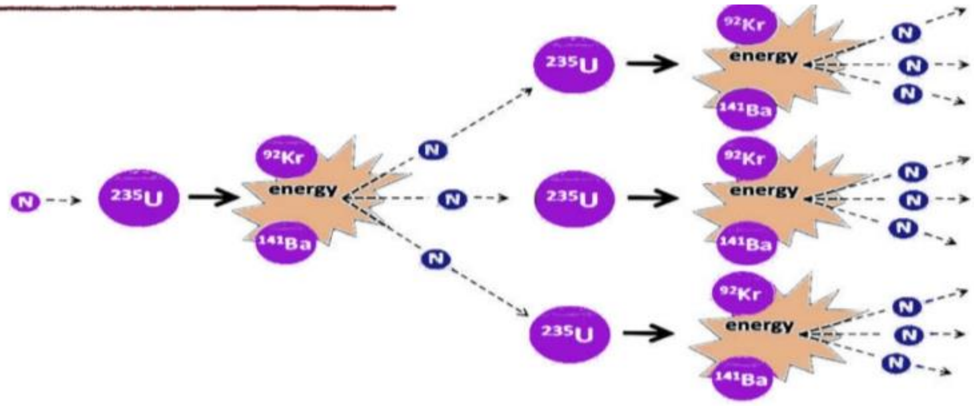
$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$n \rightarrow$ number of half life times

Nuclear Reactor



Nuclear chain Reaction



SUMMARY

- **Atomic Number:**
  The number of protons in the nucleus is called the atomic number. It is denoted by Z.
- **Mass number:**
  The total number of protons and neutrons present in a nucleus is called the mass number of the element. It is denoted by A.
- **No. of Protons, Electrons, nucleons and Neutrons in an Atom:**
  a) Number of protons in an atom = Z
  b) Number of electrons in an atom = Z
  c) Number of nucleons in an atom = A
  d) Number of neutrons in an atom = N = A – Z.
- **Nuclear Mass:**
  The total mass of the protons and neutrons present in a nucleus is called the nuclear mass.
- **Nuclide:**
  A nuclide is a specific nucleus of an atom characterized by its atomic number Z and mass number A. It is represented as, $_{Z}X^{A}$
  Where X = chemical symbol of the element, Z = atomic number and A = mass number
- **Isotopes:**
  a) The atoms of an element which have the same atomic number but different mass number are called isotopes.
  b) Isotopes have similar chemical properties but different physical properties.
- **Isobars:**
  The atoms having the same mass number but different atomic number are called isobars.
- **Isotones:**
  The nuclides having the same number of neutrons are called isotones.
- **Isomers:**
  These are nuclei with same atomic number and same mass number but in different energy states.
- **Electron Volt:**
  It is defined as the energy acquired by an electron when it is accelerated through a potential difference of 1 volt and is denoted by eV.
- **Atomic Mass Unit:**
  a) It is $\frac{1}{12}$th of the actual mass of a carbon atom of isotope $_{6}C^{12}$. It is denoted by amu or just by u.
  b) 1 amu = 1.660565 X 10-27 kg
  c) The energy equivalence of 1 amu is 1 amu = 931 MeV
- **Discovery of Neutrons:**

a) Neutrons were discovered by Chadwick in 1932.
b) When beryllium nuclei are bombarded by alpha-particles, highly penetrating radiations are emitted, which consists of neutral particles, each having mass nearly that of a proton. These particles were called neutrons.

$$ {}_{2}^{4}He + {}_{4}^{9}Be \rightarrow {}_{0}^{1}n + {}_{1}^{12}C $$

c) A free neutron decays spontaneously, with a half- life of about 900 s, into a proton, electron and an antineutrino.

$$ {}_{0}^{1}n \rightarrow {}_{1}^{1}H + {}_{-1}^{0}e + \bar{v} $$

- **Size of the Nucleus:**
  a) It is found that a nucleus of mass number A has a radius

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

  Where, $R_0 = 1.2 \text{ x } 10^{-15} m$

  b) This implies that the volume of the nucleus, which is proportional to R^3 is proportional A.
- **Density of the Nucleus:**
  Density of nucleus is constant; independent of A, for all nuclei and density of nuclear matter is approximately 2.3 x $10^{17} kg$ m^{-3} which is very large as compared to ordinary matter, say water which is 10^3 kg m^{-3}.
- **Mass-Energy equivalence:**
  Einstein proved that it is necessary to treat mass as another form of energy. He gave the mass-energy equivalence relation as,

  $$E = mc^2$$

  Where m is the mass and c is the velocity of light in vacuum.
- **Mass Defect:**
  The difference between the rest mass of a nucleus and the sum of the rest masses of its constituent nucleons is called its mass defect. It is given by,

  $$\Delta m = [Zm_p + (A-Z)m_n] - m$$
- **Binding Energy:**
  a) It may be defined as the energy required to break a nucleus into its constituent protons and neutrons and to separate them to such a large distance that they may not interact with each other.
  b) It may also be defined as the surplus energy which the nucleus gives up by virtue of their attractions which they become bound together to form a nucleus.
  c) The binding energy of a nucleus ${}_{Z}X^{A}$ is,

  $$B.E. = [Zm_p + (A-Z)m_n - m]c^2$$
- **Binding Energy per Nucleon:**
  It is average energy required to extract one nucleon from the nucleus.
  It is obtained by dividing the binding energy of a nucleus by its mass number.

$$\bar{B} = \frac{B.E}{A} = \frac{[Zm_p + (A-Z)m_n - m]c^2}{A}$$

- **Nuclear Forces:**
    a) These are the strong in attractive forces which hold protons and neutrons together in a tiny nucleus.
    b) These are short range forces which operate over very short distance of about 2 – 3 fm of separation between any two nucleons.
    c) The nuclear force does not depend on the charge of the nucleon.
- **Nuclear Density:**
  The density of a nucleus is independent of the size of the nucleus and is given by,

$$\rho_v = \frac{\text{Nuclear mass}}{\text{Nuclear volume}}$$

$$= \frac{m_v}{\frac{4}{3}\pi R^2} = 2.9 \text{ x } 10^{17} \text{ kg m}^{-3}$$

- **Radioactivity:**
    a) It is the phenomenon of spontaneous disintegration of the nucleus of an atom with the emission of one or more radiations like α -particles, β -particles or γ -rays.
    b) The substances which spontaneously emit penetrating radiation are called radioactive substances.
- **Radioactivity Displacement Law:**
  It states that,
  a) When a radioactive nucleus emits an α -particle, atomic number decreases by 2 and mass number decreases by 4.
  b) When a radioactive nucleus emits β -particle, its atomic number increases by 1 but mass number remains same.
  c) The emission of a γ -particle does not change the mass number or the atomic number of the radioactive nucleus. The γ -particle emission by a radioactive nucleus lowers its energy state.
- **Alpha Decay:**
  It is the process of emission of an α -particle from a radioactive nucleus. It may be represented as,

$${}_{Z}^{A}X \rightarrow {}_{Z-2}^{A-4}Y + {}_{2}^{4}He + Q$$

- **Beta Decay:**
  It is the process of emission of an electron from a radioactive nucleus. It may be represented as,

$${}_{Z}^{A}X \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \bar{v}$$

- **Gamma Decay:**

It is the process of emission of a γ -ray photon during the radioactive disintegration of a nucleus. It can be represented as,

$$\underset{\text{(Excited State)}}{{}^{A}_{Z}X} \rightarrow \underset{\text{(Ground State)}}{{}^{A}_{Z}X} + \gamma$$

- **Radioactive Decay Law:**
  It states that the number of nuclei disintegrated of undecayed radioactive nuclei present at that instant. It may be written as,
  $$N(t) = N(0)e^{-\lambda t}$$
  Where N(0) is the number of nuclei at t = 0 and λ is disintegration constant.
- **Decay or disintegration Constant:**
  It may be defined as the reciprocal or the time interval in which the number of active nuclei in a given radioactive sample reduces to 36.8% of its initial value.
- **Half-life:**
  The half-life of a radioactive substance is the time in which one-half of its nuclei will disintegrate. It is inversely proportional to the decay constant of the radioactive substance.
  $$T_{1/2} = \frac{0.693}{\lambda}$$
- **Mean Life:**
  The mean-life of a radioactive sample is defined as the ratio of the combined age of all the atoms and the total number of atoms in the given sample. It is given by,
  $$\tau = \frac{T_{1/2}}{0.693} = 1.44T_{1/2}$$
- **Rate of Decay or Activity of a Radioactive Sample:**
  It is defined as the number of radioactive disintegrations taking place per second in a given sample. It is expressed as,
  $$R(t) = \left[\frac{dN}{dt}\right] = \lambda N(t) = \lambda N(0)e^{-\lambda t}$$
- **Curie:**
  a) It is the SI unit of decay.
  b) One curie is the decay rate of 3.7×10^{10} disintegrations per second.
- **Rutherford:**
  One Rutherford is the decay rate of 10^6 disintegrations per second.
- **Natural Radioactivity:**
  It is the phenomenon of the spontaneous emission of-α , β and γ radiations from the nuclei of naturally occurring isotopes.
- **Artificial or Induced Radioactivity:**
  It is the phenomenon of inducing radioactivity in certain stable nuclei by bombarding them by suitable high energy sub atomic particles.
- **Nuclear Reaction:**

It is a reaction which involves the change of stable nuclei of one element into the nucleus of another element.

- **Nuclear Fission:**
  It is the process in which a heavy nucleus when excited gets split into two smaller nuclei of nearly comparable masses. For example,
  $$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + Q$$
- **Nuclear Reactor:**
  It is a device in which a nuclear chain reaction is initiated, maintained and controlled.
- **Nuclear Fusion:**
  It is the process of fusion of two smaller nuclei into a heavier nucleus with the liberation of large amount of energy.
- **Critical size and Critical Mass:**
  a) The size of the fissionable material for which reproduction factor is unity is called critical size and its mass is called critical mass of the material.
  b) The chain reaction in this case remains steady or sustained.
- **Moderator:**
  a) Any substance which is used to slow down fast moving neutrons to thermal energies is called a moderator.
  b) The commonly used moderators are water, heavy water (D_2O) and graphite.