Nuclei

1. State any two properties of a nucleus. (2024)

Ans. Stating two properties of a nucleus

(Any TWO)

(i) The nucleus is positively charged

(ii) The nucleus consists of protons and neutrons

(iii) The nuclear density is independent of mass number

(iv) The radius of the nucleus, R = Ro $A^{1/3}$

2. Why is the density of a nucleus much more than that of an atom? (2024)

Ans. Why density of a nucleus is much more than that of an atom

Atoms have large amount of empty spaces. Mass is concentrated in nucleus.

3. Show that the density of the nuclear matter is the same for all nuclei. (2024)

Ans. Showing that density of nuclear matter is same for all nuclei

Density = Mass / Volume

$$= \frac{m\ A}{\frac{4}{3}\pi R^3} = \frac{m\ A}{\frac{4}{3}\pi R_o^3\ A}$$

$$= \frac{m}{\frac{4}{3}\pi R_o^3}$$

So, density is independent of mass number

Previous Years' CBSE Board Questions

13.3 Size of the Nucleus

MCQ

1. The ratio of the nuclear densities of two nuclei having mass numbers 64 and 125 is

(a) $\frac{64}{125}$ (b) $\frac{4}{5}$ (c) $\frac{5}{4}$ (d) 1

(2023) Ap

2. In Rutherford's nuclear model of the atom, the entire positive charge and most of the mass of the atom are concentrated in the nucleus. The electrons move in orbits around the nucleus. The nucleus is made of protons and neutrons. Because the nucleus is extremely small as compared to the atom, most of an atom is empty space. The protons and the neutrons are held together in the nucleus by very strong nuclear forces.

(i) The radius R of a nucleus of mass number A is given by

(a) $R = R_0A^3$ (b) $R = R_0A^{1/3}$
(c) $R = R_0^3A$ (d) $R = R_0^3A^{1/3}$

(ii) The ratio of nuclear density of nuclei X^{27} to Y^8 is

(a) 3 : 2 (b) 27 : 8 (c) 1 : 1 (d) 2 : 3

(iii) In the following nuclear reaction

$^{238}_{92}\text{U} + n \rightarrow {}^{Y}_{X}\text{Np} + e^- + \bar{\nu} + Q,$

the values of X and Y are

(a) $X = 92$; $Y = 238$ (b) $X = 92$; $Y = 239$
(c) $X = 93$; $T = 239$ (d) $X = 93$; $Y = 238$

(iv) The saturation property of the nuclear forces is due to the fact that they are

(a) charge independent forces.
(b) non-central forces.
(c) spin-dependent forces.
(d) short-range forces.

(v) In Geiger-Marsden scattering experiment, thin gold foil is used to scatter alpha particles because alpha particles will

SA II (3 marks)

5. Show that density of nucleus is independent of its mass number A. *(1/3, Delhi 2019)* U

6. In the study of Geiger-Marsden experiment on scattering of α-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.
From the relation $R = R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, show that nuclear matter density is independent of A.

(Delhi 2015) Ap

13.4 Mass-Energy and Nuclear Binding Energy

MCQ

7. The difference in mass of ^7X nucleus and total mass of its constituent nucleons is 21.00 u. The binding energy per nucleon for this nucleus is equal to the energy equivalent of

(a) 3 u (b) 3.5 u (c) 7 u (d) 21 u

(2023) Ap

8. When two nuclei ($A \le 10$) fuse together to form a heavier nucleus, the

(a) binding energy per nucleon increases
(b) binding energy per nucleon decreases
(c) binding energy per nucleon does not change
(d) total binding energy decreases. *(2020)* R

VSA (1 mark)

9. Which property of nuclear force explains the approximate constance of binding energy per nucleon with mass number A for nuclei in the range $30 < A < 170$? *(2019 C)*

10. Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two — the parent or the daughter nucleus — would

(a) not suffer more than one scattering and gold nucleus is 50 times heavier than alpha particle.
(b) not suffer more than one scattering and gold nucleus is lighter than alpha particle.
(c) not suffer more than few scatterings and gold nucleus is 25 times heavier than alpha particle.
(d) suffer more than one scattering and gold nucleus is 25 times heavier than alpha particle. *(2020C)*

VSA (1 mark)

3. Why is the mass of a nucleus always less than the sum of the masses of its constituents? *(2019C)*

4. The nuclear radius of $^{27}_{13}\text{Al}$ is 3.6 fermi. Find the nuclear radius of $^{64}_{29}\text{Cu}$. *(2020)* R

have higher binding energy per nucleon? *(2018)* R

SA I (2 marks)

11. Draw the plot of the binding energy per nucleon as a function of mass number for different nuclei. The nuclei lying at the middle flat portion of the curve are more stable. Explain. *(2023)* U

12. If both the number of protons and neutrons in a nuclear reaction is conserved, in what way is mass converted into energy (or vice versa)? Explain giving one example. *(Delhi 2015C)*

SA II (3 marks)

13. Calculate the binding energy of an alpha particle in MeV. Given

mass of proton = 1.0007828 u
mass of a neutron = 1.008665 u
mass of He nucleus = 4.002800 u
$1\ \text{u} = 931\ \text{MeV}/c^2$ *(2023)*

14. Draw a graph showing the variation of binding energy per nucleon with mass number of different nuclei. Write any two salient features of the curve. How does this curve explain the release of energy both in the processes of nuclear fission and fusion? *(AI 2019)* An

OR

Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number *A*. *(2018)*

OR

Draw a plot of B.E./*A* versus mass number *A* for $2 < A < 170$. Use this graph to explain the release of energy in the process of nuclear fusion of two light nuclei. *(Delhi 2014C)* An

13.5 Nuclear Force

MCQ

15. Which of the following statements is not true for nuclear forces?
(a) They are stronger than Coulomb forces.
(b) They have about the same magnitude for different pairs of nucleons.
(c) They are always attractive
(d) They saturate as the separation between two nucleons increases. *(2023)*

13.7 Nuclear Energy

VSA (1 mark)

20. Why does the process of spontaneous nuclear fission occur in heavy nuclei? *(2019C)* R

SA I (2 marks)

21. Briefly describe the multi-step process involved in the generation of energy in the Sun. *(2023)*

22. Calculate the energy released in MeV in the following reaction : $^{2}_{1}\text{H} + ^{3}_{1}\text{H} \longrightarrow ^{4}_{2}\text{He} + n$

Given : $m(^{2}_{1}\text{H}) = 2.014102\,\text{u}$
$m(^{3}_{1}\text{H}) = 3.016049\,\text{u}$
$m(^{4}_{2}\text{H}) = 4.002603\,\text{u}$
$m_n = 1.008665\ \text{u}$ *(2022C)* Ap

23. (a) Differentiate between nuclear fission and nuclear fusion.
(b) Deuterium undergoes fusion as per the reaction.

$$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \longrightarrow ^{3}_{2}\text{He} + ^{1}_{0}n + 3.27\,\text{MeV}$$

Find the duration for which an electric bulb of 500 W can be kept glowing by the fusion of 100 g of deuterium. *(Term-II 2021-22)*

24. Calculate for how many years will the fusion of 2.0 kg deuterium keep 800 W electric lamp glowing. Take the fusion reaction as

$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \longrightarrow ^{3}_{2}\text{He} + ^{1}_{0}n + 3.27\,\text{MeV}$ *(2020)* An

25. A nucleus with mass number $A = 240$ and

SA I (2 marks)

16. 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. *(AI 2015)* Ap

SA II (3 marks)

17. Draw a plot showing the variation of potential energy of two nucleons as a function of distances between them. Identify the regions in which the force between the nucleons is (i) attractive, and (ii) repulsive. Justify your answers. *(2023)*

18. (a) The density of the nuclear matter is tremendously larger than the physical density of the material. Explain.
(b) The nuclear forces are not coulomb forces between nucleons. Explain.
(c) Draw a plot of the potential energy between a pair of nucleons as a function of distance between them inside a nucleus. *(2020)*

19. Write three characteristic properties of nuclear force. *(AI 2015)* R

B.E./A = 7.6 MeV breaks into two fragments each of A = 120 with B.E./A = 8.5 MeV. Calculate the released energy. *(Delhi 2016)*

26. Calculate the energy in fusion reaction : ${}_1^2H+{}_1^2H \to {}_2^3He+n$, where B.E. of ${}_1^2H$ = 2.23 MeV and of ${}_2^3He$ = 7.73 MeV. *(Delhi 2016)* Ap

27. Complete the following nuclear reactions.
(a) ${}_5^{10}B+{}_0^1n \to {}_2^4He+$........
(b) ${}_{42}^{94}Mo+{}_1^2H \to {}_{43}^{95}Te+$........ *(Delhi 2015C)* U

SA II (3 marks)

28. A heavy nucleus P of mass number 240 and binding energy 7.6 MeV per nucleon splits into two nuclei Q and R of mass number 110 and 130 and binding energy per nucleon 8.5 MeV and 8.4 MeV respectively. Calculate the energy released in the fission. *(2023)*

29. In a typical nuclear reaction, e.g.
${}_1^2H+{}_1^2H \to {}_2^3He+{}_0^1n+3.27$ MeV, although number of nucleons is conserved, yet energy is released. How? Explain. *(1/3, Delhi 2016)*

CBSE Sample Questions

13.5 Nuclear Force

MCQ

1. Which of the following statements about nuclear forces is not true?
(a) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometres.
(b) The nuclear force is much weaker than the Coulomb force.
(c) The force is attractive for distances larger than 0.8 fm and repulsive if they are separated by distances' less than 0.8 fm.
(d) The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. *(2022-23)* R

13.7 Nuclear Energy

VSA (1 mark)

2. In the following nuclear reaction, identify unknown labelled X.
${}_{11}^{22}Na+X \to {}_{10}^{22}Ne+\nu_e$ *(2020-21)* R

SA II (3 marks)

3. How long can an electric lamp of 100 W be kept glowing by fusion of 2 kg of deuterium?
Take the fusion reaction as
${}_1^2H+{}_1^2H \longrightarrow {}_2^3He+n+3.27$ MeV
(Term II 2021-22) Ap

4. (a) Give one point of difference between nuclear fission and nuclear fusion.
(b) Suppose we consider fission of a ${}_{26}^{56}Fe$ into two equal fragments of ${}_{13}^{28}Al$ nucleus. Is the fission energetically possible? Justify your answer by working out Q value of the process.
Given (m) ${}_{26}^{56}Fe$ = 55.93494 u and
(m) ${}_{13}^{28}Al$ = 27.98191.
(2020-21)

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (d): Nuclear density is constant and independent of mass number so the ratio is 1.

2. (i) (b) Radius of nucleus is given by $R = R_0A^{1/3}$

(ii) (c) As, nuclear density is given by $\rho = \frac{3m}{4\pi R_0^3}$. This means ρ is independent of A. Sor ratio would be 1 : 1.

(iii) (b)

(iv) (d) The saturation property of the nucler forces is due to the fact that they are short range forces.

(v) (a) In geiger-Mardsen scattering experiment thin gold foil is used to scatter alpha particle because alpha particle will not suffer more than one scattering and gold nucleus is 50 times heavier than alpha particle.

3. During the formation of a nucleus, the protons and neutrons come closer to a distance of 10^{-14} m. The energy required for the purpose is spent by the nucleus at the expense of their masses. So mass of the nucleus found is less than the sum of the masses of the individual nucleous.

4. Experimental measurements shows that volume of a nucleus is proportional to its mass number A.

$$R = R_0A^{\frac{1}{3}}$$

$$\therefore \quad V = \frac{4}{3}\pi\left(R_0\, A^{1/3}\right)^3 \Rightarrow V = \frac{4}{3}\pi R_0^3 A$$

Density of nuclear matter, $\rho = \frac{mA}{V}$

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

This shows that the nuclear density is independent of A.

$$\Rightarrow \frac{R_{Al}}{R_{Cu}} = \left(\frac{A_{Al}}{A_{Cu}}\right)^{\frac{1}{3}} \Rightarrow R_{Cu} = R_{Al}\left(\frac{A_{Cu}}{A_{Al}}\right)^{\frac{1}{3}}$$

$$= 3.6\left(\frac{64}{27}\right)^{\frac{1}{3}} = 4.8 \text{ fermi}$$

Concept Applied

- Radius of a nucleus is proportional to cube root of its mass number.

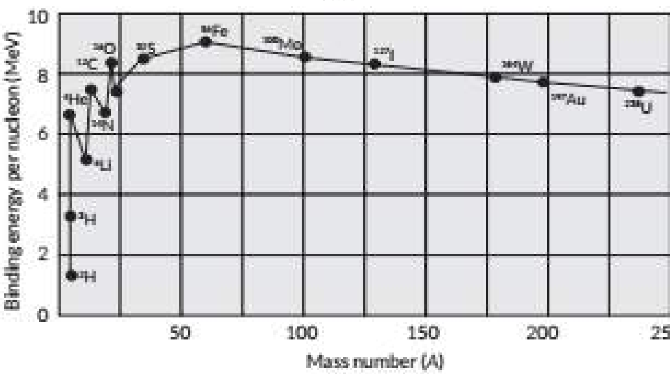
5. Nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments of scattering of α-particle by atoms. He found that the scattering result could be explained.

Atoms consists of a small, central, massive and positive core surrounded by orbiting electron. The experiment results indicated that the size of the nucleus is of the order of 10^{-14} metres and it thus 10,000 times smaller than the size of atom.

Relation between the radius and mass number of the nucleus $R = R_0\,A^{1/3}$

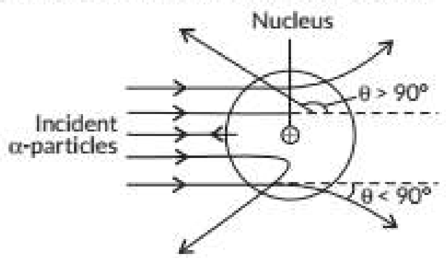
If m is the average mass of a nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

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



The above curve tells us that the binding energy per nucleus is smaller for heavier nuclei as well as for lighter nuclei than for the middle order nuclei (with mass number lying between 30 to 170). Meaning heavier nulei are less stable thus they undergo fission and lighter nuclei undergo fusion in order to form the nucleus lying in the range of the mass number 30 to 170.

6. Trajectory of α-particles in coulomb field of target nucleus shows that only a small fraction of the number of incident α-particles (1 in 8000) rebound back.



This shows that the number of α-particles undergoing head-on collision is small. This implies that the entire positive charge of the atom is concentrated in a small volume. So, this experiment is an important way to determine an upper limit on the size of nucleus.

$$\text{Density of nucleus} = \frac{\text{Mass of nucleus}}{\text{Volume}}$$

$$\rho = \frac{A \times m}{\frac{4}{3}\pi R^3}; \text{ where } R = R_0 A^{1/3}$$

$$\text{Density } \rho = \frac{A \times m}{\frac{4}{3}\pi R_0^3 A} = \frac{m}{\frac{4}{3}\pi R_0^3}; \rho = \frac{3m}{4\pi R_0^3}$$

$\rho = 2.97 \times 10^{17}$ kg m^{-3}
so, nuclear density is constant irrespective of mass number or size.

7. (a): When two lighter nuclei fuse to form a heavier nucleus, its binding energy per nucleon increases.

8. (a): The difference in mass ^7X nucleus and total mass of its constituent nucleus is 21.00 u

Total mass of constituent nucleus = 21.00 u

No. of nucleons present in ^7X, $n = 7$

So, Binding energy per nucleon $= \frac{21.00}{7}$ u $= 3.0$ u

So, option (a) is correct.

9. The characteristic property of nuclear force that explains the constancy of binding energy per nucleon is the saturation or short range nature of nuclear forces.
In heavy nuclei, nuclear size > range of nuclear force.

10. In nuclear fusion, daughter nucleus would have higher binding energy per nucleon.

11. Binding energy curve:

constant, *i.e.* practically independent of the atomic number for nuclei of middle mass number ($30 < A < 170$). The curve has a maximum value of about 8.75 MeV for $A = 56$ and has a value of 7.6 MeV for $A = 238$.

(ii) E_{bn} is lower for both light nuclei ($A < 30$) and heavy nuclei ($A > 170$).

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 from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei

12. A certain number of neutrons and protons are brought together to form a nucleus of a certain charge and mass, and energy ΔE_b will be released in this process. The energy ΔE_b is called the binding energy of the nucleus. If we separate a nucleus into its nucleons we would have to transfer a total energy equal to ΔE_b, to the nucleons.

Example : ${}_{92}U^{235} + {}_0n^1 \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^1_0n + Q$

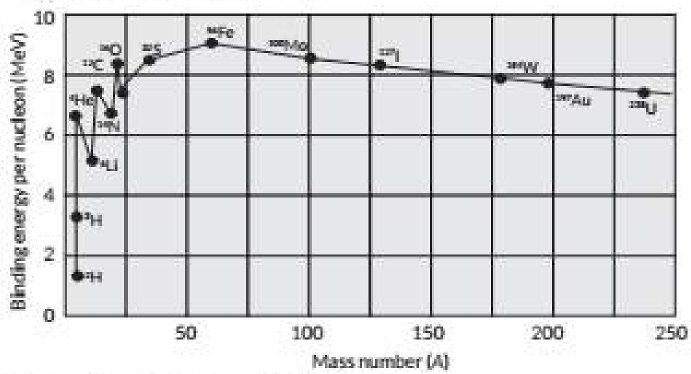
The energy (Q) released was estimated to be 200 MeV per fission (or about 0.9 MeV per nucleon) and is equivalent to the difference in masses of the nuclei before and after the fission.

13. Given, $m_p = 1.0007828$ u
$m_n = 1.008665$ u
$m_{He} = 4.002800$ u

$\Delta m = 2 \times m_p + 2 \times m_n - m_{He}$
$= 2 \times 1.0007828 + 2 \times 1.008665 - 4.002800$
$= 2.001565 + 2.01733 - 4.002800 = 0.016095$ u

So, binding energy $= \Delta m \times 931$ MeV
$= 0.016095 \times 931 = 14.9844$ MeV

14. Binding energy curve:



Two salient features of the curve

(i) The binding energy per nucleon, E_{bn}, is practically than the coulomb force acting between charges or the gravitational forces between masses.

(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few fermi.

(iii) For a separation greater than r_0, the force is attractive and for separation less than r_0, the force is strongly repulsive.

18. (a) The density of the nuclear matter is tremendously larger than the physical density of the material. This is due to the fact that most of the atom is empty and its whole mass is concentrated in its nucleus.

results in the liberation of energy. This is what happens in nuclear fission which is the basis of the atom bomb.

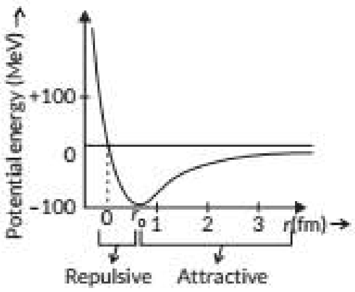
Nuclear fusion : The binding energy per nucleon is small for light nuclei, *i.e.*, they are less stable. So when two light nuclei combine to form a heavier nucleus, the higher binding energy per nucleon of the latter results in the release of energy. This is what happens in a nuclear fusion which is the basis of the hydrogen bomb.

Answer Tips

- The binding energy curve can be used to explain the phenomena of nuclear fission and nuclear fusion.

15. **(c)** : Nuclear forces are not always attractive as range below 1 fermi, it becomes repulsive in nature.

16. Plot of potential energy of a pair of nucleons as a function of their separation is given in the figure.

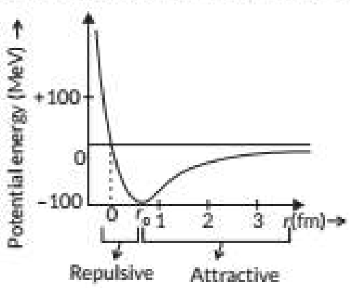


Conclusions: (i) The nuclear force is much stronger than the coulomb force acting between charges or the gravitational forces between masses.

(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few fermies.

(iii) For a separation greater than r_0, the force is attractive and for separation less than r_0, the force is strongly repulsive.

17. Plot of potential energy of a pair of nucleons as a function of their separation is given in the figure.



Conclusions: (i) The nuclear force is much stronger

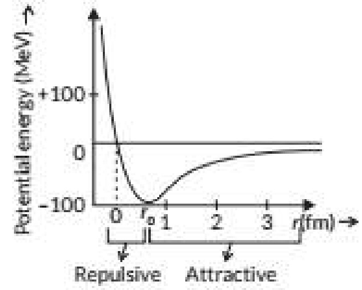
$${}_1^2H + {}_1^1H \rightarrow {}_2^3He + \gamma + 5.49\,MeV \quad ...(iii)$$

$${}_2^3He + {}_2^3He \rightarrow {}_2^4He + {}_1^1H + 12.86\,MeV \quad ...(iv)$$

For the fourth reaction to occur, the first three reactions occur twice, in which case two light helium unite to form ordinary helium nucleus. If we consider the combination

(b) Coulombian force between two proton is repulsive. However, within a nucleus a number of protons and neutrons exist together within a very small space. So it is clear that nuclear force is not coulomb force but it is an extremely short range force which is attractive in nature and responsible for maintaining all the nucleons together.

(c)



19. Properties of nuclear force are :

(i) Nuclear forces are short range forces and are strongly attractive within a range of 1 fermi to 4.2 fermi.

(ii) Nuclear forces above 4.2 fermi are negligible, whereas below 1 fermi, they become repulsive in nature. It is this repulsive nature below 1 fermi, which prevents the nucleus from collapsing under strong attractive force.

(iii) Nuclear forces are charge independent. The same magnitude of nuclear force act between a pair of protons, pair of proton and neutron and pair of neutrons. The attractive nuclear force is due to exchange of π mesons (π^0, π^+, π^-) between them.

20. Large nuclei have large number of like charge particles close to each other and hence they are unstable in nature. Because of this instability they undergoes nuclear fission reaction to form two stable nuclei.

21. The fusion reaction in the sun is a multi-step process in which the hydrogen is burned into helium. Thus, the fuel in the sun is the hydrogen in its core. The proton-proton (p, p) cycle by which this occurs is represented by the following sets of reactions:

$${}_1^1H + {}_1^1H \rightarrow {}_1^2H + e^+ + \nu + 0.42\,MeV \quad ...(i)$$

$$e^+ + e^- \rightarrow \gamma + \gamma + 1.02\,MeV \quad ...(ii)$$

$\therefore$ Total energy $= 3.011 \times 10^{25} \times 2.616 \times 10^{-13}$
$= 7.88 \times 10^{12}$ J

$$\text{Power} = \frac{\text{Energy}}{\text{Time}} \Rightarrow t = \frac{7.88 \times 10^{12}}{500} = 1.58 \times 10^{10}\text{ s}$$

$$= \frac{1.58 \times 10^{10}}{365 \times 24 \times 60 \times 60} = 500 \text{ years}$$

2 (i) + 2(ii) + 2 (iii) + 2(iv), the net effect is

$$4{}_1^1H + 2e^- \rightarrow {}_2^4He + 2\nu + 6\gamma + 26.7MeV$$

or $\left(4{}_1^1H + 4e^-\right) \rightarrow \left({}_2^4He + 2e^-\right) + 2\nu + 6\gamma + 26.7MeV$

Thus, four hydrogen atoms combine to form an ${}_2^4He$ atom with a release of 26.7 MeV of energy.

22. The mass defect is the difference between the mass of reactants and the mass of products.

$${}_1^2H + {}_1^3H \longrightarrow {}_2^4He + n$$

The energy released,

$E_{released} = E_B({}_1^2H) + E_B({}_1^3H) - E_B({}_2^4He) - m_n$

$E_{released} = 2.014102\ \mu + 3.016049\ u - 4.002603\mu - 1.008665\ u$

$E_{released} = 5.030151\ \mu - 5.011268\ \mu = 0.018883\ u$

Now 1 u = 931.5 MeV

So, $E_{released} = 0.018883 \times 931.5$ MeV = 17.5895 MeV

23. (a)

Nuclear Fission	Nuclear Fusion
1. The process of splitting of a heavy nucleus into two nuclei of nearly comparable masses with liberation of energy is called nuclear fission. Example: ${}_{92}^{235}U + {}_0^1n \rightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3{}_0^1n + Q$	1. When two or more than two light nuclei fuse together to form heavy nucleus with the liberation of energy, the process is called nuclear fusion. Example: ${}_1^2H + {}_1^2H \rightarrow {}_2^3He + {}_0^1n + 3.2MeV$
2. A suitable bullet or projectile like neutron is needed to initiate nuclear fission	2. The lighter nuclei have to be brought very close to each other against electrostatic repulsion.
3. Fission of single nucleus of U_{92}^{235} produces approx. 200 MeV energy.	3. Four protons combine to form helium nucleus which produces approx. 24 MeV energy.

(b) Given : m = 100 g, P = 500 W

Here two deuterium nuclei produce 3.27 MeV energy $= 5.232 \times 10^{-13}$ J

$\therefore$ Energy per nuclei $= \dfrac{5.232\times10^{-13}}{2} = 2.616 \times 10^{-13}$ J

No. of deuterium atoms in 100 g

$$= \frac{6.023\times10^{23}\times100}{2} = 3.011\times10^{25} \text{ atoms}$$

Key Points

- In A g of sample ${}_ZX^A$, there will be 6.022×10^{23} number of ${}_ZX^A$ atoms.

24. Given m = 2 kg, P = 800 W.

Here, two deuterium nuclei produce 3.27 MeV energy $= 5.232 \times 10^{-13}$ J

$\therefore$ Energy per nuclei $= \dfrac{5.232\times10^{-13}}{2} = 2.616 \times 10^{-13}$ J

Number of deuterium atom in 2 kg

$$= \frac{6.023\times10^{23}\times2000}{2} = 6.023 \times 10^{26} \text{ atom}$$

$\therefore$ Total energy $= 6.023 \times 10^{26} \times 2.616 \times 10^{-13} = 15.75 \times 10^{13}$ J

$$\text{Power} = \frac{\text{Energy}}{\text{Time}} \Rightarrow t = \frac{15.75\times10^{13}}{800} = 1.96\times10^{11} s$$

$$= \frac{1.96\times10^{11}}{365\times24\times60\times60} = 6.2\times10^3 \text{ years}$$

25. For a big nucleus, A = 240, BE/A = 7.6 MeV

Initial binding energy = 240 × 7.6 = 1824 MeV

For two small nuclei, A = 120, BE/A = 8.5 MeV

Final binding energy = 2 × 120 × 8.5 = 2040 MeV

Energy released during fission

= (Final B.E.) – (Initial B.E.)

= 2040 – 1824 = 216 MeV

26. Fusion reaction,

$${}_1^2H + {}_1^2H \longrightarrow {}_2^3He + n$$

Energy released = final B.E. – initial B.E.

= 7.73 – (2.23 + 2.23) = 3.27 MeV.

27. (a) ${}_5^{10}B + {}_0^1n \rightarrow {}_2^4He + {}_3^7Li$

$10 + 1 = 4 + A$

$A = 11 - 4 = 7$

$5 + 0 = 2 + Z$

$Z = 5 - 2 = 3$

$\therefore A = 7, Z = 3$

(b) ${}_{42}^{94}Mo + {}_1^2H \rightarrow {}_{43}^{95}Te + {}_0n^1$

$94 + 2 = 95 + A$

$A = 96 - 95 = 1$

$42 + 1 = 43 + Z$

$Z = 43 - 43 = 0$

Commonly Made Mistake

- In every nuclear reaction, mass number is conserved and charge number is also conserved.

28. (b) $P^{240} \rightarrow \frac{BE}{A} = 7.6\,\text{MeV /nucleon}$

$Q^{110} \rightarrow \frac{BE}{A} = 8.5\,\text{MeV /nucleon}$

$R^{130} \rightarrow \frac{BE}{A} = 8.4\,\text{MeV /nucleon}$

Energy released

$E = 130 \times 8.4 + 110 \times 8.5 - 240 \times 7.6$

$E = 1092 + 935 - 1824$

$E = 203$ MeV

29. In a nuclear reaction, the sum of the masses of the target nucleus (^2_1H) and the bombarding particle (^2_1H) may be greater than the product nucleus (^3_2He) and the outgoing neutron ^1_0n. So from the law of conservation of mass-energy some energy (3.27 MeV) is evolved due to mass defect in the nuclear reaction. This energy is called Q-value of the nuclear reaction.

Answer Tips

- Q-value = (Δm in a.m.u) × 931.5 MeV

CBSE Sample Questions

1. (b): The nuclear force is much stronger than the Coulomb force acting between charges. So, option (b) is not true. **(1)**

2. The unknown X is electron ($^{0}_{-1}e$). **(1)**

3. Number of atoms present in 2 g of deuterium $= 6 \times 10^{23}$

Number of atoms present in 2.0 kg of deuterium $= 6 \times 10^{26}$

Energy released in fusion of 2 deuterium atoms = 3.27 MeV **(1)**

Energy released in fusion of 2.0 kg of deuterium atoms

$= \frac{3.27}{2} \times 6 \times 10^{26}$ MeV

$= 9.81 \times 10^{26}$ MeV $= 15.696 \times 10^{13}$ J

Power of bulb = 100 W **(1)**

or, energy consumed by bulb per sec = 100 J

Time for which bulb will glow $= \frac{15.696 \times 10^{13}}{100}$ s

$= 4.97 \times 10^4$ year **(1)**

4. (a)

Nuclear Fission	Nuclear Fusion
• The process of splitting of a heavy nucleus into two nuclei of nearly comparable masses with liberation of energy is called nuclear fission.	• When two or more than two light nuclei fuse together to form heavy nucleus with the liberation of energy, the process is called nuclear fusion.
• Example: $^{235}_{92}U + ^1_0n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^1_0n + Q$	• Example: $^2_1H + ^2_1H \rightarrow ^4_2He + 24\,\text{MeV}$

(1)

(b) Given : $M_1 = 55.93494$ u is atomic mass of Fe

$M_2 = 27.98191$ u is atomic mass of Al

$^{56}_{26}Fe \rightarrow 2\,^{28}_{13}Al$

Q value is $(M_1 - 2M_2) \times 931.5$ MeV

$= (55.93494 - 2 \times 27.98191) \times 931.5$

$= -26.902$ MeV

Q value is negative. Thus fission is not possible. **(2)**