Chapter

13 NUCLEUS

1. Ratio of radius of an atom to the radius of its nucleus is around

(a) 10^{-2} (b) 10^{4} (c) 10^{12} (d) 10^{15}

2. Volume of a nucleus to the volume of its atoms is around

(a) 10^{2} (b) 10^{-2} (c) 10^{-12} (d) 10^{-15}

3. Ratio of mass of nucleus with mass of atom is approximately

(a) 1 (b) 10 (c) 10^{3} (d) 10^{10}

4. Chlorine has two isotopes having masses 34.98 u and 36.98 u with relative abundance of 75.4% and 24.6% , respectively . The average atomic mass of chlorine is

(a) 34.98 (b) 36.98 (c) 35.47 (d) 35

5. Masses of nuclei of hydrogen , deuterium and tritium are in ratio
(a) 1:2 :3 (b) 1:1:1 (c)1: 1:2 (d) 1:2 : 4

6. If an element has 3 isotopes with atomic masses m_1 , m_2 and m_3 with percentage abundances of n_1 , n_2 andn_3 respectively , then average atomic mass of element is

(a) $m_1n_1 + m_2n_2 + m_3\, n_3$
(b) $\frac{m_1n_1 + m_2n_2 + m_3\, n_3}{m_1 + m_2 + m_3}$
(c) $\frac{m_1 + m_2 + m_3}{n_1 + n_2 + n_3}$
(d) $\frac{m_1n_1 + m_2n_2 + m_3\, n_3}{n_1 + n_2 + n_3}$

7. Two stable isotopes of lithium ${}^{6}_{3}Li$ and ${}^{7}_{3}Li$ have respective abundances of 7.5 % and 92.5% . These isotopes have masses of 6.0152u and 7.01600 u , respectively . The atomic mass of lithium is
(a) 6.940934 (b) 6.849325 u
(c) 6.01512 (d)6.01600 u

8. Boron has two stable isotopes $5^{B^{10}}$ and $5^{B^{11}}$. Their respective masses are 10.01294 u and 11.00931u and the atomic mass of boron is 10.811 u . The abundance of $5^{B^{10}}$ and $5^{B^{11}}$ are respectively nearing to

(a) 50 % 50% (b) 20 % , 80%
(c) 25% , 75 % (d) 5% , 95%

9. If the nuclear radius of 27_{Al} is 3.6 Fermi , the approximate nuclear radius of 64_{Cu} in Fermi is
(a) 2.4 (b) 1.2 (c) 4.8 (d) 3.6

10. How much mass has to converted into energy to produce electric power of 200 MW for one hour ?
(a) $2 \times 10^{-6}kg$ (b) $8 \times 10^{-6}kg$
(c) $1 \times 10^{-6}kg$ (d) $3 \times 10^{-6}kg$

11. Given , mass of a neutron = 1.00866 u , mass of a proton = 1.00727 u , mass of ${}^{16}_{8}O$ into its constituents is

(a) $12.7MeV$
(b) Cannot be estimated from given data
(c) $1.49 \times 10^{-10}J$
(d) 127.5 MeV

12. A gamma ray photon creates an electron - positron pair (pair creation). If the rest mass energy of an electron is 0.5 MeV and the total KE of electron - positron pair is 0.78 MeV , then the energy of the γ- ray photon must be

(a) 0.78 MeV (b) 1.78 MeV
(c) 1.28 MeV (d) 0.28 MeV

13. Given $m(^{56}_{26}Fe)$ = 55.934939 u and m($^{209}_{83}Bi$) = 208. 980388 u
m_{proton} = 1.007825 u , $m_{netutron}$ = 1.008665 u. Then, BE per nucleon of Fe and Bi are respectively
(a) 8.790 MeV , 7.848 MeV
(b) 7.75 MeV , 6.84 MeV
(c) 7.5 MeV , 6.5 MeV
(d) Data insufficient

14. 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 + $^1_1\,H \rightarrow ^4_2He + ^4_2He$ + Q , the value of energy Q released is

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

15. Decay rate , r = -$\frac{dN}{dt}$, is the number of nuclei decaying in one second . It is also called as

(a) activity of sample
(b) disintegration constant
(c) half- life of sample
(d) mean life of sample

16. For a radioactive sample half - life $T_{1/2}$ and disintegration constant λ are related as

(a) $T_{1/2}$ = log 2. λ (b) $T_{1/2} = \frac{\log 2}{\lambda}$
(c) $T_{1/2} \times$ log 2 = λ (d) None of these

17. In the earth , only those radiation elements are found naturally which

(a) Have less half - life time
(b) Have more half -life time
(c) Lie deep inside earth
(d) Lie on the surface of earth

18. Tritium has a half - life of 12.5 yr undergoing β -decay fraction of sample remaining un decayed after 25yr will be

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

19. Complete the reaction
$^A_Z X \rightarrow$ .... P .... + $^4_2\,He$. here , P refers to

(a) $^{A-4}\,_2 Y$ (b) $^A_2\;Y$ (c) $^{A-2}_{Z-4}Y$ (d) $^{A-4}_{Z-2}Y$

20. Given , atomic masses are $^{238}_{90}U$ = 238.05079u ^4_2He = 4.00260 u . $^{234}_{92}Th$ = 234.04363 u , $^1_1\,H$ = 1.00783 u . The energy released during the ∝ - decay of $^{238}_{92}U$ is

(a) 4.25 MeV (b) 4.5 MeV

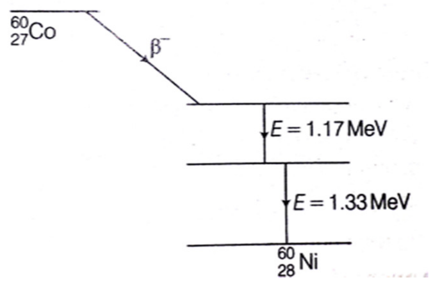
(c) 6 MeV (d) 5 MeV

21. In B^+ - decay , process occurring inside the nucleus is

(a) $n \rightarrow p + e^+ + v$ (b) $p \rightarrow n + e^+ + v$

(c) $e \rightarrow n + p + \bar{v}$ (d) $p \rightarrow n + e^+ + \bar{v}$

22. Energy level diagram shown depicts



(a) Emission of only one β^- - particle
(b) Emission of one β^- - particle and two γ - ray photons of equal frequencies
(c) Emission of one β^- particle and two γ - photons of different frequencies
(d) Emission of two γ –ray photons

23. Two radioactive substance A and B have decay constant 5 λ 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

(a) 1/ 4λ (b) 4λ (c) 2λ (d) 1/ 2λ

24. A radioactive isotope has a half - life of T years . It reduces to 3.125 % of its original value in

(a) $2\,T$ (b) $3\,T$ (c) $5\,T$ (d) $15\,T$

25. 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

(a) $40\,yr$ (b) $60\,yr$ (c) $80\,yr$ (d) $100\,yr$

26. 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 becomes equal after

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

27. Operating of a reactor is said to be critical when K , the multiplication factor becomes

(a) 0 (b) 2 (c) ∞ (d) 1

28. An atomic power nuclear reactor can deliver 300 MW. The energy released due to fission of each nucleus of uranium atoms U^{238} is 170 MeV . The number of uranium atoms fissioned per hour will be

(a) 30×10^{25} (b) 4×10^{25}
(c) 10×10^{25} (d) 5×10^{25}

29. A nucleus of uranium decays at rest into nuclei of thorium and helium. Then ,

(a) The helium nucleus has more kinetic energy than the thorium nucleus
(b) The healium 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

30. Nuclear winter is

(a) Winter caused by absorption of heat energy by a fusion reaction on earth's surface
(b) Winter caused by radioactive waste blocking sunlight to reach earth's surface
(c) Winter caused due to cooling of sun's core
(d) Winter caused due to collapse of sun core

Hints and Explanations

1. (b)

Radius of atom $\simeq 10^{-10}$
Radius of nucleus $\simeq 10^{-14}$
$\therefore \frac{Radius\ of\ atom}{Radius\ of\ nucleus} = \frac{10^{-10}}{10^{-14}} \simeq 10^4$

2. (c)

3. (a)

As nearly 99.9% mass of atom is in nucleus .
$\frac{Mass\ of\ nucleus}{mass\ of\ atom} = \frac{99.9}{100} = 0.99 \approx 1$

4. (c)
The average mass of a chlorine atom is obtained by the weighted average of the masses of the two isotopes , which is
$= \frac{75.4 \times 34.98 + 24.6 \times 36.98}{100} = 35.47u$

5. (a)

6. (d)

7. (a)

$m = \frac{m_1 n_1 + m_2 n_2}{n_1 + n_2}$
$= \frac{6.01512 \times 7.5 + 7.01600 \times 92.5}{100}$
= 6.94093 u

8. (b)

Percentage of ${}^{10}_{5}B$ in sample be x . Then percentage of ${}^{11}_{5}B$ is (100 − x) . So , using formula of Average atomic masses of isotopes
$10.811 = \frac{10.01294 \times x + 11.00931\,(100 - x)}{100}$
$\Longrightarrow$ 1081 .1 = 1100.931 – 0.99637 x
$\Longrightarrow$ 0.99637 x = 19.831
$\therefore\ x = \frac{19.831}{0.99637} = 19.3 \approx 20\%$

9. (c)
Nuclear radius r $\propto A^{1/3}$ where A is mass number
R = $r_0 A^{1/3}$ = $r_0 (27)^{1/3}$ = $3\, r_0$
$r_0 = \frac{3.6}{3}$ = 1.2 fm
64_{Cu} , r = $r_0\, A^{1/3}$ = 1.2 $fm\, (64)^{1/3}$ 4.8 fm

10. (b)
P = 200 MW = $2 \times 10^8 W$
t = 1 h = 3600s
$E = P \times t$ = $2 \times 10^8 \times 3600 J$
$E = mc^2$
$m = \frac{E}{c^2} = \frac{2 \times 10^8 \times 3600}{(3 \times 10^8)^2} = 8 \times 10^{-6} kg$

11. (d)
Mass of 8 neutrons $8 \times 1.00866\, u$
Mass of 8 protons = $8 \times 1.00727\, u$
The expected mass of ${}^{16}_{8}O$ nucleus.
= $8 \times 2.01593\, u$ = 16.12744 u
The atomic mass of ${}^{16}_{8}O$ found from mass spectroscopy experiments is seen to be 15.99493 u
ΔM = 16.12744 u – 15.99493 u = 0.13691 u

12. (b)
Energy of γ – ray photon
= KE of electron positron pair + Mass energy
= 0.78 + 0.5 × 2 (an e^- and e^+ are created)
= 1.78 meV

13. (a)

${}^{56}_{26}Fe$ nucleus has 26 protons and 30 neutrons
∴ Mass defect = (26 m_p + 30 m_n) – m (${}^{56}_{26}Fe$)
= 56.46340 – 55.934939 = 0.528461 amu
$Total\ BE$ = 0.528461 ×931.5 MeV
= 492.26 MeV
∴ Binding energy per nucleon
$= \frac{492.26}{56}$ = 8. 790 MeV

Bi , E_{bn} = 7.848 MeV

14. (d)
The binding energy for 1^{H^1} is around zero and also not given in the question so we can ignore it

Q = $2(4 \times 7.06) - 7 \times (5.60)$
= $(8 \times 7.60) - (7 \times 5.60)$
= (56.48 – 39.2) MeV
= 17.28 MeV ≃ 17.3 MeV

15. (a)

16. (b)
17. (b)

Those radioactive elements whose half-life is short compared to the age of the universe (13.7 billion years) are not found in observable quantities in nature today. They have , however , been seen in the laboratory in nuclear reactions. Tritium and plutonium belong to this category .

18. (c)
Fraction of radioactive substance left = $\frac{N}{N_0}$
= $\left(\frac{1}{2}\right)^n$
$\Longrightarrow \quad N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = \frac{N_0}{4}$

19. (d)

20. (a)
The $\propto$ decay of ${}^{238}_{92}U$ is given by equation
${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + Q$
The energy released in this process is given by
$Q = (M_U - M_{Th} - M_{He})c^2$
Q = (238.05079 – 234.04363 – 4.00260) u × c^2
= $(0.00456\, u)c^2$
= $(0.00456\, u)\ (931.5\ MeV/u)$ = 4.25 MeV

21. (b)
In β^+ - decay , a proton transforms into neutron (inside the nucleus) by reaction
$P \rightarrow n + e^+ + v$

22. (c)
Beta emission , the $^{60}_{27}Co$ nucleus transforms into $^{60}_{28}Ni$ nucleus in its excited state . The excited $^{60}_{28}Ni$ nucleus so formed , then de-excites to its ground state by successive emission of 1.17 MeV and 1.33 MeV gamma rays.

23. (d)

Number of nuclei after time t ,
$N = N_0 e^{-\lambda t}$
$N_1 = N_0 e^{-5\lambda t}$
$N_2 = N_0 e^{-\lambda t}$

$\Longrightarrow \frac{N_1}{N_2} = N_0 e^{(-5\lambda + \lambda)t} = e^{-4\lambda t} = \frac{1}{e^{4\lambda t}}$

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

$\therefore \quad \frac{1}{e^2} = \frac{1}{e^{4\lambda t}} \quad \Longrightarrow t = \frac{1}{2\lambda}$

24. (c)

N = $\frac{3.125}{100} N_0 = \frac{1}{32} N_0 \quad \Longrightarrow \quad$ N = $N_0 e^{-\lambda t}$

$\Longrightarrow \frac{1}{32} N_0 = N_0 e^{-\lambda t}$

$\Longrightarrow e^{\lambda t} = 32 = 2^5$
$\Longrightarrow \lambda t = 5 \ log_e 2$

$\Longrightarrow \left(\frac{0.693}{T}\right) t = 5 \times 0.693 \qquad \therefore t = 5T \ yr$

25. (b)
$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n, \frac{N}{N_0} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

Number of half -lives = 3

$\Longrightarrow \quad T = 20 \ yr$

$\therefore T = \frac{t}{n}$ or t = $T \times n = 20 \times 3yr = 60yr$

26. (d)
For 40 g amount,

40 g $\xrightarrow{20\ s}$ 20 g $\xrightarrow{20\ s}$ 10 g

For 160 g amount,

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

27. (d)

28. (b)
Power= $\frac{Energy}{Time}$ = 300× $10^6 W$ = $3 \times 10^8 Js^{-1}$

170 MeV = 170× $10^6 \times 10^{-19}$ = $27.2 \times 10^{-12} J$

Number of atoms fissioned per second
= $\frac{3 \times 10^8}{27.2 \times 10^{-12}} = \frac{3 \times 10^{20}}{27.2}$

Number of atoms fissioned per hour
= $\frac{3 \times 10^{20} \times 3600}{27.2} = \frac{3 \times 36}{27.2} \times 10^{22}$

29. (a)
$92^{U^{238}} \rightarrow 92^{Th^{238}} + 2^{He^4}$
According to law of conservation of linear momentum ,

$|P_{Th}| = |P_{He}| = P$
$\Longrightarrow$ kinetic energy of an element ,

$KE = \frac{P^2}{2m}$
m is mass of an element
$KE \propto \frac{1}{M}$

$M_{He} < M_{Th} \Longrightarrow K_{He} > K_{Th}$

30. (b)