CHAPTER

13

Nuclei

A Quick Recapitulation of the Chapter

1. In every atom, the positive charge is densely concentrated at the centre of the atom forming its nucleus.
2. A nucleus has a structure of its own. It consists of protons and neutrons. Electrons revolve around the nucleus.
3. The unit to express atomic masses is called **atomic mass unit**. Atomic mass unit is defined as $\frac{1}{12}$th of the mass of carbon atom (C_{12}).

   i.e., $1\,\text{u} = 1.660539 \times 10^{-27}$ kg

   (i) Mass of proton $(m_p) = 1.00727$ u

   (ii) Mass of neutron $(m_n) = 1.00866$ u

   (iii) Mass of electron $(m_e) = 0.000549$ u

   Relation between amu and MeV

   $$1 \text{ amu} \approx 931 \text{ MeV}$$
4. Number of proton (Z) inside the nucleus of an atom is exactly equal to the number of electrons revolving round the nucleus of that atom. This number is called the **atomic number** or **charge number**.
5. The number of neutron in the nucleus of an atom is called the neutron number N. The sum of the number of protons and neutrons is called the **mass number** A. Thus, $A = N + Z$
6. **Isotopes** of an element are nuclides having same atomic number Z but different mass number A (or different neutron number N).

   ${}_1H^1$, ${}_1H^2$, ${}_1H^3$ and ${}_6C^{11}$, ${}_6C^{12}$, ${}_6C^{14}$ etc., are isotopes.
7. Nuclides having same mass number A but different atomic number Z are called **isobars**. Isobars represent different chemical properties.

   ${}_1H^3$, ${}_2He^3$ and ${}_6C^{14}$, ${}_7C^{14}$ are examples of isobars.
8. Nuclides with different atomic number Z and different mass number A but same neutron number are called **isotones**.

   ${}^3_1H$, ${}^4_2He$ and ${}^{198}_{80}Hg$, ${}^{199}_{79}Au$ are examples of isotones.
9. The radius of a nucleus depends only on its mass number A according to the relation $R = R_0 A^{1/3}$, where R_0 is a constant having a value 1.2×10^{-15} m or 1.2 fm.
10. The difference in mass of a nucleus and its constituent nucleons is called the **mass defect** of that nucleus. Thus, mass defect,

    $$\Delta M = Zm_p + (A + Z)\, m_n - M$$

    where, M is the mass of given nucleus.
11. The energy equivalent of the mass defect of a nucleus is called its **binding energy**.

    Thus, binding energy

    $$\Delta E_b = \Delta Mc^2$$
    $$= [ZM_p + (A - Z)\, M_n - M]\, c^2$$
12. In the mass number range $A = 30$ to 170, the binding energy per nucleon is nearly constant, about 8 MeV/nucleon.
13. Binding energy per nucleon

    $$= \frac{\text{Total binding energy}}{\text{Mass number (\textit{i.e.,} total number of nucleon)}}$$
    $$= \frac{\Delta m \times 931}{A} \frac{\text{MeV}}{\text{Nucleon}}$$

    Binding energy per nucleon $\propto$ Stability of nucleus.
14. **Radioactivity** is the phenomenon of spontaneous disintegration of the nucleus of an atom with emission of one or more radiations like α-particle, β-particle or γ-rays.

15. **Radioactive decay** is a nuclear transformation process in which the radioactive rays are emitted from the nucleus of the atom.

16. According to **Radioactivity Decay Law,** the rate of decay of radioactive atom at any instant is proportional to the number of atoms present at that instant.

    (i) $\frac{dN}{dt} \propto N, \frac{dN}{dt} = -\lambda N$

    where, λ = decay constant and N = number of Active nucleus present in the sample at any instant t.

    (ii) $N = N_0 e^{-\lambda t}$, where N_0 = Number of atoms present initially.

17. The SI unit of radioactivity is Becquerel (Bq).

    1 Becquerel (Bq) = 1 disintegration/second

    1 Curie (Ci) = 3.7×10^{10} decays/second

    1 Rutherford (Rd) = 10^6 decays/second

18. **Half-life period** of a radioactive sample is the time in which half of the quantity of the sample initially present gets disintegrated. The half-life period is related to decay constant λ as,

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

19. After n half-lives, the quantity of a radioactive substance left intact (undecayed) is given by

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

20. **Average life** of a radioactive element is total life time of all the atoms of the radioactive element and divided by the total number of atoms present initially in the sample of the element.

$$\tau = \frac{1}{\lambda} = 1.44 T_{1/2} \Rightarrow T_{1/2} = 0.693\, \tau$$

21. Time required to decay from N_0 to N

$$t = \frac{2.303}{\lambda} \log_{10}\left(\frac{N_0}{N}\right)$$

22. In α**-decay**, the mass number of the product nucleus is four less than that of decaying nucleus while the atomic number decreases by two.

$${}_Z^AX \longrightarrow {}_{Z-2}^{A-4}Y + {}_2^4\text{He} + \bar{\nu}$$

23. (i) The Q-value of a nuclear process is

    Q = final kinetic energy-initial kinetic energy.

    Due to conservation of mass-energy this can also be given by

    Q = (sum of initial masses – sum of final masses) c^2

    (ii) For the above α-decay in point 22

$$Q = (m_x - m_y - m_{\text{He}})\, c^2$$

24. In β**-decay**, the mass number of product nucleus remains same but atomic number increases or decreases by one. In beta-minus decay (β^-), an electron and an anti-neutrino are created and emitted from the nucleus *via* the reaction given below

$$n \rightarrow p + e^- + \bar{\nu}$$
$${}_Z^AX \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e + \bar{\nu}$$

In beta-plus decay (β^+), a positron and a neutrino are created and emitted from the nucleus *via* the reaction given below

$$p \rightarrow n + e^+ + \nu$$
$${}_Z^AX \rightarrow {}_{Z-1}^{A}Y + {}_{+1}^{0}e + \bar{\nu}$$

25. A γ**-ray** is emitted when α or β-decay results in a daughter nucleus in an excited state. Atom then returns to ground state by a single photon transition or successive transitions involving more than one photon.

$${}_Z^AX \rightarrow {}_Z^AX + \gamma$$

26. **Nuclear fission** is the process of splitting of a heavy nucleus (${}_{92}U^{235}$ or ${}_{94}U^{239}$) into two lighter nuclei of comparable masses alongwith the release of a large amount of energy after bombarded by slow neutrons.

27. **Nuclear fusion** is the process in which two or more light nuclei combine to form a single larger nucleus, with emission of energy.

[Objective Questions Based on NCERT Text]

Topic 1

Composition of 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 atom 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. Nucleus of an atom has a
(a) boundary that diffuses into atom like atmosphere of earth diffuses into vacuum
(b) boundary that keeps on changing due to interaction of protons and neutrons
(c) sharply defined boundary that remains unaltered in ordinary conditions
(d) uneven boundary

5. Atomic mass unit (1 u) is
(a) 1/ 12 of mass of ${}^{12}\text{C}$ atom
(b) 1/ 14 of mass of ${}^{14}\text{C}$ atom
(c) 1/12 of mass of ${}^{14}\text{C}$ atom
(d) 1/6 of mass of ${}^{12}\text{C}$ atom

6. 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

7. The lightest element hydrogen has
(a) only one isotope (b) two isotopes
(c) three isotopes (d) four isotopes

8. Unstable isotope of hydrogen is
(a) hydrogen (b) deuterium (c) helium (d) tritium

9. Which of the following is not true about the nucleus?
(a) Positive charge of nucleus is due to the protons
(b) All the electrons of an atom are outside the nucleus
(c) Charge of nucleus is $+Ze$
(d) Charge of electrons may be greater than $-Ze$ in an atom

10. 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

11. Masses of nuclei of deuterium and tritium are not same because
(a) they contain different number of protons
(b) they contain some other neutral matter in different amounts
(c) they contain protons of different masses
(d) their nuclear densities are different

12. Least stable particle is
(a) electron (b) proton
(c) neutron (d) meuon

13. A free neutron decays into
(a) an electron and a proton
(b) a proton, an electron and a anti-neutrino
(c) an electron and a positron
(d) free neutrons are stable

14. As compared to ${}^{12}\text{C}$ atom, ${}^{14}\text{C}$ atom has
(a) two extra protons and two extra electrons
(b) two extra protons but no extra electrons
(c) two extra neutrons and no extra electrons
(d) two extra neutrons and two extra electrons

15. If an element has 3 isotopes with atomic masses m_1, m_2 and m_3 with percentage abundances of n_1, n_2 and n_3 respectively, then average atomic mass of element is
(a) $m_1n_1 + m_2n_2 + m_3n_3$ (b) $\dfrac{m_1n_1 + m_2n_2 + m_3n_3}{m_1 + m_2 + m_3}$
(c) $\dfrac{m_1 + m_2 + m_3}{n_1 + n_2 + n_3}$ (d) $\dfrac{m_1n_1 + m_2n_2 + m_3n_3}{n_1 + n_3 + n_3}$

16. Two stable isotopes of lithium ${}^6_3\text{Li}$ and and ${}^7_3\text{Li}$ have respective abundances of 7.5% and 92.5%. These isotopes have masses of 6.01512u and 7.01600u, respectively. The atomic mass of lithium is
(a) 6.940934 u (b) 6.849325 u
(c) 6.01512 u (d) 6.01600 u

17. Boron has two stable isotopes ${}_5\text{B}^{10}$ and ${}_5\text{B}^{11}$. Their respective masses are 10.01294 u and 11.00931 u and the atomic mass of boron is 10.811 u. The abundance of ${}_5\text{B}^{10}$ and ${}_5\text{B}^{11}$ are respectively nearing to
(a) 50%, 50% (b) 20%, 80%
(c) 25%, 75% (d) 5%, 95%

18. The mass number of a nucleus is equal to the number of … A … . In $^{226}_{88}$Ra nucleus, there are … B … and … C … . Here A, B and C refer to
(a) electrons it contains, 138 protons and 88 neutrons
(b) protons it contains, 226 neutrons and 88 electrons
(c) neutrons it contains, 226 protons and 88 electrons
(d) nucleons it contains, 138 neutrons and 88 protons

19. In 14g of $^{14}_{6}$C isotope of carbon, the number of protons, neutrons and electrons are
(a) $48 \times 10^{23}, 48 \times 10^{23}, 36 \times 10^{21}$
(b) $36 \times 10^{23}, 36 \times 10^{23}, 36 \times 10^{21}$
(c) $36 \times 10^{23}, 48 \times 10^{23}, 36 \times 10^{23}$
(d) $48 \times 10^{23}, 36 \times 10^{23}, 48 \times 10^{23}$

20. The nuclei $^{13}_{6}$C and $^{14}_{7}$N may be described as
(a) isobars
(b) isotopes of C
(c) isotones
(d) isotopes of N

21. If α-particles of higher energies are targeted over gold foil, then distance of closest approach will be
(a) smaller
(b) larger
(c) remains same
(d) zero, as an α-particle of high energy strikes the nucleus

22. Two nuclei have their mass numbers in the ratio of 1 : 3. The ratio of their nuclear densities would be
(a) $(3)^{1/3} : 1$ (b) 1 : 1 (c) 1 : 3 (d) 3 : 1

23. The ratio of the nuclear radii of the gold isotope $^{197}_{79}$Au and silver isotope $^{107}_{47}$Au is
(a) 1.23 (b) 0.216
(c) 2.13 (d) 3.46

24. Density of a nucleus is
(a) more for lighter elements and less for heavier elements
(b) more for heavier elements and less for lighter elements
(c) very less compared to ordinary matter
(d) a constant

25. If the nuclear radius of ^{27}Al is 3.6 Fermi, the approximate nuclear radius of ^{64}Cu in Fermi is **[CBSE AIPMT 2012]**
(a) 2.4 (b) 1.2
(c) 4.8 (d) 3.6

26. If R is the radius and A is the mass number, then log R *versus* log A graph will be
(a) a straight line (b) a parabola
(c) an ellipse (d) None of these

27. Surface area of a nucleus (assuming it to be a perfect sphere), is (where, A = mass number)
(a) $(1.8 \times 10^{-29})\,A^{1/3}$ (b) $(1.8 \times 10^{-29})\,A^{2}$
(c) $(1.8 \times 10^{-29})\,A^{2/3}$ (d) $(1.8 \times 10^{-29})\,A^{3}$

Topic 2

Mass-Energy and Nuclear Binding Energy

28. Energy equivalent of 2 g of a substance is
(a) 18×10^{13} mJ (b) 18×10^{13} J
(c) 9×10^{13} mJ (d) 9×10^{13} J

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

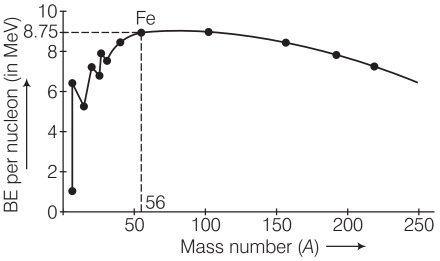
30. Mass of nucleus is
(a) equal to mass of nucleons
(b) more than mass of nucleons
(c) less than mass of nucleons
(d) may be more or less, depends on size of nucleus

31. Given, mass of a neutron = 1.00866 u, mass of a proton = 1.00727 u, mass of $^{16}_{8}$O = 15.99053 u Then, the energy required to separate $^{16}_{8}$O into its constituents is
(a) 12.7 MeV
(b) Cannot be estimated from given data
(c) 1.49×10^{-10} J
(d) 127.5 MeV

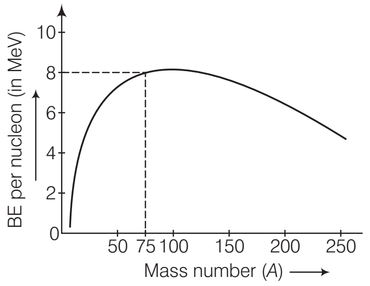
32. Binding energy (E_b) is
(a) energy required to separate nucleus from its atoms
(b) energy required to break a nucleus into its nucleons
(c) energy required to remove all electrons of the atom
(d) energy required to break an atom into electrons, protons and neutrons

33. Correct plot of binding energy per nucleon (E_{bn}) with the mass number (A) is shown in

(a)



(b)



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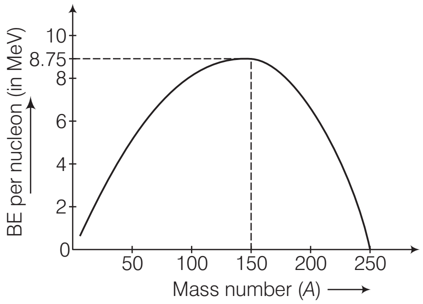
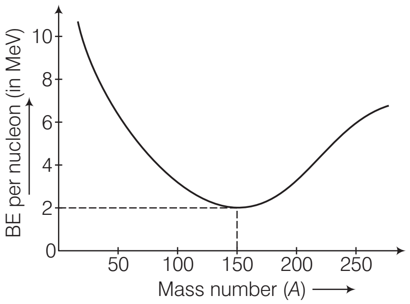


(d)



34. 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

35. Given, $m\,({}^{56}_{26}\text{Fe}) = 55.934939$ u and $m\,({}^{209}_{83}\text{Bi})$ $= 208.980388$ u
$m_{\text{proton}} = 1.007825$ u, $m_{\text{neutron}} = 1.008665$ 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

36. The binding energy per nucleon of ${}^{7}_{3}\text{Li}$ and ${}^{4}_{2}\text{He}$ nulcei are 5.60 MeV and 7.06 MeV, respectively. In the nuclear reaction ${}^{7}_{3}\text{Li} + {}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} + Q$, the value of energy Q released is **[CBSE AIPMT 2014]**

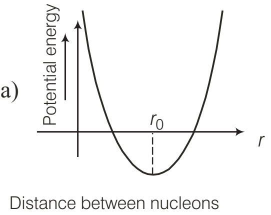
(a) 19.6 MeV (b) – 2.4 MeV
(c) 8.4 MeV (d) 17.3 MeV

37. Correct order is

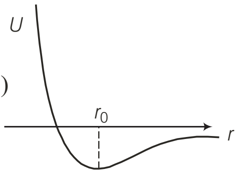
(a) $F_{\text{gravitation}} > F_{\text{electrostatic}} > F_{\text{nuclear}}$
(b) $F_{\text{nuclear}} > F_{\text{gravitation}} > F_{\text{electrostatic}}$
(c) $F_{\text{nuclear}} > F_{\text{electrostatic}} > F_{\text{gravitation}}$
(d) $F_{\text{gravitation}} > F_{\text{nuclear}} > F_{\text{electrostatic}}$

38. Which of the following is a correct graph of potential energy (U) of a pair of nucleons as a function of their separation (r)?

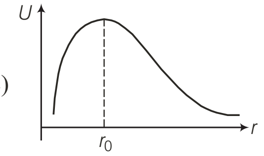
(a)



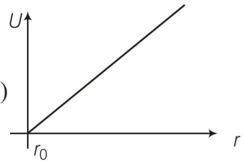
(b)



(c)



(d)



39. Nuclear force is

(a) larger for proton-proton pair
(b) larger for neutron-neutron pair
(c) larger for proton-neutron pair
(d) same for neutron-neutron, proton-proton or neutron-proton pairs

40. Two protons are attracting each other, then separation between them is

(a) 10^{-10} m (b) 10^{-2} m (c) 10^{-8} m (d) 10^{-15} m

41. Nuclear forces show saturation property, this can be explained by the fact that

(a) binding energy per nucleon *versus* mass number curve rises sharply with increase in mass number for ware mass numbers
(b) binding energy per nucleon *versus* mass number curve falls for heavier masses
(c) binding energy per nucleon *versus* mass number curve is flat for mass numbers 50 to 100
(d) binding energy per nucleon *versus* mass number curve has a maxima for $A = 56$

Topic 3

Radioactivity

42. Emission of radiation from a salt of uranium potassium sulphate (irradiated by sunlight is)

(a) stopped by using a thin metal foil
(b) stopped by few centimetres of air
(c) stopped by using a thin metal plate wrapped by a thick paper
(d) Cannot be stopped by any of above methods

43. For any radioactive sample number of nuclei undergoing the decay per unit time is proportional to

(a) reciprocal of activity of sample
(b) mass of 1 mole of sample
(c) number of decayed nuclei in sample
(d) number of undecayed nuclei present at that time in the sample

44. 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

45. SI unit for activity is

(a) Curie
(b) Rutherford
(c) Pascal
(d) Becquerel

46. The counting rate observed from a radioactive source at $t = 0$ s was 1600 count/s^{-1} and at $t = 8$ s, it was 100 count/s^{-1}. The counting rate observed at $t = 6$ s was

(a) 400
(b) 300
(c) 200
(d) 150

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

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

48. In the earth, only those radioactive 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

49. Out of the following radioactive substances which are not found in naturally on earth?

(i) Tritium
(ii) Deuterium
(iii) Uranium
(iv) Plutonium

(a) (i) and (ii)
(b) (ii) and (iii)
(c) (i) and (iv)
(d) (i) and (iii)

50. Tritium has a half-life of 12.5 yr undergoing β-decay. Fraction of sample remaining undecayed after 25 yr will be

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

51. In the α-decay of $^{238}_{92}\text{U} \longrightarrow X + ^{4}_{2}\text{He}$

The nucleus X is

(a) $^{234}_{90}\text{Th}$
(b) $^{235}_{90}\text{U}$
(c) $^{237}_{91}\text{Pa}$
(d) Cannot be determined

52. Select the correct statement.

(a) β radioactivity is the process in which an electron is emitted from an unstable atom whose atomic number Z remains unchanged
(b) γ radioactivity is the process in which daughter nucleus has atomic number one unit more than the parent nucleus
(c) α radioactivity is the process in which an unstable atom emits helium atom
(d) α emission is the process in which a heavy atom emits electromagnetic radiation of very high frequency

53. Complete the reaction

$^{A}_{Z}X \longrightarrow \ldots P \ldots + ^{4}_{2}\text{He}$. Here, P refers to

(a) $^{A-4}_{2}Y$
(b) $^{A}_{2}Y$
(c) $^{A-2}_{Z-4}Y$
(d) $^{A-4}_{Z-2}Y$

54. In a nuclear reaction $^{238}_{92}\text{U} \rightarrow ^{A}_{Z}\text{Th} + ^{4}_{2}\text{He}$, the value of A and Z are

(a) $A = 234, Z = 94$
(b) $A = 238, Z = 94$
(c) $A = 234, Z = 90$
(d) $A = 238, Z = 90$

55. Q value of α-decay is

(a) $\Delta M \cdot c^2$, where $\Delta M =$ mass defect
(b) amount of heat required for disintegration
(c) amount of heat released in reaction
(d) energy shared by daughter nucleus

56. Energy released in α-decay is

(a) dissipated completely in form of heat in the atmosphere
(b) carried completely by helium nuclei emitted
(c) carried completely by daughter nucleus
(d) shared by daughter nucleus and the α-particles

57. Given, atomic masses are $^{238}_{92}\text{U} = 238.05079\text{u}$

$^{4}_{2}\text{He} = 4.00260\text{u}$, $^{234}_{90}\text{Th} = 234.04363\text{u}$,

$^{1}_{1}\text{H} = 1.00783\text{u}$. The energy released during the α-decay of $^{238}_{92}\text{U}$ is

(a) 4.25 MeV
(b) 4.5 MeV
(c) 6 MeV
(d) 5 MeV

58. Using data of previous problem, we can conclude that

(a) $^{238}_{92}\text{U}$ can decay into $^{237}_{91}\text{Pa}$

(b) $^{238}_{92}\text{U}$ can decay into $^{234}_{90}\text{Th}$

(c) $^{238}_{92}\text{U}$ can decay into either $^{234}_{90}\text{Th}$ or into $^{237}_{91}\text{Pa}$

(d) Data not sufficient to analyse

59. In beta (β^-) decay, emission consists of

(a) ^4_2He (b) $^0_{-1}e$ (c) $^0_{+1}e$ (d) ^1_1H

60. In beta (β^+) decay, emission consists of

(a) ^4_2He (b) $^0_{-1}e$ (c) $^0_{+1}e$ (d) ^1_1H

61. In case of beta minus (β^-) decay an electron is emitted by the nucleus alongwith

(a) a neutrino (b) an anti-neutrino

(c) a positron (d) a neutron

62. In case of beta positive (β^+) decay, a positron is emitted alongwith

(a) an electron (b) a neutrino

(c) an anti-neutrino (d) a positron

63. In β^+-decay, process occurring inside the nucleus is

(a) $n \longrightarrow p + e^+ + \nu$ (b) $p \longrightarrow n + e^+ + \nu$

(c) $e \longrightarrow n + p + \bar{\nu}$ (d) $p \longrightarrow n + e^+ + \bar{\nu}$

64. When a nucleus is in an excited state

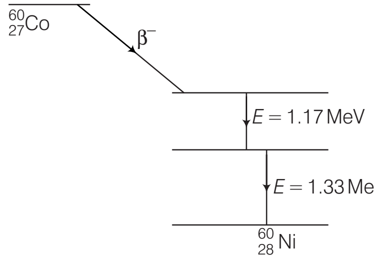
(a) it can stay in excited state

(b) it gives excess energy to surrounding electrons and comes to a lower energy state

(c) it can make a transition to a lower energy state by emission of electromagnetic radiation

(d) it can emit a proton or neutron with excess kinetic energy and so achieves a lower energy state

65. 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

66. Out of 80 kg of a radioactive substance 10 kg decays in 1 h. The decay constant of material is

(a) $5.80 \times 10^{-4}\text{s}^{-1}$ (b) $1.16 \times 10^{-3}\text{s}^{-1}$

(c) $2.32 \times 10^{-3}\text{s}^{-1}$ (d) $4.64 \times 10^{-3}\text{s}^{-1}$

67. A sample of ^{67}Ga with a half-life of 78 h has a mass of 3.4 g. Initial decay rate of sample is

(a) $8.00 \times 10^{16}\ \text{s}^{-1}$ (b) $6.27 \times 10^{16}\ \text{s}^{-1}$

(c) $7.53 \times 10^{16}\ \text{s}^{-1}$ (d) $8.53 \times 10^{15}\ \text{s}^{-1}$

68. Activity of a radioactive sample reduces from 8 counts to 1 count in 3 h. Half-life of sample is

(a) 2 h (b) 1 h (c) 3 h (d) 4 h

69. 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

(a) $1/4\lambda$ (b) 4λ (c) 2λ (d) $1/2\lambda$

70. If half-life of a radioactive substance is 1 month, then which of these are true?

(a) 7/8th part of substance disintegrate in 3 months

(b) 1/8th part of substance disintegrate in 4 months

(c) Substance disintegrates completely in 4 months

(d) The substance disintegrates completely in 2 months

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

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

72. The half-life of a radioactive substance is 20 s, the time taken for the sample to decay by 7/8th of its initial value is

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

73. A radio isotope X with a half life 1.4×10^9 yr decays to 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

74. 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

75. 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

Topic 4

Nuclear Energy

76. Binding energy per nucleon (E_{bn}) is nearly constant ($\geq$ 8.0 MeV) for elements whose mass number range is
(a) $A < 30$ (b) $30 \leq A \leq 170$
(c) $A \geq 170$ (d) $0 < A \leq 56$

77. If a nucleus with mass number $A = 240$ with $E_{bn} = 7.6$ MeV breaks into two fragments of $A = 120$ and $E_{bn} = 8.5$ MeV, then released energy is around
(a) 216 MeV
(b) 200 MeV
(c) 100 MeV
(d) Cannot be estimated from given data

78. In the fission reaction of ${}^{235}_{92}\mathrm{U}$, on an average number of neutrons (per fission) released is
(a) 1 (b) 2 (c) 3 (d) 2.5

79. In fission reaction of a ${}^{235}_{92}\mathrm{U}$ sample, chain reaction is possible because
(a) released energy is of order 200 MeV
(b) fissionable nucleus ${}^{236}_{92}\mathrm{U}$ is formed
(c) more neutrons are released then consumed
(d) excessive amount of heat is released

80. For sustaining the chain reaction in a sample (of small size) of ${}^{235}_{92}\mathrm{U}$, it is desirable to slow down fast neutrons by
(a) friction (b) elastic damping/scattering
(c) absorption (d) None of these

81. For maintaining sustained chain reaction, the following is required
(a) protons (b) electrons (c) neutrons (d) positrons

82. Operation of a reactor is said to be critical when K, the multiplication factor becomes
(a) 0 (b) 2 (c) ∞ (d) 1

83. A sample of uranium U contains
(a) more of isotope ${}^{235}_{92}\mathrm{U}$ and less of ${}^{238}_{92}\mathrm{U}$
(b) more of impurities alongwith a small amount of ${}^{238}_{92}\mathrm{U}$
(c) equal amounts of isotopes ${}^{235}_{92}\mathrm{U}$ and ${}^{238}_{92}\mathrm{U}$
(d) more of isotope ${}^{238}_{92}\mathrm{U}$ and less of ${}^{235}_{92}\mathrm{U}$

84. The abundant ${}^{238}_{92}\mathrm{U}$ isotope is non-fissionable but produces which radioactive element when captures neutron
(a) Thorium (b) produces plutonium
(c) absorbs fast neutrons (d) rejects slow neutrons

85. In any nuclear reactor amount of a radioactive substance required as a fuel is
(a) very less (b) very large
(c) of moderate amounts (d) None of these

86. On bombarding U^{235} by slow neutron, 200 MeV energy is released. If the power output of atomic reactor is 1.6 MW, then the rate of fission will be
(a) $5 \times 10^{22}\ \mathrm{s}^{-1}$ (b) $5 \times 10^{16}\ \mathrm{s}^{-1}$
(c) $8 \times 10^{16}\ \mathrm{s}^{-1}$ (d) $20 \times 10^{16}\ \mathrm{s}^{-1}$

87. In any fission process, ratio of mass of daughter nucleus to mass of parent nucleus is
(a) less than 1
(b) greater than 1
(c) equal to 1
(d) depends on the mass of parent nucleus

88. For a nuclear to be in critical condition, the value of neutron multiplication factor (K) must be
(a) $K > 1$ (b) $K < 1$ (c) $K = 1$ (d) $K = 0$

89. Heavy water is used in a nuclear reactor to
(a) absorb the neutrons (b) slow down the neutrons
(c) act as coolant (d) None of these

90. 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^{22}
(c) 10×10^{20} (d) 5×10^{15}

91. In a nuclear reactor, the fuel is consumed at the rate of $1\ \mathrm{mgs}^{-1}$. The power generate (in kW) is
(a) 9×10^{14} (b) 9×10^{7} (c) 9×10^{8} (d) 9×10^{12}

92. 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

93. Thermonuclear fusion is
(a) fusion due to high temperatures
(b) fusion due to high pressures
(c) fusion due to high volumes
(d) fusion due to high velocities

94. For thermonuclear fusion to occur between two protons at rest,
(a) temperature on the surface of sun is sufficient
(b) temperature inside the core of sun is sufficient
(c) temperature much higher than the core temperature of sun is required
(d) room temperature is sufficient

95. In fusion reaction occurring in the sun,
(a) hydrogen is converted into carbon
(b) hydrogen and helium are converted into carbon and other heavier metals/elements
(c) helium is converted into hydrogen
(d) hydrogen is converted into helium

96. Which of the following are suitable for the fusion process?
(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

97. The fusion process is possible at high temperature, because at higher temperatures
(a) the nucleus disintegrates
(b) the molecules disintegrates
(c) atoms become ionised
(d) the nucleus get sufficient energy to overcome the strong force of repulsion

98. 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's core

Special Format Questions

I. Assertion and Reason

Directions (Q. Nos. 99-103) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

99. Assertion Nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same.

Reason The nuclear force does not depend on the electric charge.

100. Assertion The detection of neutrinos is extremely difficult.

Reason Neutrinos interact only very weakly with matter.

101. Assertion A free neutron is unstable.

Reason Free neutron disintegrates into proton, electron and an anti-neutrino *i.e.*, $n \rightarrow p + e^- + \bar{\nu}$

102. Assertion An α-particle is emitted when uranium 238 decays into thorium.

Reason The decay of uranium 238 to thorium is represented by ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$

The helium nuclei is called an alpha particle.

103. Assertion Naturally, thermonuclear fusion reaction is not possible on earth.

Reason For thermonuclear fusion to take place, extreme condition of temperature and pressure are required.

II. Statement Based Questions Type I

Directions (Q. Nos. 104-110) *In the following questions, a statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I
(c) Statement I is correct but Statement II is incorrect
(d) Statement I is incorrect but Statement II is correct

104. Statement I Kilogram is not a convenient unit to measure mass of an atom.

Statement II The mass of an atom is very small.

105. Statement I Mass and energy are separately conserved in a reaction.

Statement II Law of conservation of mass and law of conservation of energy are valid for every reaction.

106. Statement I Binding energy per nucleon is a constant for average mass numbers.

Statement II Nuclear forces are short range forces and so they are saturated for a medium or large sized nucleus.

107. Statement I Energy always releases in fission (splitting of a heavy nucleus into lighter nuclei), $(A > 170)$.

Statement II Nucleons of lighter nuclei are more tightly bound, $(30 < A < 170)$.

108. Statement I On an average $2\frac{1}{2}$ neutrons are liberated per fission of ${}^{235}_{92}\text{U}$ but a chain reaction in a sample of ${}^{235}_{92}\text{U}$ is still not possible.

Statement II Neutrons liberated are readily absorbed by other ${}^{235}_{92}\text{U}$ atoms present in the sample.

109. Statement I Energy is released when two lighter nuclei are fused together $(A < 30)$.

Statement II Binding energy per nucleon of heavy nuclei is less than that of lighter nuclei. $(30 < A < 170)$.

110. Statement I In a fusion reaction, two lighter nuclei combine to form a single nucleus with release of energy.

Statement II Elements more heavier than iron are not produced by fusion.

Statement Based Questions Type II

111. Which of the following statements are correct?

I. Atoms of isotopes have same electronic structure.
II. Atoms of isotopes occupies same place in periodic table.
III. Atoms of isotopes have same number of protons.
IV. Atoms of isotopes have same number of neutrons.

(a) I and II (b) I, II and III
(c) I, II, III and IV (d) II and IV

112. Which of the following are correct?

I. Nuclear density is a constant for all matter.
II. Nuclear density is around 2.3×10^{17} kg/m^3.
III. Nuclear density is very large compared to ordinary matter.
IV. Mass of ordinary matter is mainly due to nucleus.

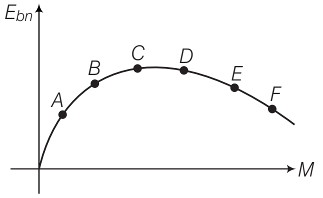
(a) I, II and III (b) II and III
(c) I and II (d) I, II, III and IV

113. For binding energy per nucleon *versus* mass number curve, which of the following are correct?

I. Binding energy per nucleon E_{bn} is independent of mass number in range $30 < A < 170$.
II. Binding energy is lower for both light nuclei $(A < 30)$ and heavy nuclei $(A > 170)$.
III. Binding energy is maximum of about 8.75 MeV for $A = 56$.
IV. In region $0 < A < 80$, binding energy increases with mass number.

(a) I, II, III and IV (b) I, II and IV
(c) II, III and IV (d) I, II and III

114. Plot of binding energy per nucleon E_{bn} against the nuclear mass M is



For masses A, B, C, D, E and F corresponding to different nuclei. Consider reactions

I. $A + B \longrightarrow C + \varepsilon$
II. $C \longrightarrow A + B + \varepsilon$
III. $D + E \longrightarrow F + \varepsilon$
IV. $F \longrightarrow D + E + \varepsilon$

where, ε is the energy released.
In which reaction ε is positive?

(a) I and IV (b) I and III
(c) II and IV (d) II and III

115. In one half-life time duration

I. activity of a sample reduced to half of its initial value.
II. total number of nuclei present are reduced to half of its initial value.
III. number of radio active nuclei present is reduced to half of its initial value.
IV. mass of sample is reduced to half of its initial value.

Out of these, correct statements are

(a) I and II (b) I and III
(c) II and IV (d) II and III

116. Which of the following are fission reactions?

I. ${}^{1}_{0}n + {}^{235}_{92}\text{U} \rightarrow {}^{236}_{92}\text{U} \rightarrow {}^{144}_{56}\text{Ba} + {}^{89}_{36}\text{Kr} + 3{}^{1}_{0}n$
II. ${}^{1}_{0}n + {}^{235}_{92}\text{U} \rightarrow {}^{236}_{92}\text{U} \rightarrow {}^{133}_{51}\text{Sb} + {}^{99}_{41}\text{Nb} + 4{}^{1}_{0}n$
III. ${}^{1}_{0}n + {}^{235}_{92}\text{U} \rightarrow {}^{1.40}_{54}\text{Xe} + {}^{94}_{38}\text{Sr} + 2{}^{1}_{0}n$
IV. ${}^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} + n$

(a) I , II and IV (b) III and IV
(c) II, III and IV (d) I, II and III

117. In α-decay which of these are true?

I. ${}^{4}_{2}\text{He}$ is emitted.
II. Mass number of daughter nucleus decreases by 4.
III. Atomic number of daughter nucleus decreases by 2.
IV. ${}^{4}_{2}\text{He}$ is electrically neutral.

(a) I and II (b) I, II and IV
(c) I, II and III (d) I, II, III and IV

118. Nuclear force is a strong attractive force which

I. is responsible for high value of binding energy per nucleon.
II. overcomes the repulsive force of proton and proton.

III. binds protons and neutrons into the nucleus.
IV. is very short range.

Which of the above statements are correct?

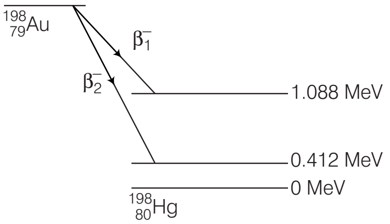
(a) I and II (b) II and IV
(c) II, III and IV (d) I, II, III and IV

119. For a fusion reaction to takes place, conditions required are

I. large amount of fusing material.
II. high temperature.
III. large nucleus sizes of fusing material.
IV. small nuclear sizes of fusing material.

(a) I, II and III (b) II, III and IV
(c) I, III and IV (d) I, II and IV

120. β-decay of ${}^{198}_{79}\text{Au}$ is shown



Frequency of γ-ray photons emitted will be

I. 2.626×10^{20} Hz II. 0.944×10^{20} Hz
III. 1.631×10^{20} Hz IV. 0.564×10^{20} Hz

(a) I, II and IV (b) II, III and IV
(c) II and III (d) I, II and III

121. If a nuclear power reactor is highly polluting, why then they are built

I. they produce lots of stable elements for a small amount of fuel.
II. they reduce green house effect by producing steam.
III. they reduce green house effect by saving fossil fuels.
IV. they produce power to meet our growing demands.

(a) I and II (b) II and III
(c) I and III (d) III and IV

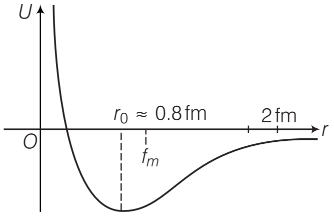
III. Matching Type

122. Match the following nuclei with the type of characteristic shown.

	Column I		Column II
A.	Isotopes	1.	${}^7_3\text{Li}, {}^7_4\text{Be}$
B.	Isobars	2.	${}_8\text{O}^{18}, {}_9\text{F}^{19}$
C.	Isotones	3.	${}_8\text{O}^{17}, {}_9\text{F}^{17}$
D.	Mirror nuclei	4.	${}_{92}\text{U}^{235}, {}_{92}\text{U}^{238}$

	A	B	C	D		A	B	C	D
(a)	1	3	4	2	(b)	4	1	3	2
(c)	4	3	2	1	(d)	3	4	2	1

123. Potential energy for a pair of nucleons *versus* separation between the nucleons is plotted below.



Match the following columns.

	Column I		Column II
A.	Force between nucleons is zero.	1.	$r > 0.8$ fm
B.	Force between nucleons is attractive.	2.	$r < 0.8$ fm
C.	Force between nucleons is repulsive.	3.	$r = 0.8$ fm
D.	Potential energy is minimum.	4.	$r = 0$

	A	B	C	D		A	B	C	D
(a)	3	1	2	4	(b)	3	2	1	4
(c)	4	3	2	1	(d)	3	1	2	3

124. Match the following columns with type of decay and their products.

	Column I		Column II
A.	α-decay	1.	X-rays
B.	β^+-decay	2.	Electromagnetic waves
C.	γ-decay	3.	Electrons
D.	*K*-electron-capture	4.	${}^4\text{He}_2$, Helium nucleus

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	4	2	3	1
(c)	1	2	3	4	(d)	4	2	1	3

125. Match the following columns.

	Column I		Column II
A.	${}^{242}_{94}\text{Pu} \rightarrow {}^{238}_{92}\text{U} + {}^4_2\text{He}$	1.	*K*-electron capture
B.	${}^{210}_{83}\text{Bi} \rightarrow {}^{210}_{84}\text{Po} + e^- + \bar{\nu}$	2.	β^+-decay
C.	${}^{97}_{43}\text{Te} \rightarrow {}^{97}_{42}\text{Mo} + e^+ + \nu$	3.	β^--decay
D.	${}^{120}_{54}\text{Xe} + e^- \longrightarrow {}^{120}_{53}\text{I} + \nu$	4.	α-decay

	A	B	C	D		A	B	C	D
(a)	4	3	2	1	(b)	1	4	3	2
(c)	4	2	3	1	(d)	4	3	1	2

126. Match the nuclear processes given in Column I with the appropriate option (s) in Column II. **[JEE Advanced 2015]**

	Column I		Column II
A.	Nuclear fusion	P.	Absorption of thermal neutrons by ${}^{235}_{92}\text{U}$
B.	Fission in a nuclear reactor	Q.	${}^{60}_{27}\text{Co}$ nucleus
C.	β-decay	R.	Energy production in stars *via* hydrogen conversion to helium
D.	γ-ray emission	S.	Heavy water
		T.	Neutrino emission

	A	B	C	D
(a)	PT	QR	RT	SQ
(b)	RS	PT	QR	S
(c)	R	PS	QT	Q
(d)	S	RT	QP	RS

127. Match Column I of the nuclear processes with Column II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the Column.

	Column I		Column II
A.	α-decay	1.	${}^{15}_{8}\text{O} \rightarrow {}^{15}_{7}\text{O} + \ldots$
B.	β^+-decay	2.	${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + \ldots$
C.	Fission	3.	${}^{185}_{83}\text{Bi} \rightarrow {}^{184}_{82}\text{Pb} + \ldots$
D.	Proton emission	4.	${}^{239}_{94}\text{Pu} \rightarrow {}^{140}_{57}\text{La} + \ldots$

	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	4	2	3	1
(c)	1	2	3	4	(d)	4	2	1	3

IV. Passage Based Questions

■ **Directions** (Q. Nos. 128-130) *These questions are based on the following situation. Choose the correct options from those given below.*

In an experiment on two radioactive isotopes of an element (which do not decay into one another), their mass ratio at a given instant was formed to be 3. The decaying isotope has a large mass and activity of 1.0 curie initially. The half-lives of the two radioactive isotopes are known to be 12 h and 16 h. Activity of the each isotope and their mass ratio after 2 days was studied.

128. Ratio of number of atoms of first isotope to that of the other isotope is

(a) 2 (b) 1.5 (c) 1 (d) 1.75

129. Activity of first isotope is

(a) $\frac{3}{2}\mu\text{Ci}$ (b) $\frac{1}{4}\mu\text{Ci}$ (c) $\frac{1}{8}\mu\text{Ci}$ (d) $\frac{1}{16}\mu\text{Ci}$

130. Activity of second isotope is

(a) $\frac{1}{8}\mu\text{Ci}$ (b) $\frac{1}{32}\mu\text{Ci}$ (c) $\frac{1}{2}\mu\text{Ci}$ (d) $\frac{1}{48}\mu\text{Ci}$

■ **Directions** (Q. Nos. 131-132) *These questions are based on the following situation. Choose the correct options from those given below.*

A nucleus of mass $M + \Delta m$ is at rest and decays into two daughter nuclei of equal mass $M/2$ each. Speed of light is c.

131. The speed of daughter nuclei is

(a) $c\sqrt{\frac{\Delta m}{M + \Delta m}}$ (b) $c\frac{\Delta m}{M + \Delta m}$

(c) $c\sqrt{\frac{2\Delta m}{M}}$ (d) $c\sqrt{\frac{\Delta m}{M}}$

132. The binding energy per nucleon for the parent nucleus is E_1 and that for daughter nuclei is E_2. Then

(a) $E_1 = 2E_2$ (b) $E_2 = 2E_2$ (c) $E_1 > E_2$ (d) $E_2 > E_1$

■ **Directions** (Q. Nos. 133-135) *These questions are based on the following situation. Choose the correct options from those given below.*

Suppose that a reactor using uranium -235 has an output of 700 MW and is 20% efficient. An atom of U^{235} undergoes fission in a reactor liberated 200 MeV energy.

133. Energy generated from the reactor per fission is

(a) 3.2×10^{-11} J (b) 6.4×10^{-11} J

(c) 3.2×10^{-12} J (d) 6.4×10^{-12} J

134. How many uranium atoms does it consume in 24 h?

(a) 9.5×10^{21} (b) 9.5×10^{22} (c) 9.5×10^{23} (d) 9.5×10^{24}

135. What mass of uranium does it consume during 24 h?

(a) 2.5 kg (b) 3.7 kg (c) 2.5 g (d) 3.7 g

V. More than One Option Correct

136. If the binding energy per nucleon in ${}_3\text{Li}^7$ and ${}_2\text{He}^4$ nuclei are respectively 5.60 MeV and 7.06 MeV respectively, then

(a) the energy of proton in the reaction ${}_3\text{Li}^7 + p \rightarrow 2\,{}_2\text{He}^4$ is 18.3 MeV

(b) total BE of nucleons in ${}_3\text{Li}^7$ is 39.20 MeV

(c) total BE of nucleons in $2({}_2\text{He}^4)$ is 56.48 MeV

(d) Both (a) and (b) are correct

137. Consider the following reaction

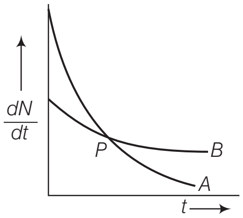
$$ {}_Z X^A \rightarrow {}_{Z+1}Y^A \rightarrow {}_{Z-1}K^{A-4} \rightarrow {}_{Z-1}K^{A-4} $$

Radioactive radiations emitted is/are

(a) α and β (b) α and γ

(c) α, β and γ (d) Only α and β

138. The variation of decay rate of two radioactive samples A and B with time is shown in figure. Which of the following statements are true?



(a) Decay constant of A is greater than that of B, hence A always decays faster than B

(b) Decay constant of B is greater than that of A but its decay rate is always smaller than that of A

(c) Decay constant of A is greater than that of B but it does not always decay faster than B

(d) Decay constant of B is smaller than that of A but still its decay rate becomes equal to that of A at a later instant

NCERT & NCERT Exemplar Questions

NCERT

139. The three stable isotopes of neon, ${}^{20}_{10}\text{Ne}$, ${}^{21}_{10}\text{Ne}$ and ${}^{22}_{10}\text{Ne}$ have respective abundances of 90.51%, 0.27% and 9.22%. The atomic masses of the three isotopes are 19.99 u, 20.99 u and 21.99 u, respectively. Obtain the average atomic mass of neon.

(a) 20.18 u (b) 12.5 u (c) 8.55 u (d) 1.257 u

140. Obtain the binding energy (in MeV) of a nitrogen nucleus (${}^{14}_{7}\text{N}$), given $m({}^{14}_{7}\text{N}) = 14.00307$ u.

(a) 210 (b) 104.67 (c) 83.5 (d) 75.25

141. A given coin has a mass of 3.0 g. Calculate the nuclear energy that would be required to separate all the neutrons and protons from each other. For simplicity, assume that the coin is entirely made of ${}^{63}_{29}\text{Cu}$ atoms (of mass 62.92960 u).

(a) 2.5×10^{25} MeV (b) 0.5×10^{12} MeV

(c) 1.58×10^{25} MeV (d) 7.5×10^{12} MeV

142. Obtain the amount of ${}^{60}_{27}\text{Co}$ necessary to provide a radioactive source of 8.0 mCi strength. The half-life of ${}^{60}_{27}\text{Co}$ is 5.3 yr.

(a) 7.12×10^{-6} g (b) 1.2×10^{-5} g

(c) 4.5×10^{-6} g (d) 3.5×10^{-5} g

143. The half-life of ${}^{90}_{38}\text{Sr}$ is 28 yr. What is the disintegration rate of 15 mg of this isotope?

(a) 5.7×10^{10} Bq (b) 7.877×10^{10} Bq

(c) 4.3×10^{10} Bq (d) 2.34×10^{10} Bq

144. The fission properties of ${}^{239}_{94}\text{Pu}$ are very similar to those of ${}^{235}_{92}\text{U}$. The average energy released per fission is 180 MeV. How much energy, in MeV is released if all the atoms in 1 kg of pure ${}^{239}_{94}\text{Pu}$ undergo fission?

(a) 4.53×10^{26} eV (b) 1.25×10^{26} eV

(c) 8.06×10^{26} eV (d) 3.75×10^{26} eV

145. Calculate the height of the potential barrier for a head on collision of two deuterons. [Hint : The height of the potential barrier is given by the Coulomb repulsion between the two deuterons when they just touch each other. Assume that they can be taken as hard spheres of radius 2.0 fm.]

(a) 215 kV (b) 360 kV

(c) 120 kV (d) 450 kV

146. Boron has two stable isotopes ${}^{10}_{5}\text{B}$ and ${}^{11}_{5}\text{B}$. Their respective masses are 10.01294 u and 11.00931 u and the atomic mass of boron is 10.811 u. Then, the abundances of ${}^{10}_{5}\text{B}$ and ${}^{11}_{5}\text{B}$ are

(a) 19.9, 80.1 (b) 80.1, 19.9

(c) 92.5, 7.5 (d) 7.5, 92.5

147. The binding energy of the nuclei ${}^{56}_{26}\text{Fe}$ in units of MeV is $[m({}^{56}_{26}\text{Fe}) = 55.934939 \text{ u}]$

(a) 7.20 MeV

(b) 8.79 MeV

(c) 10.2 MeV

(d) 13.6 MeV

148. A 1000 MW fission reactor consumes half of its fuel in 5 yr. The reactor operates 80% of the time that all the energy generated arises from the fission of ${}^{235}_{92}\text{U}$ and this nuclide is consumed only by the fission process.The power of reactor $P = 1000$ MW. How much ${}^{235}_{92}\text{U}$ did it contain initially?

(a) 2050 kg

(b) 3070 kg

(c) 4000 kg

(d) 5000 kg

149. How long can an electric lamp of 100 W be kept glowing by fusion of 2.0 kg of deuterium? Take the fusion reaction as

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

(a) 6×10^{3} yr (b) 5×10^{4} yr

(c) 7×10^{5} yr (d) 10×10^{6} yr

150. Suppose India had a target of producing by 2020 AD, 200000 MW of electric power, ten percent of which was to be obtained from nuclear power plants. Suppose we are given that, on an average, the efficiency of utilization (*i.e.*, conversion to electric energy) of thermal energy produced in a reactor was 25%. How much amount of fissionable uranium would our country need per year by 2020? Take the heat energy per fission of ^{235}U to be about 200 MeV.

(a) 2×10^2 kg

(b) 3×10^2 kg

(c) 2×10^3 kg

(d) 3×10^4 kg

NCERT Exemplar

151. Suppose we have a large number of containers each containing initially 10000 atoms of a radioactive material with a half-life of 1 yr. After 1 yr

(a) all containers will have 5000 atoms of the material

(b) all containers will contains same number of atoms of the material but that number will only be approximately 5000

(c) the containers will general have different number of the atoms but their average is around 5000

(d) None of the containers have more than 5000 atoms

152. When nucleus in an atom undergoes a radioactive decay, the electronic energy level of the atom

(a) do not change for any type of radioactivity

(b) change for α and β-radioactivity but not for γ-radioactivity

(c) change for α-radioactivity but not for others

(d) change for β-radioactivity but not for others

153. M_X and M_Y denote the atomic masses of the parent and the daughter nuclei, respectively in a radioactive decay. The Q value for a β^--decay is Q_1 and that for a β^+ decay is Q_2. If m_e denotes the mass of an electron, then which of the following statements is correct?

(a) $Q_1 = (M_X - M_Y)\,c^2$ and $Q_2 = (M_X - M_Y - 2M_e)\,c^2$

(b) $Q_1 = (M_X - M_Y)\,c^2$ and $Q_2 = (M_X - M_Y)\,c^2$

(c) $Q_1 = (M_X - M_Y - 2M_e)\,c^2$ and $Q_2 = (M_X - M_Y + 2M_e)\,c^2$

(d) $Q_1 = (M_X - M_Y + 2M_e)\,c^2$ and $Q_2 = (M_X - M_Y + 2M_e)\,c^2$

154. Heavy stable nuclei have more neutrons than protons. This is because of the fact that

(a) neutrons are heavier than protons

(b) electrostatic force between protons is repulsive

(c) neutrons decay into protons by beta decay

(d) nuclear force between neutrons is weaker than protons

155. In a nuclear reactor, moderator slow down the neutrons which come out in a fission process. The moderator have light nuclei. Heavy nucleus will not serve the purpose because

(a) they will break up

(b) elastic collision with neutrons with heavy nuclei will not slow them down

(c) weight of reactor is appreciably high

(d) substances with heavy nuclei are not liquids or gases at room temperature

156. Fusion processes like combining two deuterons to form a He nucleus are impossible at ordinary temperatures and pressures.

The reason for this can be traced to the fact that

(a) nuclear forces are long-range

(b) nuclei are positively charged

(c) the original nuclei must be completely ionised before fusion can takes place

(d) the original nuclei must break up from combining with each other

157. Samples of two radioactive nuclides A and B are taken. λ_A and λ_B are the disintegration constants of A and B, respectively. In which of the following cases, the two samples can simultaneously have the same decay rate at any time?

(a) Initial rate of decay of A is twice the initial rate of decay of B and $\lambda_A = \lambda_B$

(b) Initial rate of decay of A is twice the initial rate of decay of B and $\lambda_A > \lambda_B$

(c) Initial rate of decay of B is twice the initial rate of decay of A and $\lambda_A > \lambda_B$

(d) $\dfrac{\lambda A}{\lambda B} = \dfrac{NB}{NA}$

158. The gravitational force between a H-atom and another particle of mass m will be given by Newton's law

$$F = G\,\frac{M.m}{r^2}, \text{ where } r \text{ is in km and}$$

(a) $M = m_{\text{proton}} + m_{\text{electron}}$

(b) $M = m_{\text{proton}} + m_{\text{electron}} - \dfrac{B}{c^2}$ $(B = 13.6 \text{ eV})$.

(c) M is not related to the mass of the hydrogen atom.

(d) $M = m_{\text{proton}} + m_{\text{electron}} - \dfrac{|V|}{c^2}$ ($|V|$ = magnitude of the potential energy of electron in the H-atom.

Answers

1.	(b)	**2.**	(c)	**3.**	(a)	**4.**	(c)	**5.**	(a)	**6.**	(c)	**7.**	(c)	**8.**	(d)	**9.**	(d)	**10.**	(a)	**11.**	(b)	**12.**	(c)	**13.**	(b)	**14.**	(c)	**15.**	(d)
16.	(a)	**17.**	(b)	**18.**	(d)	**19.**	(c)	**20.**	(c)	**21.**	(a)	**22.**	(b)	**23.**	(a)	**24**	(d)	**25.**	(c)	**26.**	(a)	**27.**	(c)	**28.**	(b)	**29.**	(b)	**30.**	(c)
31.	(d)	**32.**	(b)	**33.**	(a)	**34.**	(b)	**35.**	(a)	**36.**	(d)	**37.**	(c)	**38.**	(b)	**39.**	(d)	**40.**	(d)	**41.**	(c)	**42.**	(d)	**43.**	(d)	**44.**	(a)	**45.**	(d)
46.	(c)	**47.**	(b)	**48.**	(b)	**49.**	(c)	**50.**	(c)	**51.**	(a)	**52.**	(c)	**53.**	(d)	**54.**	(c)	**55.**	(a)	**56.**	(d)	**57.**	(a)	**58.**	(b)	**59.**	(b)	**60.**	(c)
61.	(b)	**62.**	(b)	**63.**	(b)	**64.**	(c)	**65.**	(c)	**66.**	(a)	**67.**	(c)	**68.**	(b)	**69.**	(d)	**70.**	(a)	**71.**	(c)	**72.**	(c)	**73.**	(c)	**74.**	(b)	**75.**	(d)
76.	(b)	**77.**	(a)	**78.**	(d)	**79.**	(c)	**80.**	(b)	**81.**	(c)	**82.**	(d)	**83.**	(d)	**84.**	(b)	**85.**	(a)	**86.**	(b)	**87.**	(a)	**88.**	(c)	**89.**	(b)	**90.**	(b)
91.	(b)	**92.**	(a)	**93.**	(a)	**94.**	(c)	**95.**	(d)	**96.**	(a)	**97.**	(d)	**98.**	(b)	**99.**	(a)	**100.**	(a)	**101.**	(a)	**102.**	(a)	**103.**	(a)	**104.**	(a)	**105.**	(b)
106.	(a)	**107.**	(a)	**108.**	(a)	**109.**	(c)	**110.**	(a)	**111.**	(b)	**112.**	(d)	**113.**	(d)	**114.**	(a)	**115.**	(b)	**116.**	(d)	**117.**	(c)	**118.**	(d)	**119.**	(d)	**120.**	(d)
121.	(d)	**122.**	(c)	**123.**	(d)	**124.**	(a)	**125.**	(a)	**126.**	(c)	**127.**	(a)	**128.**	(b)	**129.**	(d)	**130.**	(b)	**131.**	(c)	**132.**	(d)	**133.**	(d)	**134.**	(d)	**135.**	(b)
136.	(b,c)	**137.**	(c)	**138.**	(c,d)	**139.**	(a)	**140.**	(b)	**141.**	(c)	**142.**	(a)	**143.**	(b)	**144.**	(a)	**145.**	(b)	**146.**	(a)	**147.**	(b)	**148.**	(b)	**149.**	(b)	**150.**	(d)
151.	(c)	**152.**	(b)	**153.**	(a)	**154.**	(b)	**155.**	(b)	**156.**	(b)	**157.**	(d)	**158.**	(b)														

Hints *and* Explanations

1. (*b*) Radius of atom $\simeq 10^{-10}$

Radius of nucleus $\simeq 10^{-14}$

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

2. (*c*) Volume of a nucleus is about 10^{-12} times volume of an atom.

3. (*a*) As nearly 99.9% mass of atom is in nucleus.

$$\therefore \quad \frac{\text{Mass of nucleus}}{\text{Mass of atom}} = \frac{99.9}{100} = 0.99 \approx 1$$

6. (*c*) The average mass of a chlorine atom is obtained by the weighted average of the masses of the two isotopes, which is

$$= \frac{75.4 \times 34.98 + 24.6 \times 36.98}{100} = 35.47\text{u}$$

10. (*a*) Since, the nuclei of deuterium and tritium are isotopes of hydrogen, they must contain only one proton each. But the masses of the nuclei of hydrogen, deuterium and tritium are in the ratio of 1 : 2 : 3, because of presence of neutral matter in deuterium and tritium nuclei.

13. (*b*) A free neutron, unlike a free proton, is unstable. It decays into a proton, an electron and a anti-neutron (another elementary particle).

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

14. (*c*) For ${}^{12}_{6}\text{C}$, $A = 12 = N + Z, Z = 6 \Rightarrow N = 6$

For ${}^{14}_{6}\text{C}$; $A = 14 = N + Z, Z = 6 \Rightarrow N = 8$

Also, number of electrons in both atoms

= number of protons = $Z = 6$.

16. (*a*) As we know that,

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

$= 6.940934$ u

17. (*b*) Let the percentage of ${}^{10}_{5}\text{B}$ in sample be x. Then, percentage of ${}^{11}_{5}\text{B}$ is $(100 - x)$. So, using formula of average atomic masses of isotopes,

$$10.811 = \frac{10.01294 \times x + 11.00931\,(100 - x)}{100}$$

$$\Rightarrow \quad 1081.1 = 1100.931 - 0.99637x$$

$$\Rightarrow \quad 0.99637x = 19.831$$

$$\therefore \quad x = \frac{19.831}{0.99637} = 19.3 \approx 20\%$$

19. (*c*) Protons, neutrons and electrons in an atom of ${}^{14}_{6}\text{C}$ are 6, 8 and 6, respectively. 14 g of ${}^{14}_{6}\text{C}$ contains 6×10^{23} (1 mole) atoms, number of protons, neutrons and electrons in 14 g of ${}^{14}_{6}\text{C}$ are $6 \times 6 \times 10^{23} = 36 \times 10^{23}$ = number of protons.

$8 \times 6 \times 10^{23} = 48 \times 10^{23}$ = number of neutrons

and $6 \times 6 \times 10^{23} = 36 \times 10^{23}$ = number of electrons.

20. (*c*) As, we know both have same number of neutrons, so they described as isotones.

21. (*a*) When a more energetic particle is used, it can penetrate more against Coulomb's repulsion.

22. (*b*) $A_1 : A_2 = 1 : 3$

Their radii will be in the ratio

$$R_0 A_1^{1/3} : R_0 A_2^{1/3} = 1 : 3^{1/3}$$

$$\text{Density } \rho = \frac{A}{4/3\pi R^3}$$

$$\therefore \quad \rho_{A_1} : \rho_{A_2} = \frac{1}{\frac{4}{3}\pi R_0^3 \cdot 1^3} : \frac{3}{\frac{4}{3}\pi R_0^3 (3^{1/3})^3} = 1 : 1$$

23. (*a*) Here $A_1 = 197, \quad A_2 = 107$

$$\therefore \quad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{197}{107}\right)^{1/3} = 1.225$$

24. (*d*) Density $= \dfrac{\text{Mass}}{\text{Volume}} = \dfrac{mA}{\frac{4}{3}\pi R_0^3 A} = \dfrac{3m}{4\pi R_0^3}$, $m = m_p = m_N$

$$\approx 2.3 \times 10^{17}\ \text{kgm}^{-3}, \quad \text{which is a constant.}$$

25. (*c*) Nuclear radius $r \propto A^{1/3}$, where A is mass number

$$r = r_0 A^{1/3} = r_0 (27)^{1/3} = 3r_0$$

$$r_0 = \frac{3.6}{3} = 1.2\ \text{fm}$$

For ^{64}Cu , $\quad r = r_0\ A^{1/3} = 1.2\ \text{fm}\ (64)^{1/3} = 4.8\ \text{fm}$

26. (*a*) $R = R_0 A^{1/3}$ $\quad \log R = \log R_0 + \frac{1}{3}\log A$

Which is equation of a straight line with variables log A and log R.

27. (*c*) Surface area $= 4\pi R^2 = 4\pi\ (R_0 A^{1/3})^2$

$$= 4\pi\ R_0^2 \cdot A^{2/3}$$

$$= 4\ (3.14)(1.2 \times 10^{-15})^2 A^{2/3}$$

$$= (1.8 \times 10^{-29})\ A^{2/3}$$

28. (*b*) Energy, $E = 2 \times 10^{-3} \times (3 \times 10^8)^2$ J

$$E = 2 \times 10^{-3} \times 9 \times 10^{16} = 18 \times 10^{13}\ \text{J}$$

Thus, if one gram of matter is converted to energy, there is a release of enormous amount of energy.

29. (*b*) We have, $P = 200\ \text{MW} = 2 \times 10^8$ W

$$t = 1\,\text{h} = 3600\ \text{s}$$

$$E = P \times t = 2 \times 10^8 \times 3600\,\text{J}$$

as $\quad E = mc^2$

$$m = \frac{E}{c^2} = \frac{2 \times 10^8 \times 3600}{(3 \times 10^8)^2} = 8 \times 10^{-6}\ \text{kg}$$

31. (*d*) Mass of 8 neutrons $= 8 \times 1.00866$ u

Mass of 8 protons $= 8 \times 1.00727$ u

Therefore, the expected mass of $^{16}_{8}\text{O}$ nucleus.

$$= 8 \times 2.01593\ \text{u} = 16.12744\ \text{u}.$$

The atomic mass of $^{16}_{8}\text{O}$ found from mass spectroscopy experiments is seen to be 15.99493 u.

Thus, $\Delta M = 16.12744\ \text{u} - 15.99493\ \text{u} = 0.13691\ \text{u}$

34. (*b*) Energy of γ-ray photon

= KE of electron positron pair + Mass energy

$= 0.78 + 0.5 \times 2$ (an e^- and e^+ are created)

$= 1.78$ MeV

35. (*a*) $^{56}_{26}$ Fe nucleus has 26 protons and 30 neutrons.

$\therefore$ Mass defect $= (26 m_p + 30\ m_n) - m(^{56}_{26}\text{Fe})$

$$= 56.46340 - 55.934939 = 0.528461\ \text{amu}$$

Total BE $= 0.528461 \times 931.5$ MeV $= 492.26$ MeV

$\therefore$ Binding energy per nucleon

$$= \frac{492.26}{56} = 8.790\ \text{MeV}$$

Similarly for Bi, $E_{\text{bn}} = 7.848$ MeV

36. (*d*) The binding energy for $_1\text{H}^1$ is around zero and also not given in the question so we can ignore it

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

$$= (8 \times 7.60) - (7 \times 5.60)$$

$$= (56.48 - 39.2)\ \text{MeV}$$

$$= 17.28\ \text{MeV} \simeq 17.3\ \text{MeV}$$

38. (*b*) Potential energy of a pair of nucleons as a function of their separation. For a separation greater than r_0, the force is attractive and for separations less than r_0, the force is strongly repulsive. For potential energy U, force $F = -\,dU/dr$.

40. (*d*) Nuclear force is attractive in nature and exists only for a short distance ~ 10^{-15} m. It becomes repulsive when nucleons come very close.

46. (*c*) Number of half-lives

$$n = 100 = \frac{1600}{2^n}$$

or $\quad n = 4 \Rightarrow 4t_{1/2} = 8\ \text{s} \quad \Rightarrow \quad t_{1/2} = 2\text{s}$

$$N = \frac{N_0}{2^3} = \frac{1600}{8} = 200 \qquad (\because 6\text{s} = 3t_{1/2})$$

48. (*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.

50. (*c*) Fraction of radioactive substance left $= \dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^n$

$$\Rightarrow \qquad N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = \frac{N_0}{4}$$

51. (*a*) When $^{238}_{92}\text{U}$ undergoes α-decay, it transforms to $^{234}_{90}\text{Th}$

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

54. (*c*) $^{238}_{92}\text{U} \rightarrow ^{234}_{90}\text{Th} + ^{4}_{2}\text{He}$

When a α-particle is emitted mass number decreases by 4 and atomic number by 2.

56. (*d*) This energy is shared by the daughter nucleus $^{A-4}_{Z-2}Y$ and the α-particle, $^{4}_{2}\text{He}$ in the form of kinetic energy.

57. (*a*) The α-decay of $^{238}_{92}\text{U}$ is given by equation.

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

The energy released in this process is given by

$$Q = (M_{\text{U}} - M_{\text{Th}} - M_{\text{He}})\,c^2$$

Substituting the atomic masses as given in the data, we find

$$Q = (238.05079 - 234.04363 - 4.00260)\text{u} \times c^2$$

$$= (0.00456\ \text{u})c^2$$

$$= (0.00456\ \text{u})\ (931.5\ \text{MeV/u}) = 4.25\ \text{MeV}$$

58. (*b*) If $^{238}_{92}\text{U}$ spontaneously emits a proton, the decay process would be

$$^{238}_{92}\text{U} \rightarrow\ ^{237}_{91}\text{Pa} + ^{1}_{1}\text{H}$$

The Q for this process to happen is

$$= (M_{\text{U}} - M_{\text{Pa}} - M_{\text{H}})c^2$$

$$= (238.05079 - 237.05121 - 1.00783)u \times c^2$$

$$= (-0.00825\text{ u})c^2 = (0.00825\text{ u})(931.5\text{ MeV/u})$$

$$= -7.68\text{ MeV}$$

Thus, the Q of the process is negative and therefore it cannot proceed spontaneously. We will have to supply an energy of 7.68 MeV to a $^{238}_{92}\text{U}$ nucleus to make it emit a proton.

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

is more feasible/probable reaction.

63. (b) In β^+-decay, a proton transforms into neutron (inside the nucleus) by reaction

$$p \to n + e^+ + \nu \ldots$$

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

66. (a) Fraction of material that remains undecayed

$$N = N_0 e^{-\lambda t} \Rightarrow N = N_0 e^{-t \ln 2/T_{1/2}}$$

$$\Rightarrow \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow \frac{10}{80} = \left(\frac{1}{2}\right)^{\frac{1\text{h}}{T_{1/2}}}$$

$$\Rightarrow \quad T_{1/2} = \frac{1\text{h}}{3} = 20\text{ min} = 1200\text{ s}$$

and $$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1200} = 5.8 \times 10^{-4}\text{ s}^{-1}$$

67. (c) Decay rate, $R = \lambda N$

$$R_0 = \lambda N_0$$

$$\lambda = \frac{\log 2}{T_{1/2}} = \frac{\log 2}{78\text{ h}}$$

$$= 8.89 \times 10^{-3}\ (\text{h}^{-1}) = 2.47 \times 10^{-6}\text{s}^{-1}$$

$$N_0 = \frac{3.4}{67} \times 6 \times 10^{23} = 3.05 \times 10^{22}$$

$$\therefore \quad R_0 = (2.47 \times 10^{-6})(3.05 \times 10^{22})$$

$$= 7.53 \times 10^{16}\text{s}^{-1}$$

68. (b) $A_0 = 8$, $A = 1$, time $= 3$ h

$$\left(\frac{A}{A_0}\right) = \left(\frac{1}{2}\right)^n \Rightarrow \left(\frac{1}{8}\right) = \left(\frac{1}{2}\right)^n \Rightarrow n = 3$$

$$n = \frac{t}{T_{1/2}} \text{ or } T_{1/2} = \frac{t}{n} = \frac{3}{3} = 1\text{ h}$$

69. (d) Number of nuclei after time t,

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

Now, $$N_1 = N_0 e^{-5\lambda t}$$

$$N_2 = N_0 e^{-\lambda t}$$

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

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

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

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

For $t = 3$ months, $$\left(\frac{N}{N_0}\right) = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

$\therefore$ Disintegrated part in 3 months $= 1 - \frac{1}{8} = \frac{7}{8}$ part

71. (c) $$N = \frac{3.125}{100} N_0 = \frac{1}{32} N_0 \Rightarrow N = N_0 e^{-\lambda t}$$

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

$$\Rightarrow \quad e^{\lambda t} = 32 = 2^5$$

$$\Rightarrow \quad \lambda t = 5 \log_e 2$$

$$\Rightarrow \quad \left(\frac{0.693}{T}\right) t = 5 \times 0.693$$

$$\therefore \quad t = 5T\text{ yr}$$

72. (c) After three half-lives, the fraction of undecayed nuclei

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

$\therefore$ Time taken for the sample of decay by $\left(1 - \frac{1}{8}\right)$th or $\frac{7}{8}$ th of initial value.

$$= 3T_1 = 3 \times 20 = 60\text{ s}$$

73. (c) Ratio of $X : Y$ is given $= 1 : 7$

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

$\Rightarrow$ Let the initial total mass is m.

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

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

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

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

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

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

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

Number of half-lives $= 3$

$$\Rightarrow \quad T = 20\text{ yr}$$

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

75. (*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 $160\,\text{g} \xrightarrow[\text{half-life}]{10\,\text{s}} 80\,\text{g} \xrightarrow{10\,\text{s}} 40\,\text{g}$

$$\xrightarrow{10\,\text{s}} 20\,\text{g} \xrightarrow{10\,\text{s}} 10\,\text{g}$$

So, after 40s, A_1 and A_2 remains same.

77. (*a*) The energy released (*i.e.*, Q value) in the fission reaction of nuclei like uranium is of the order of 200 MeV per fissioning nucleus. This is estimated as follows.

Let us take a nucleus with $A = 240$ breaking into two fragments each of $A = 120$. Then,

E_{bn} for $A = 240$ nucleus is about 7.6 MeV.

E_{bn} for the two $A = 120$ fragment nuclei is about 8.5 MeV.

So, gain in binding energy for nucleon is about 0.9 MeV.

Hence, the total gain in binding energy is 240×0.9 or 216 MeV.

80. (*b*) Fast neutrons are slowed down by elastic scattering with light nuclei each collision takes away nearly 50% of energy.

82. (*d*) For $K = 1$, the operation of the reactor is said to be critical, which is what we wish it to be for steady power operation. If K becomes greater than one, the reaction rate and the reactor power increases exponentially. Unless the factor K is brought down very close to unity, the reactor will become supercritical and can even explode.

83. (*d*) Uranium are obtained naturally from earth contains only a very small part (0.01%) of U^{235} and remaining (99.9%) is U^{238}.

84. (*b*) The abundant ${}^{238}_{92}\text{U}$ isotope, which does not fission, on capturing a neutron leads to the formation of plutonium.

The series of reactions involved is

$${}^{238}_{92}\text{U} + n \rightarrow {}^{239}_{92}\text{U} \rightarrow {}^{239}_{93}\text{Np} + e^- + \bar{\nu}$$

$${}^{239}_{93}\text{Np} \rightarrow {}^{239}_{94}\text{Pu} + e^- + \bar{\nu}$$

Plutonium is highly radioactive and can also undergo fission under bombardment by slow neutrons.

86. (*b*) Energy released on bombarding U^{235} by neutron

$$= 200\text{ MeV}$$

Power output of atomic reactor = 1.6 MW

$$\therefore \text{ Rate of fission} = \frac{1.6 \times 10^6}{200 \times 10^6 \times 1.6 \times 10^{-19}} = 5 \times 10^{16}\ \text{s}^{-1}$$

87. (*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.

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

88. (*c*) In critical condition, $K = 1$. The chain reaction will be steady. The size of the fissionable material used is said to be critical size and its mass the critical mass.

90. (*b*) $\text{Power} = \dfrac{\text{Energy}}{\text{Time}} = 300 \times 10^6\ \text{W} = 3 \times 10^8\ \text{Js}^{-1}$

$$170\text{ MeV} = 170 \times 10^6 \times 1.6 \times 10^{-19} = 27.2 \times 10^{-12}\,\text{J}$$

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

$$= \frac{3 \times 10^{20} \times 3600}{27.2} = \frac{3 \times 36}{27.2} \times 10^{22}$$

$$= 4 \times 10^{22}\ \text{m}$$

91. (*b*) From Einstein's mass energy relation the energy releases is

$$\Delta E = \Delta mc^2$$

where, Δm is mass and c is speed of light.

Given, $\quad \Delta m = 1\text{ mg} = 1 \times 10^{-6}\text{ kg}, c = 3 \times 10^8\ \text{ms}^{-1}$

$\therefore \qquad \Delta E = 1 \times 10^{-6} \times (3 \times 10^8)^2 = 9 \times 10^{10}\,\text{J}$

The rate at which energy is dissipated is known as power,

i.e., $\qquad P = \dfrac{\Delta E}{t} = \dfrac{9 \times 10^{10}}{1} = 9 \times 10^{10}\ \text{W}$

$\therefore \qquad P = 9 \times 10^7\ \text{kW}$

92. (*a*) ${}_{92}\text{U}^{238} \longrightarrow {}_{92}\text{Th}^{238} + {}_2\text{He}^4$

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

$$|p_{\text{Th}}| = |p_{\text{He}}| = p$$

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

$$\text{KE} = \frac{p^2}{2m}$$

where, m is mass of an element.

Thus, $\qquad \text{KE} \propto \dfrac{1}{M}$

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

98. (*b*) High temperature conditions for fusion reactions can be created by exploding a fission bomb. Super-explosions equivalent to 10 megatons of explosive power of TNT were tested in 1954. Such bombs which involve fusion of isotopes of hydrogen, deuterium and tritium are called hydrogen bombs.

It is estimated that a nuclear arsenal sufficient to destroy every form of life on this planet several times over is in position to be triggered by the press of a button. Such a nuclear holocaust will not only destroy the life that exists now but its radioactive fallout will make this planet unfit for life for all times.

Scenarios based on theoretical calculations predict a long nuclear winter, as the radioactive waste will hang like a cloud in the earth's atmosphere and will absorb the sun's radiation.

100. (*a*) Neutrinos interact only very weakly with matter, they can even penetrate the earth without being absorbed. It is for this reason that their detection is extremely difficult and their presence went unnoticed for long.

105. (*b*) It was presumed that mass and energy were conserved separately in a reaction. However, Einstein showed that mass is another form of energy and one can convert mass-energy into other forms.

106. (*a*) The constancy of binding energy per nucleon can be understood in terms of its short-range. The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometres. 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.

109. (*c*) Two very light nuclei $(A \leq 10)$ joining to form a heavier nucleus. The binding energy per nucleon of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. This means that the final system is more tightly bound than the initial system.

110. (*a*) Heavier elements are formed by fusion but elements massive than iron cannot be produced by fusion, because iron has highest E_{bn}.

111. (*b*) The chemical properties of elements depend on their electronic structure. As the atoms of isotopes have identical electronic structure they have identical chemical behaviour and are placed in the same location in the periodic table.

114. (*a*) In reaction I, $A + B \longrightarrow C + \varepsilon$

It is a fusion reaction and reaction *e.g.*,

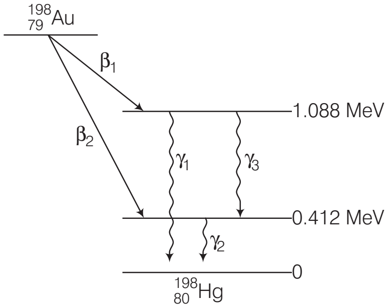
$$F \longrightarrow D + E + \varepsilon$$

So, it is a fission reaction.

Hence, energy is released in both.

119. (*d*) To generate useful amount of energy, nuclear fusion must occur in bulk matter. Heat is needed is to raise the temperature of the material until the particles have enough energy - due to their thermal motions alone - to penetrate the Coulomb barrier. This process is called thermonuclear fusion. Fusion occurs among small size nuclei.

120. (*d*)



Frequency of emitted γ-rays, $\nu = \dfrac{E_2 - E_1}{h}$

$$\therefore \qquad \nu(\gamma_1) = \frac{(1.088) \times 1.6 \times 10^{-13}}{6.63 \times 10^{-34}}$$

$$= 2.626 \times 10^{20} \text{ Hz}$$

$$\nu(\gamma_2) = \frac{(0.412 - 0) \times 1.6 \times 10^{-13}}{6.63 \times 10^{-34}}$$

$$= 0.994 \times 10^{20} \text{ Hz}$$

$$\nu(\gamma_3) = \frac{(1.088 - 0.412) \times 1.6 \times 10^{-13}}{6.63 \times 10^{-34}}$$

$$= 1.631 \times 10^{20} \text{ Hz}$$

122. (*c*) For $^{235}_{92}$U and $^{238}_{92}$U $Z = 92$; Number of protons equal are isotopes. In $^{17}_{8}$O and $^{17}_{9}$F, $A = 17$, Mass number are same $\Rightarrow$ Isobars. In $^{18}_{8}$O and $^{19}_{9}$F, $N = A - Z = 10$ for both

Since, number of neutrons are same, so there are isotones.

In $^{7}_{3}$Li $A = 7, Z = 3 \Rightarrow N = 4$ of in $^{7}_{4}$ Be; $A = 7, Z = 4$ $\Rightarrow \quad N = 3$.

As in both N and Z values are interchanged (lateral inversion of image of a plane mirror).

So, they are mirror nuclei.

123. (*d*) A rough plot of the potential energy between two nucleons as a function of distance shows that the potential energy is a minimum at a distance r_0 of about 0.8 fm.

This means that the force is attractive for distances larger than 0.8 fm and repulsive if they are separated by distances less than 0.8 fm.

124. (*a*) α-decay in which a helium nucleus $^4_2$He is emitted. β-decay in which electrons or positrons are emitted. γ-decay in which high energy photons are emitted, k electrons capture, high energy radiations are emitted.

125. (*a*)

$$^{242}_{94}\text{Pu} \longrightarrow {}^{238}_{92}\text{U} + {}^{4}_{2}\text{He} \qquad (\alpha\text{-decay})$$

$$^{210}_{83}\text{Bi} \longrightarrow {}^{210}_{84}\text{Po} + e^- + \bar{\nu} \qquad (\beta^-\text{-decay})$$

$$^{97}_{43}\text{Te} \longrightarrow {}^{97}_{42}\text{Mo} + e^+ + \nu \qquad (\beta^+\text{-decay})$$

$$^{120}_{54}\text{Xe} + e^- \longrightarrow {}^{120}_{53}\text{I} + \nu \quad (K\text{-electron capture})$$

128. (*b*) As, $A_1 = \lambda_1 N_1$ and $A_2 = \lambda_2 N_2$

$$\lambda_1 N_1 = \lambda_2 N_2 \qquad \ldots\text{(i)}$$

$$\Rightarrow \qquad \frac{N_1}{N_2} = 3 \qquad (\because N_1 > N_2)$$

$T_1 = 12$ h and $T_2 = 16$ h

After 2 days, *i.e.*, $2 \times 24 = 48$ h

$$N_1' = N_1 \left(\frac{1}{2}\right)^{t/T} \quad \left(\text{But } \frac{t}{T} = \frac{48}{12} = 4\right)$$

$$\therefore \qquad N_1' = N_1 \left(\frac{1}{2}\right)^4$$

$$\text{Also,} \qquad N_2' = N_2 \left(\frac{1}{2}\right)^3 \qquad \ldots\text{(iii)}$$

$$\therefore \qquad \frac{N_1'}{N_2'} = \frac{N_1}{N_2} \frac{\left(\frac{1}{2}\right)^4}{\left(\frac{1}{2}\right)^3} = 3 \times \frac{8}{16} = \frac{3}{2} = 1.5$$

129. (*d*) Activity of rapidly decaying isotope after 2 days

$$A_1' = \lambda_1 N_1' = \lambda_1 N_1 \left(\frac{1}{2}\right)^4 = \frac{1\,\mu\text{C}}{16}$$

130. (*b*) Activity of the other isotope after 2 days $A_2' = \lambda_2 N_2'$

Now, $T_1 = \dfrac{0.6931}{\lambda_2}$ and $T_2 = \dfrac{0.6931}{\lambda_2}$

$$\therefore \qquad \frac{\lambda_1}{\lambda_2} = \frac{T_2}{T_1} = \frac{16}{12} = \frac{4}{3}$$

$\therefore \quad \lambda_2 = \frac{3}{4}\lambda_1$

After $\frac{N_1'}{N_2'} = \frac{3}{2}$ or $N_2' = \frac{2}{3}N_1$

Equation becomes $A_2' = \frac{3}{4}\lambda_1 \times \frac{2}{3}N_1' = \frac{1}{2}\lambda \times N_1'$

$$= \frac{1}{2} \times \frac{1}{16}\,\mu\text{Ci} = \frac{1}{32}\,\mu\text{Ci}$$

131. (*c*) Total kinetic energy of products = Total energy released

$$\frac{p^2}{2m} + \frac{p^2}{2m} = (\text{mass defect})c^2 \quad \left(\text{where, } m = \frac{M}{2}\text{given}\right)$$

$$\Rightarrow \quad 2\left(\frac{p^2}{2m}\right) = \left[(M + \Delta m) - \left(\frac{M}{2} + \frac{M}{2}\right)\right]c^2$$

$$\Rightarrow \quad 2 \times \left[\frac{p^2}{2\left(\frac{M}{2}\right)}\right] = (\Delta m)c^2$$

$$\Rightarrow \quad \frac{2\left(\frac{M}{2}v\right)^2}{M} = (\Delta m)c^2$$

$$\Rightarrow \quad v = c\sqrt{\frac{2\Delta m}{M}}$$

132. (*d*) Because energy is releasing.

Binding energy per nucleon of product > that of parent.

$$\Rightarrow \quad E_2 > E_1$$

133. (*d*) Energy released in each fission of $U^{235} = 200$ MeV

$$= 200 \times 10^6 \times 1.6 \times 10^{-19}\,\text{J} = 3.2 \times 10^{-11}\ \text{J}$$

Since, only 20% of this is utilized efficiently, therefore energy generated from the reactor per fission.

$$= 3.2 \times 10^{-11} \times 0.20 = 6.4 \times 10^{-12}\ \text{J}$$

134. (*d*) Since, the output of the reactor is $700 \times 10^6\ \text{Js}^{-1}$, the number of fission required per second is

$$= \frac{700 \times 10^6}{6.4 \times 10^{-12}\,\text{J}} = 1.1 \times 10^{20}\,\text{s}^{-1}$$

The number of uranium – 235 atoms consumed in 24 hours.

$$= 24 \times 60 \times 60 \times 1.1 \times 10^{20} = 9.5 \times 10^{24}$$

135. (*b*) There are 6.02×10^{26} atoms in 235 kg of U-235. Therefore, the mass of U-235 consumed during 24 hours is

$$\frac{9.5 \times 10^{24}}{6.02 \times 10^{26}} \times 235\,\text{kg} = 3.7\,\text{kg}$$

136. (*b,c*) Total BE of nucleons in ${}_3\text{Li}^7 = 7 \times 5.60 = 39.20$ MeV

Total BE of nucleons in $2\,({}_2\text{He}^4) = (4 \times 7.06) \times 2$

$$= 56.48\ \text{MeV}$$

Therefore, energy of protons in the reaction

= difference of BE's

= 56.48 – 39.20

= 17.3 MeV

138. (*c,d*) $\left.\frac{dN}{dt}\right|_{t=0}$ = Initial decay rate of *A* is more than that of *B* but *B* finally have a decay rate more than that of *A*..Also, decay rate of *B* is equal to that of *A* at a later instant (Intersection point). A has smaller half-life which imply *A* has greater decay constant.

139. (*a*) Average atomic mass (m) = Weighted average of all isotopes

$$= \frac{90.51 \times 19.99 + 0.27 \times 20.99 + 9.22 \times 21.99}{90.51 + 0.27 + 9.22}$$

$$= \frac{1809.29 + 5.67 + 202.75}{100}$$

$$= \frac{2017.7}{100} = 20.18\ \text{u}$$

Thus, the average atomic mass of neon is 20.18 u.

140. (*b*) Given, mass of proton, $m_p = 1.007834$,

Mass of neutron, $m_n = 1.00867$ u

${}^{14}_{7}\text{N}$ nucleus contains 7 protons and 7 neutrons.

Mass defect (Δm) = mass of nucleons – mass of nucleus

$$= 7m_p + 7m_n - m_N$$

$$= 7 \times 1.00783 + 7 \times 1.00867 - 14.00307$$

$$= 7.05481 + 7.06069 - 14.00307 = 0.11243\ \text{u}$$

Binding energy of nitrogen nucleus = $\Delta m \times 931$ MeV

$$= 0.11243 \times 931\ \text{MeV}$$

$$= 104.67\ \text{MeV}$$

Thus, the binding energy is 104.67 MeV.

141. (*c*) Given, mass of coin = 3 g

Number of atoms in 1 g of Cu $= \frac{6.023 \times 10^{23}}{63}$

Number of atoms in 3 g of Cu $= \frac{6.023 \times 10^{23}}{63} \times 3$

$$= 2.868 \times 10^{22}$$

Number of protons in Cu atom, = 29

Number of neutrons in Cu atom = 63 – 29 = 34

Mass defect in each atom, $\Delta m = 29 \times m_p + 34 \times m_n - m_{\text{Cu}}$

$= 29 \times 1.00783 + 34 \times 1.00867 - 62.9260 = 0.59225$ u

$\therefore$ Total mass defect in all atoms $= 0.59225 \times 2.868 \times 10^{22}$

$$= 1.6985 \times 10^{22}\ \text{u}$$

Binding energy = Mass defect × 931 MeV

$$= 1.6985 \times 10^{22} \times 931 = 1.58 \times 10^{25}\ \text{MeV}$$

Thus, the energy required to separate all the neutrons and protons is 1.58×10^{25} MeV *i.e.,* equal to binding energy.

142. (*a*) Activity, $\frac{dN}{dt} = 8\ \text{mCi} = 8 \times 10^{-3} \times 3.7 \times 10^{10}$

$$= 8 \times 3.7 \times 10^{7}\ \text{disintegration/s}$$

$(\because 1\ \text{Ci} = 3.7 \times 10^{10}$ disintegration/s)

Half-life of ${}^{60}_{27}\text{Co}$, $T_{1/2} = 5.3$ yr

$$= 5.3 \times 365 \times 24 \times 60 \times 60$$

$$= 1.67 \times 10^{8}\ \text{s}$$

We know that

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1.67 \times 10^8} = 4.14 \times 10^{-9}/\text{s}$$

Activity, $\frac{dN}{dt} = \lambda N$

or $N = \frac{dN/dt}{\lambda} = \frac{8 \times 3.7 \times 10^7}{4.14 \times 10^{-9}} = 7.133 \times 10^{16}$

By using the concept of Avogadro number,

Mass of 6.023×10^{23} atoms of ${}^{60}_{27}\text{Co} = 60\text{ g}$

Mass of 7.133×10^{16} atoms of ${}^{60}_{27}\text{Co} = \frac{60 \times 7.133 \times 10^{16}}{6.023 \times 10^{23}}$

Mass $m = 7.12 \times 10^{-6}$ g

Thus, the required mass of ${}^{60}_{27}\text{Co}$ is 7.12×10^{-6} g.

143. (*b*) Given, half-life of ${}^{90}_{38}\text{Sr}$, $T_{1/2} = 28\text{ yr}$

$$= 28 \times 365 \times 24 \times 60 \times 60\text{ s}$$

According to Avogadro number concept,

90 g of Sr contains = 6.023×10^{23} atom

15 mg of Sr contains = $\frac{6.023 \times 10^{23} \times 15 \times 10^{-3}}{90}$

Number of atoms, $N = 1.0038 \times 10^{20}$

Activity, $\frac{dN}{dt} = \lambda N$ or $\frac{dN}{dt} = \left(\frac{0.6931}{T_{1/2}} \cdot\right) N$

$$= \frac{0.6931 \times 1.0038 \times 10^{20}}{28 \times 365 \times 24 \times 60 \times 60} \quad \left(\because \lambda = \frac{0.693}{T_{1/2}}\right)$$

$\Rightarrow \frac{dN}{dt} = 7.877 \times 10^{10}$ disintegration/s

$= 7.877 \times 10^{10}$ Bq

144. (*a*) According to the concept of Avogadro number

The number of atoms in 239 g of ${}^{239}_{94}\text{Pu} = 6.023 \times 10^{23}$

Number of atoms in 1 kg of ${}^{239}_{94}\text{Pu} = \frac{6.023 \times 10^{23} \times 1000}{239}$

$= 2.52 \times 10^{24}$

The average energy released in one fission = 180 MeV

So, total energy released in fission of 1 kg of ${}^{239}_{94}\text{Pu}$

$= 180 \times 2.52 \times 10^{24} = 4.53 \times 10^{26}$ MeV

145. (*b*) Given, radius $r = 2\text{ fm} = 2 \times 10^{-15}$ m

For head on collision, the distance between the centres of two deuterons

$d = 2r \Rightarrow d = 4 \times 10^{-15} = 4 \times 10^{-15}$ m

Charge on each deuteron, $e = 1.6 \times 10^{-19}$ C

Potential energy = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{d}$

$$= \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{4 \times 10^{-15}} \quad \left(\because \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\right)$$

$$= \frac{5.76 \times 10^{-14}}{1.6 \times 10^{-19}} = 360\text{ keV}$$

146. (*a*) Given, mass of ${}^{10}\text{B} = 10.01294$ u

Mass of ${}^{11}\text{B} = 11.00931$ u

Atomic mass of boron = 10.811 u

Let the abundance of ${}^{10}\text{B}$ be x%.

So, the abundance of ${}^{11}\text{B}$ be $(100 - x)$%.

Atomic mass = Weighted average of the isotopes

$$10.811 = \frac{x \times 10.01294 + (100 - x) \times 11.00931}{(x + 100 - x)}$$

Abundance of ${}^{10}\text{B}$, $x = 19.9\%$

Abundance of ${}^{11}\text{B}$, $(100 - x) = 100 - 19.9 = 80.1\%$

147. (*b*) Given, mass of proton $m_p = 1.00783$ u

Mass of neutron, $m_n = 1.00867$ u

For ${}^{56}_{26}\text{Fe}$,

${}^{56}_{26}\text{Fe}$ contains 26 protons and $(56 - 26) = 30$ neutrons

Mass defect (Δm) = mass of nucleons – mass of nucleus of ${}^{56}_{26}\text{Fe}$

Mass defect $(\Delta m) = 26 \times m_p + 30 \times m_n - m_N$

$= 26 \times 1.00783 + 30 \times 1.00867 - 55.934939$

$= 26.20345 + 30.25995 - 55.934939$

$= 0.528461$ u

Total binding energy = $\Delta m \times 931$ MeV

$= 0.528461 \times 931.5 = 492.26$ MeV

Average binding energy per nucleon of ${}^{56}_{26}\text{Fe}$

$$= \frac{\text{Binding energy}}{\text{Total number of nucleons}}$$

$$= \frac{492.26}{56} = 8.790\text{ MeV}$$

148. (*b*) Use the concept that the energy generated in one fission of ${}^{235}_{92}\text{U}$ is 200 MeV.

Let x kg of ${}^{235}\text{U}$ is used.

According to Avogadro number concept

235 g of ${}^{235}\text{U}$ contains = 6.023×10^{23} atoms

$\therefore$ x kg of ${}^{235}\text{U}$ contains = $\frac{6.023 \times 10^{23}}{235 \times 10^{-3}} \times x$ atoms

As half fuel is used in 5 yr and each atoms gives energy of 200 MeV, so energy given by fuel is

$$= \frac{6.023 \times 10^{23} \times x \times 200 \times 1.6 \times 10^{-13}}{235 \times 2 \times 10^{-3}}\text{ J} \quad \text{...(i)}$$

Energy produced in reactor in 5 yr as 80%

$$= 1000 \times 10^6 \times 5 \times 365 \times 24 \times 60 \times 60 \times \frac{80}{100}$$

(From formula $E = Pt$) ...(ii)

Equate Eqs. (i) and (ii), we get

$$= \frac{6.023 \times 10^{23} \times 200 \times 1.6 \times 10^{-13} x}{235 \times 2 \times 10^{-3}}$$

$$= \frac{10^9 \times 5 \times 365 \times 24 \times 3600 \times 80}{100}$$

$$\Rightarrow \qquad x = \frac{5 \times 365 \times 24 \times 36 \times 80 \times 235 \times 2 \times 10^{-3} \times 10^{9}}{6.023 \times 10^{10} \times 200 \times 1.6}$$

$$= 3071.5 \text{ kg}$$

The initial amount of ${}^{235}_{92}\text{U}$ is 3071.5 kg.

149. (*b*) Let *t* be the time.

According to the Avogadro number concept

Number of atoms in 2 g of deuterium = 6.023×10^{23}

Number of atoms in 2 kg of deuterium

$$= \frac{6.023 \times 10^{23} \times 2 \times 10^{3}}{2} = 6.023 \times 10^{26} \text{ nuclei}$$

From given equation, energy released during fusion of two deuterium = 3.27 MeV

$\therefore$ Energy released by one deuterium $= \frac{3.27}{2} = 1.635$ MeV

Energy released in 6.023×10^{26} deuterium atoms

$$= 1.635 \times 6.023 \times 10^{26} = 9.848 \times 10^{26} \text{ MeV}$$

$$= 9.848 \times 10^{26} \times 1.6 \times 10^{-13} = 15.75 \times 10^{13} \text{ J}$$

Energy used by bulb in 1s = 100 J

15.75×10^{13} J energy used in time $= \frac{1 \times 15.75 \times 10^{13}}{100}$

$$= 15.75 \times 10^{11} \text{ s}$$

($\because$ We know that 1 yr = 60 × 24 × 60 × 365 s)

$$= \frac{15.75 \times 10^{11}}{60 \times 24 \times 60 \times 365} \text{ yr} = 4.99 \times 10^{4} \text{ yr}$$

Thus, the bulbs glow for 4.99×10^{4} yr.

150. (*d*) Total target power = 200000 = 2×10^{5} MW

Total nuclear power = 10% of total

$$= \frac{10}{100} \times 2 \times 10^{5}$$

$$= 2 \times 10^{4} \text{ MW}$$

Energy produced/fission = 200 MeV

Efficiency of power plant = 25%

Energy converted into electrical energy per fission

$$= \frac{25}{100} \times 200 = 50 \text{ MeV}$$

$$= 50 \times 1.6 \times 10^{-13} \text{ J}$$

Total electrical energy to be produced in per year

$$= 2 \times 10^{4} \text{ MW} = 2 \times 10^{4} \times 10^{6} \text{ W}$$

$$= 2 \times 10^{10} \text{ W} = 2 \times 10^{10} \text{ J/s}$$

$$= 2 \times 10^{10} \times 60 \times 60 \times 24 \times 365 \text{ J/yr.}$$

Number of fission in one year,

$$n = \frac{2 \times 10^{10} \times 60 \times 60 \times 24 \times 365}{50 \times 1.6 \times 10^{-13}}$$

$$n = \frac{2 \times 36 \times 24 \times 365}{8} \times 10^{24}$$

Mass of 6.023×10^{23} atoms of ${}^{235}\text{U} = 235 \text{ g} = 235 \times 10^{-3}$ kg

Mass of ${}^{235}_{92}\text{U}$ required to produce $\frac{2 \times 36 \times 24 \times 365}{8} \times 10^{24}$ atom

$$= \frac{235 \times 10^{-3} \times 2 \times 36 \times 24 \times 365 \times 10^{24}}{6.023 \times 10^{23} \times 8}$$

$$= 3.08 \times 10^{4} \text{ kg}$$

151. (*c*) Disintegration laws are based on an statistical model and give average values.

152. (*b*) γ-decay occurs due to de-excitation of a nucleus and energies involves is essentially in MeV.

Electronic energy levels have values only in eV.

153. (*a*) For a β^--decay, ${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y_1 + {}^{0}_{-1}e + \nu^-$

$\therefore$ Q_1 value of decay

$$= [(M_X - Z M_e) - \{M_Y - (Z+1) M_e\} - M_e]c^2$$

$$= (M_X - M_Y)c^2$$

For β^+-decay, ${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y_2 + {}^{0}_{1}e + \nu$

$\therefore$ Q_2 value of decay

$$= [(M_X - ZM_e) - \{M_Y - (Z-1) M_e\} - M_e]c^2$$

$$= (M_X - M_Y - 2M_e)c^2$$

154. (*b*) Force between neutrons is only attractive. Nuclear force which is short range force.

$\therefore$ For stable nuclides, either $\frac{N}{Z} = 1$ or $\frac{N}{Z} > 1$

Nuclides with $\frac{N}{Z} < 1$ are least stable.

155. (*b*) For efficient energy transfer between 2 bodies, both must be of comparable masses.

If a heavy nucleus is taken, then neutron rebounds with nearly same energy.

157. (*d*) $\lambda_A N_{OA} = \lambda_A N_{OB}$

158. (*b*) Given, $F = \frac{GMm}{r^2}$

M = effective mass of hydrogen atom

$$= \text{mass of electron} + \text{mass of proton} - \frac{B}{c^2}$$

where, B is BE of hydrogen atom = 13.6 eV.