CHAPTER 13

Nuclei

13.2 Atomic Masses and Composition of Nucleus

1. Which one of the following pairs of nuclei are isotones?
(a) ${}_{34}Se^{74}$, ${}_{31}Ga^{71}$ (b) ${}_{38}Sr^{84}$, ${}_{38}Sr^{86}$
(c) ${}_{42}Mo^{92}$, ${}_{40}Zr^{92}$ (d) ${}_{20}Ca^{40}$, ${}_{16}S^{32}$ *(2005)*

2. A nucleus represented by the symbol ${}^{A}_{Z}X$ has
(a) Z neutrons and $A - Z$ protons
(b) Z protons and $A - Z$ neutrons
(c) Z protons and A neutrons
(d) A protons and $Z - A$ neutrons *(2004)*

3. The mass number of a nucleus is
(a) always less than its atomic number
(b) always more than its atomic number
(c) sometimes equal to its atomic number
(d) sometimes less than and sometimes more than its atomic number *(2003)*

4. Atomic weight of Boron is 10.81 and it has two isotopes ${}_{5}B^{10}$ and ${}_{5}B^{11}$. Then the ratio of ${}_{5}B^{10} : {}_{5}B^{11}$ in nature would be
(a) 15 : 16 (b) 10 : 11
(c) 19 : 81 (d) 81 : 19 *(1998)*

5. The constituents of atomic nuclei are believed to be
(a) neutrons and protons
(b) protons only
(c) electrons and protons
(d) electrons, protons and neutrons *(1991)*

6. In the nucleus of ${}_{11}Na^{23}$, the number of protons, neutrons and electrons are
(a) 11, 12, 0 (b) 23, 12, 11
(c) 12, 11, 0 (d) 23, 11, 12 *(1991)*

7. The nuclei ${}_{6}C^{13}$ and ${}_{7}N^{14}$ can be described as
(a) isotones (b) isobars
(c) isotopes of carbon (d) isotopes of nitrogen *(1990)*

13.3 Size of the Nucleus

8. 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 *(2012)*

9. 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 *(2008)*

10. If the nucleus ${}^{27}_{13}Al$ has a nuclear radius of about 3.6 fm, then ${}^{125}_{32}Te$ would have its radius approximately as
(a) 9.6 fm (b) 12.0 fm
(c) 4.8 fm (d) 6.0 fm *(2007)*

11. The radius of germanium (Ge) nuclide is measured to be twice the radius of ${}^{9}_{4}Be$. The number of nucleons in Ge are
(a) 72 (b) 73 (c) 74 (d) 75 *(2006)*

12. The volume occupied by an atom is greater than the volume of the nucleus by a factor of about
(a) 10^{1} (b) 10^{5}
(c) 10^{10} (d) 10^{15} *(2003)*

13. A nucleus ruptures into two nuclear parts, which have their velocity ratio equal to 2 : 1. What will be the ratio of their nuclear size (nuclear radius)?
(a) $3^{1/2} : 1$ (b) $1 : 3^{1/2}$
(c) $2^{1/3} : 1$ (d) $1 : 2^{1/3}$ *(1996)*

14. The mass number of He is 4 and that of sulphur is 32. The radius of sulphur nucleus is larger than that of helium by the factor of
(a) 4 (b) 2
(c) 8 (d) $\sqrt{8}$ *(1995)*

15. The mass density of a nucleus varies with mass number A as
(a) A^2 (b) A
(c) constant (d) $1/A$ *(1992)*

16. The ratio of the radii of the nuclei ${}_{13}Al^{27}$ and ${}_{52}Te^{125}$ is approximately
(a) 6 : 10 (b) 13 : 52
(c) 40 : 177 (d) 14 : 73 *(1990)*

13.4 Mass-Energy and Nuclear Binding Energy

17. The energy required to break one bond in DNA is 10^{-20} J. This value in eV is nearly
(a) 6 (b) 0.6 (c) 0.06 (d) 0.006 *(NEET 2020)*

18. The energy equivalent of 0.5 g of a substance is
(a) 4.5×10^{16} J (b) 4.5×10^{13} J
(c) 1.5×10^{13} J (d) 0.5×10^{13} J
(NEET 2020)

19. How does the Binding Energy per nucleon vary with the increase in the number of nucleons?
(a) Decrease continuously with mass number.
(b) First decreases and then increases with increase in mass number.
(c) First increases and then decreases with increase in mass number.
(d) Increases continuously with mass number.
(Karnataka NEET 2013)

20. The mass of a $^7_3$Li nucleus is 0.042 u less than the sum of the masses of all its nucleons. The binding energy per nucleon of $^7_3$Li nucleus is nearly
(a) 46 MeV (b) 5.6 MeV
(c) 3.9 MeV (d) 23 MeV *(2010)*

21. If $M(A; Z)$, M_p and M_n denote the masses of the nucleus $^A_Z X$, proton and neutron respectively in units of u (1 u = 931.5 MeV/c^2) and BE represents its binding energy in MeV, then
(a) $M(A, Z) = ZM_p + (A - Z)M_n - BE$
(b) $M(A, Z) = ZM_p + (A - Z)M_n + BE/c^2$
(c) $M(A, Z) = ZM_p + (A - Z)M_n - BE/c^2$
(d) $M(A, Z) = ZM_p + (A - Z)M_n + BE$ *(2008, 2004)*

22. A nucleus $^A_Z X$ has mass represented by $M(A, Z)$. If M_p and M_n denote the mass of proton and neutron respectively and B.E. the binding energy in MeV, then
(a) B.E. = $[ZM_p + (A - Z)M_n - M(A, Z)]c^2$
(b) B.E. = $[ZM_p + AM_n - M(A, Z)]c^2$
(c) B.E. = $M(A, Z) - ZM_p - (A - Z)M_n$
(d) B.E. = $[M(A, Z) - ZM_p - (A - Z)M_n]c^2$ *(2007)*

23. Fission of nuclei is possible because the binding energy per nucleon in them
(a) increases with mass number at low mass numbers
(b) decreases with mass number at low mass numbers
(c) increases with mass number at high mass numbers
(d) decreases with mass number at high mass numbers. *(2005)*

24. The mass of proton is 1.0073 u and that of neutron is 1.0087 u (u = atomic mass unit). The binding energy of $^4_2$He is
(Given helium nucleus mass ≈ 4.0015 u)
(a) 0.0305 J (b) 0.0305 erg
(c) 28.4 MeV (d) 0.061 u *(2003)*

25. Which of the following are suitable for the fusion process?
(a) Light nuclei
(b) Heavy nuclei
(c) Element lying in the middle of the periodic table
(d) Middle elements, which are lying on binding energy curve. *(2002)*

26. M_n and M_p represent the mass of neutron and proton respectively. An element having mass M has N neutrons and Z protons, then the correct relation will be
(a) $M < \{N \cdot M_n + Z \cdot M_p\}$
(b) $M > \{N \cdot M_n + Z \cdot M_p\}$
(c) $M = \{N \cdot M_n + Z \cdot M_p\}$
(d) $M = N\{M_n + M_p\}$ *(2001)*

27. Energy released in nuclear fission is due to
(a) some mass is converted into energy
(b) total binding energy of fragments is more than the binding energy of parental element
(c) total binding energy of fragments is less than the binding energy of parental element
(d) total binding energy of fragments is equal to the binding energy of parental element. *(2001)*

28. The binding energy per nucleon is maximum in case of
(a) $^4_2$He (b) $^{56}_{26}$Fe (c) $^{141}_{56}$Ba (d) $^{235}_{92}$U *(1993)*

29. The energy equivalent of one atomic mass unit is
(a) 1.6×10^{-19} J (b) 6.02×10^{23} J
(c) 931 MeV (d) 9.31 MeV *(1992)*

30. The average binding energy of a nucleon inside an atomic nucleus is about
(a) 8 MeV (b) 8 eV
(c) 8 J (d) 8 erg *(1989)*

13.5 Nuclear Force

31. If the nuclear force between two protons, two neutrons and between proton and neutron is denoted by F_{pp}, F_{nn} and F_{pn} respectively, then
(a) $F_{pp} \approx F_{nn} \approx F_{pn}$
(b) $F_{pp} \neq F_{nn}$ and $F_{pp} = F_{nn}$
(c) $F_{pp} = F_{nn} = F_{pn}$
(d) $F_{pp} \neq F_{nn} \neq F_{pn}$ *(1991)*

32. Which of the following statements is true for nuclear forces?
(a) They obey the inverse square law of distance.
(b) They obey the inverse third power law of distance.
(c) They are short range forces.
(d) They are equal in strength to electromagnetic forces. *(1990)*

13.6 Radioactivity

33. α-particle consists of
(a) 2 protons only
(b) 2 protons and 2 neutrons only
(c) 2 electrons, 2 protons and 2 neutrons
(d) 2 electrons and 4 protons only *(NEET 2019)*

34. The rate of radioactive disintegration at an instant for a radioactive sample of half life 2.2×10^9 s is 10^{10} s^{-1}. The number of radioactive atoms in the sample at that instant is,

(a) 3.17×10^{20}
(b) 3.17×10^{17}
(c) 3.17×10^{18}
(d) 3.17×10^{19}
(Odisha NEET 2019)

35. For a radioactive material, half-life is 10 minutes. If initially there are 600 number of nuclei, the time taken (in minutes) for the disintegration of 450 nuclei is
(a) 20 (b) 10 (c) 30 (d) 15
(NEET 2018)

36. Radioactive material 'A' has decay constant '8 λ' and material 'B' has decay constant 'λ'. Initially they have same number of nuclei. After what time, the ratio of number of nuclei of material 'B' to that 'A' will be $\frac{1}{e}$?
(a) $\frac{1}{7\lambda}$ (b) $\frac{1}{8\lambda}$ (c) $\frac{1}{9\lambda}$ (d) $\frac{1}{\lambda}$
(NEET 2017)

37. The half-life of a radioactive substance is 30 minutes. The time (in minutes) taken between 40% decay and 85% decay of the same radioactive substance is
(a) 15 (b) 30 (c) 45 (d) 60
(NEET-II 2016)

38. A nucleus of uranium decays at rest into nuclei of thorium and helium. Then
(a) The helium nucleus has more momentum than the thorium nucleus.
(b) The helium nucleus has less kinetic energy than the thorium nucleus.
(c) The helium nucleus has more kinetic energy than the thorium nucleus.
(d) The helium nucleus has less momentum than the thorium nucleus. *(2015)*

39. The binding energy per nucleon of ${}^{7}_{3}Li$ and ${}^{4}_{2}He$ nuclei are 5.60 MeV and 7.06 MeV respectively. In the nuclear reaction

$$ {}^{7}_{3}Li + {}^{1}_{1}H \longrightarrow {}^{4}_{2}He + {}^{4}_{2}He + Q $$

the value of energy Q released is
(a) 19.6 MeV
(b) –2.4 MeV
(c) 8.4 MeV
(d) 17.3 MeV *(2014)*

40. A radioisotope X with a half life 1.4×10^9 years 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
(a) 1.96×10^9 years
(b) 3.92×10^9 years
(c) 4.20×10^9 years
(d) 8.40×10^9 years
(2014)

41. The half life of a radioactive isotope 'X' is 20 years. 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) 80 years
(b) 100 years
(c) 40 years
(d) 60 years *(NEET 2013)*

42. α-particles, β-particles and γ-rays are all having same energy. Their penetrating power in a given medium in increasing order will be
(a) γ, α, β
(b) α, β, γ
(c) β, α, γ
(d) β, γ, α
(Karnataka NEET 2013)

43. 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
(a) 60 s
(b) 80 s
(c) 20 s
(d) 40 s *(2012)*

44. The half life of a radioactive nucleus is 50 days. The time interval $(t_2 - t_1)$ between the time t_2 when $\frac{2}{3}$ of it has decayed and the time t_1 when $\frac{1}{3}$ of it had decayed is
(a) 30 days
(b) 50 days
(c) 60 days
(d) 15 days *(Mains 2012)*

45. The half life of a radioactive isotope X is 50 years. It decays to another element Y which is stable. The two elements X and Y were found to be in the ratio of 1 : 15 in a sample of a given rock. The age of the rock was estimated to be
(a) 150 years
(b) 200 years
(c) 250 years
(d) 100 years *(2011)*

46. A radioactive nucleus of mass M emits a photon of frequency υ and the nucleus recoils. The recoil energy will be
(a) $Mc^2 - h\upsilon$
(b) $h^2\upsilon^2/2Mc^2$
(c) zero
(d) $h\upsilon$ *(2011)*

47. A nucleus ${}^{m}_{n}X$ emits one α particle and two β^- particles. The resulting nucleus is
(a) ${}^{m-6}_{n-4}Z$
(b) ${}^{m-6}_{n}Z$
(c) ${}^{m-4}_{n}X$
(d) ${}^{m-4}_{n-2}Y$ *(2011, 1998)*

48. Two radioactive nuclei P and Q, in a given sample decay into a stable nucleus R. At time $t = 0$, number of P species are 4 N_0 and that of Q are N_0. Half-life of P (for conversion to R) is 1 minute where as that of Q is 2 minutes. Initially there are no nuclei of R present in the sample. When number of nuclei of P and Q are equal, the number of nuclei of R present in the sample would be
(a) 2 N_0
(b) 3 N_0
(c) $\frac{9N_0}{2}$
(d) $\frac{5N_0}{2}$ *(Mains 2011)*

49. The activity of a radioactive sample is measured as N_0 counts per minute at $t = 0$ and N_0/e counts per minute at $t = 5$ minutes. The time (in minutes) at which the activity reduces to half its value is

(a) $\log_e \frac{2}{5}$ (b) $\frac{5}{\log_e 2}$
(c) $5\log_{10} 2$ (d) $5\log_e 2$ *(2010)*

50. The decay constant of a radio isotope is λ. If A_1 and A_2 are its activities at times t_1 and t_2 respectively, the number of nuclei which have decayed during the time $(t_1 - t_2)$
(a) $A_1t_1 - A_2t_2$ (b) $A_1 - A_2$
(c) $(A_1 - A_2)/\lambda$ (d) $\lambda(A_1 - A_2)$
(Mains 2010)

51. In the nuclear decay given below
$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y \rightarrow {}^{A-4}_{Z-1}B^* \rightarrow {}^{A-4}_{Z-1}B,$
the particles emitted in the sequence are
(a) γ, β, α (b) β, γ, α
(c) α, β, γ (d) β, α, γ *(2009, 1993)*

52. The number of beta particles emitted by a radioactive substance is twice the number of alpha particles emitted by it. The resulting daughter is an
(a) isomer of parent (b) isotone of parent
(c) isotope of parent (d) isobar of parent *(2009)*

53. Two radioactive materials X_1 and X_2 have decay constants 5λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that X_2 will be $1/e$ after a time
(a) $1/4\lambda$ (b) e/λ
(c) λ (d) $\frac{1}{2}\lambda$ *(2008)*

54. 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 $(1/e)^2$ after a time interval
(a) 4λ (b) 2λ
(c) $1/2\lambda$ (d) $1/4\lambda$ *(2007)*

55. In a radioactive decay process, the negatively charged emitted β-particles are
(a) the electrons produced as a result of the decay of neutrons inside the nucleus
(b) the electrons produced as a result of collisions between atoms
(c) the electrons orbiting around the nucleus
(d) the electrons present inside the nucleus. *(2007)*

56. In a radioactive material the activity at time t_1 is R_1 and at a later time t_2, it is R_2. If the decay constant of the material is λ, then
(a) $R_1 = R_2$ (b) $R_1 = R_2 e^{-\lambda(t_1 - t_2)}$
(c) $R_1 = R_2 e^{\lambda(t_1 - t_2)}$ (d) $R_1 = R_2(t_2/t_1)$ *(2006)*

57. In the reaction ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n,$ if the binding energies of ${}^{2}_{1}H, {}^{3}_{1}H$ and ${}^{4}_{2}He$ are respectively a, b and c (in MeV), then the energy (in MeV) released in this reaction is
(a) $a + b + c$ (b) $a + b - c$
(c) $c - a - b$ (d) $c + a - b$ *(2005)*

58. The half life of radium is about 1600 years. If 100 g of radium existing now, 25 g will remain unchanged after
(a) 4800 years (b) 6400 years
(c) 2400 years (d) 3200 years *(2004)*

59. A sample of radioactive element has a mass of 10 g at an instant $t = 0$. The approximate mass of this element in the sample after two mean lives is
(a) 1.35 g (b) 2.50 g
(c) 3.70 g (d) 6.30 g *(2003)*

60. A nuclear reaction given by
${}_{Z}X^{A} \longrightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0} + \bar{\nu}$ represents
(a) β-decay (b) γ-decay
(c) fusion (d) fission *(2003)*

61. A sample of radioactive element containing 4×10^{16} active nuclei. Half life of element is 10 days, then number of decayed nuclei after 30 days
(a) 0.5×10^{16} (b) 2×10^{16}
(c) 3.5×10^{16} (d) 1×10^{16} *(2002)*

62. A deutron is bombarded on ${}_{8}O^{16}$ nucleus then α-particle is emitted. The product nucleus is
(a) ${}_{7}N^{13}$ (b) ${}_{5}B^{10}$ (c) ${}_{4}Be^{9}$ (d) ${}_{7}N^{14}$ *(2002)*

63. Which rays contain (positive) charged particles?
(a) α-rays (b) β-rays
(c) γ-rays (d) X-rays *(2001)*

64. $X(n, \alpha)\ {}^{7}_{3}Li,$ then X will be
(a) ${}^{10}_{5}B$ (b) ${}^{9}_{5}B$ (c) ${}^{11}_{4}Be$ (d) ${}^{4}_{2}He$
(2001)

65. Half life of a radioactive element is 12.5 hours and its quantity is 256 g. After how much time its quantity will remain1 g?
(a) 50 hrs (b) 100 hrs
(c) 150 hrs (d) 200 hrs *(2001)*

66. For the given reaction, the particle X is
${}_{6}C^{11} \rightarrow {}_{5}B^{11} + \beta^{+} + X$
(a) neutron (b) anti neutrino
(c) neutrino (d) proton *(2000)*

67. The relation between λ and $T_{1/2}$ as
($T_{1/2} \rightarrow$ half life)
(a) $T_{1/2} = \frac{\ln 2}{\lambda}$ (b) $T_{1/2}\ln 2 = \lambda$
(c) $T_{1/2} = \frac{1}{\lambda}$ (d) $(\lambda + T_{1/2}) = \ln 2$ *(2000)*

68. Alpha particles are
(a) neutrally charged (b) positron
(c) protons (d) ionized helium atoms
(1999)

69. After 1α and 2β-emissions
(a) mass number reduces by 6
(b) mass number reduces by 4
(c) mass number reduces by 2
(d) atomic number remains unchanged *(1999)*

70. Complete the equation for the following fission process

$_{92}U^{235} + {}_0n^1 \rightarrow {}_{38}Sr^{90} + ...$

(a) $_{57}X^{142} + 3_0n^1$ (b) $_{54}X^{145} + 3_0n^1$

(c) $_{54}X^{143} + 3_0n^1$ (d) $_{54}X^{142} + {}_0n^1$ *(1998)*

71. Half-lives of two radioactive substances A and B are respectively 20 minutes and 40 minutes. Initially the samples of A and B have equal number of nuclei. After 80 minutes the ratio of remaining numbers of A and B nuclei is

(a) 1 : 4 (b) 4 : 1 (c) 1 : 16 (d) 1 : 1 *(1998)*

72. The most penetrating radiation out of the following are

(a) β-rays (b) γ-rays

(c) X-rays (d) α-rays. *(1997)*

73. What is the respective number of α and β particles emitted in the following radioactive decay?

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

(a) 8 and 8 (b) 8 and 6

(c) 6 and 8 (d) 6 and 6 *(1995)*

74. The binding energies per nucleon for a deuteron and an α-particle are x_1 and x_2 respectively. The energy Q released in the reaction

$$^2H_1 + {}^2H_1 \rightarrow {}^4He_2 + Q, \text{ is}$$

(a) $4(x_1 + x_2)$ (b) $4(x_2 - x_1)$

(c) $2(x_2 - x_1)$ (d) $2(x_1 + x_2)$ *(1995)*

75. The count rate of a Geiger Muller counter for the radiation of a radioactive material of half-life of 30 minutes decreases to 5 second^{-1} after 2 hours. The initial count rate was

(a) 80 second^{-1} (b) 625 second^{-1}

(c) 20 second^{-1} (d) 25 second^{-1} *(1995)*

76. The mass of α-particle is

(a) less than the sum of masses of two protons and two neutrons

(b) equal to mass of four protons

(c) equal to mass of four neutrons

(d) equal to sum of masses of two protons and two neutrons *(1992)*

77. The half life of radium is 1600 years. The fraction of a sample of radium that would remain after 6400 years

(a) 1/4 (b) 1/2

(c) 1/8 (d) 1/16 *(1991)*

78. The nucleus $_6C^{12}$ absorbs an energetic neutron and emits a beta particle (β). The resulting nucleus is

(a) $_7N^{14}$ (b) $_7N^{13}$

(c) $_5B^{13}$ (d) $_6C^{13}$ *(1990)*

79. A radioactive element has half life period 800 years. After 6400 years what amount will remain?

(a) 1/2 (b) 1/16

(c) 1/8 (d) 1/256 *(1989)*

80. An element A decays into element C by a two step processes

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

(a) A and C are isotopes

(b) A and C are isobars

(c) A and B are isotopes

(d) A and B are isobars. *(1989)*

81. Curie is a unit of

(a) energy of gamma rays

(b) half-life

(c) radioactivity

(d) intensity of gamma rays *(1989)*

82. A radioactive sample with a half life of 1 month has the label : 'Activity = 2 micro curies on 1 – 8 – 1991'. What would be its activity two months earlier?

(a) 1.0 micro curie (b) 0.5 micro curie

(c) 4 micro curie (d) 8 micro curie *(1988)*

83. The nucleus $^{115}_{48}Cd$, after two successive β-decay will give

(a) $^{115}_{46}Pa$ (b) $^{114}_{49}In$

(c) $^{113}_{50}Sn$ (d) $^{115}_{50}Sn$ *(1988)*

13.7 Nuclear Energy

84. When a uranium isotope $^{235}_{92}U$ is bombarded with a neutron, it generates $^{89}_{36}Kr$, three neutrons and

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

(NEET 2020)

85. A certain mass of Hydrogen is changed to Helium by the process of fusion. The mass defect in fusion reaction is 0.02866 u. The energy liberated per u is (given 1 u = 931 MeV)

(a) 6.675 MeV (b) 13.35 MeV

(c) 2.67 MeV (d) 26.7 MeV

(NEET 2013)

86. The power obtained in a reactor using U^{235} disintegration is 1000 kW. The mass decay of U^{235} per hour is

(a) 10 microgram (b) 20 microgram

(c) 40 microgram (d) 1 microgram *(2011)*

87. Fusion reaction takes place at high temperature because

(a) nuclei break up at high temperature

(b) atoms get ionised at high temperature

(c) kinetic energy is high enough to overcome the coulomb repulsion between nuclei

(d) molecules break up at high temperature *(2011)*

88. The binding energy per nucleon in deuterium and helium nuclei are 1.1 MeV and 7.0 MeV, respectively. When two deuterium nuclei fuse to form a helium nucleus the energy released in the fusion is

(a) 23.6 MeV (b) 2.2 MeV

(c) 28.0 MeV (d) 30.2 MeV

(Mains 2010)

89. The binding energy of deuteron is 2.2 MeV and that of ${}^4_2He$ is 28 MeV. If two deuterons are fused to form one ${}^4_2He$ then the energy released is
(a) 30.2 MeV (b) 25.8 MeV
(c) 23.6 MeV (d) 19.2 MeV *(2006)*

90. In any fission process the ratio $\frac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is
(a) equal to 1
(b) greater than 1
(c) less than 1
(d) depends on the mass of the parent nucleus. *(2005)*

91. If in a nuclear fusion process the masses of the fusing nuclei be m_1 and m_2 and the mass of the resultant nucleus be m_3, then
(a) $m_3 = m_1 + m_2$ (b) $m_3 = |m_1 - m_2|$
(c) $m_3 < (m_1 + m_2)$ (d) $m_3 > (m_1 + m_2)$ *(2004)*

92. Solar energy is mainly caused due to
(a) burning of hydrogen in the oxygen
(b) fission of uranium present in the Sun
(c) fusion of protons during synthesis of heavier elements
(d) gravitational contraction *(2003)*

93. Nuclear fission is best explained by
(a) liquid droplet theory
(b) Yukawa π-meson theory
(c) independent particle model of the nucleus
(d) proton-proton cycle. *(2000)*

94. Which of the following is used as a moderator in nuclear reaction?
(a) Cadmium (b) Plutonium
(c) Uranium (d) Heavy water *(1997)*

95. Energy released in the fission of a single ${}^{235}_{92}U$ nucleus is 200 MeV. The fission rate of ${}^{235}_{92}U$ filled reactor operating at a power level of 5 W is
(a) 1.56×10^{-10} s^{-1} (b) 1.56×10^{11} s^{-1}
(c) 1.56×10^{-16} s^{-1} (d) 1.56×10^{-17} s^{-1} *(1993)*

96. Solar energy is due to
(a) fusion reaction (b) fission reaction
(c) combustion reaction (d) chemical reaction *(1992)*

ANSWER KEY

1.	(a)	**2.**	(b)	**3.**	(c)	**4.**	(c)	**5.**	(a)	**6.**	(a)	**7.**	(a)	**8.**	(c)	**9.**	(b)	**10.**	(d)
11.	(a)	**12.**	(d)	**13.**	(d)	**14.**	(b)	**15.**	(c)	**16.**	(a)	**17.**	(c)	**18.**	(b)	**19.**	(c)	**20.**	(b)
21.	(c)	**22.**	(a)	**23.**	(d)	**24.**	(c)	**25.**	(a)	**26.**	(a)	**27.**	(a)	**28.**	(b)	**29.**	(c)	**30.**	(a)
31.	(c)	**32.**	(c)	**33.**	(b)	**34.**	(d)	**35.**	(a)	**36.**	(*)	**37.**	(d)	**38.**	(c)	**39.**	(d)	**40.**	(c)
41.	(d)	**42.**	(b)	**43.**	(d)	**44.**	(b)	**45.**	(b)	**46.**	(b)	**47.**	(c)	**48.**	(c)	**49.**	(d)	**50.**	(c)
51.	(d)	**52.**	(c)	**53.**	(a)	**54.**	(c)	**55.**	(a)	**56.**	(b)	**57.**	(c)	**58.**	(d)	**59.**	(a)	**60.**	(a)
61.	(c)	**62.**	(d)	**63.**	(a)	**64.**	(a)	**65.**	(b)	**66.**	(c)	**67.**	(a)	**68.**	(d)	**69.**	(b,d)	**70.**	(c)
71.	(a)	**72.**	(b)	**73.**	(b)	**74.**	(b)	**75.**	(a)	**76.**	(a)	**77.**	(d)	**78.**	(b)	**79.**	(d)	**80.**	(a)
81.	(c)	**82.**	(d)	**83.**	(d)	**84.**	(a)	**85.**	(a)	**86.**	(c)	**87.**	(c)	**88.**	(a)	**89.**	(c)	**90.**	(c)
91.	(c)	**92.**	(c)	**93.**	(a)	**94.**	(d)	**95.**	(b)	**96.**	(a)								

Hints & Explanations

1. (a) : Isotones means number of neutron remains same.

2. (b) : Z is number of protons and A is the total number of protons and neutrons.

3. (c) : Mass number = atomic number + no. of neutrons
For hydrogen, number of neutrons = 0
So, mass number = Atomic number.
Hence mass number is sometimes equal to atomic number.

4. (c) : Let ${}_5B^{10}$ be present as x% so percentage of ${}_5B^{11}$ = $(100 - x)$

$\therefore$ Average atomic weight

$$= \frac{10x + 11(100 - x)}{100} = 10.81 \Rightarrow x = 19$$

$\therefore$ % of ${}_5B^{11}$ is 100 – 19 = 81. Ratio is 19 : 81.

5. (a) : Nucleus contains only neutrons and protons.

6. (a) : $Z = 11$ *i.e.*, number of protons = 11,
$A = 23$
$\therefore$ Number of neutrons = $A - Z = 12$
Number of electron = 0 (No electron in nucleus)
Therefore 11, 12, 0 is the correct answer.

7. (a) : As ${}_6C^{13}$ and ${}_7N^{14}$ have same number of neutrons (13 – 6 = 7 for C and 14 – 7 = 7 for N), they are isotones.

8. (c) : Nuclear radius, $R = R_0 A^{1/3}$
where R_0 is a constant and A is the mass number

$$\therefore \quad \frac{R_{Al}}{R_{Cu}} = \frac{(27)^{1/3}}{(64)^{1/3}} = \frac{3}{4}$$

$$\text{or} \quad R_{Cu} = \frac{4}{3} \times R_{Al} = \frac{4}{3} \times 3.6 \text{ fermi} = 4.8 \text{ fermi}$$

9. (b) : $A_1 : A_2 = 1 : 3$
Their radii will be in the ratio

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

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

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

Their nuclear densities will be the same.

10. (d) : Nuclear radii $R = (R_0) A^{1/3}$
where A is the mass number.

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

$$\text{or,} \quad R_{Te} = \frac{5}{3} \times R_{Al} = \frac{5}{3} \times 3.6 = 6 \text{ fm} \quad (\text{Given } R_{Al} = 3.6 \text{ fm})$$

11. (a) : Nuclear radii $R = R_0 (A)^{1/3}$, where $R_0 \approx 1.2$ fm
or $R \propto (A)^{1/3}$

$$\therefore \quad \frac{R_{Be}}{R_{Ge}} = \frac{(9)^{1/3}}{(A)^{1/3}} \quad \text{or,} \quad \frac{R_{Be}}{2R_{Be}} = \frac{(9)^{1/3}}{(A)^{1/3}}$$

($\because$ given $R_{Ge} = 2R_{Be}$)

or, $(A)^{1/3} = 2 \times (9)^{1/3}$
or, $A = 2^3 \times 9 = 8 \times 9 = 72$
$\therefore$ The number of nucleons in Ge is 72

12. (d) :
$$\frac{\text{Volume of atom}}{\text{Volume of nucleus}} = \frac{\frac{4}{3}\pi(10^{-10})^3}{\frac{4}{3}\pi(10^{-15})^3} = 10^{15}$$

13. (d) : Velocity ratio $(v_1 : v_2) = 2 : 1$
Mass $(m) \propto$ Volume $\propto r^3$.
According to law of conservation of momentum,

$$m_1 v_1 = m_2 v_2$$

$$\text{Therefore} \quad \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{r_2^3}{r_1^3}$$

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

or $r_1 : r_2 = 1 : 2^{1/3}$

14. (b) : Mass number of helium $(A_{He}) = 4$ and mass number of sulphur $(A_S) = 32$.
Radius of nucleus, $r = r_0 (A)^{1/3}$. Therefore

$$\frac{r_s}{r_{He}} = \left(\frac{A_s}{A_{He}}\right)^{1/3} = \left(\frac{32}{4}\right)^{1/3} = (8)^{1/3} = 2$$

15. (c) : The nuclear radius r varies with mass number A according to the relation

$$r = r_0 A^{1/3} \Rightarrow r \propto A^{1/3} \text{ or } A \propto r^3$$

$$\text{Now density} = \frac{\text{mass}}{\text{volume}}$$

Further mass $\propto A$ and volume $\propto r^3$

$$\therefore \quad \frac{\text{mass}}{\text{volume}} = \text{constant}$$

16. (a) : $R \propto (A)^{1/3}$ from $R = R_0 A^{1/3}$
$\therefore$ $R_{A1} \propto (27)^{1/3}$ and $R_{Te} \propto (125)^{1/5}$

$$\therefore \quad \frac{R_{A1}}{R_{Te}} = \frac{3}{5} = \frac{6}{10}$$

17. (c) : Given : energy, $E = 10^{-20}$ J

$$\text{Now, } 1 \text{ J} = \frac{1}{1.6 \times 10^{-19}} \text{ eV}$$

$$\therefore \quad E = \frac{10^{-20}}{1.6 \times 10^{-19}} \text{ eV} = 0.0625 \text{ eV} \simeq 0.06 \text{ eV}$$

18. (b) : Given mass $m = 0.5$ g $= 0.5 \times 10^{-3}$ kg
According to Einstein mass-energy equivalence,

$$E = mc^2 = 0.5 \times 10^{-3} \times (3 \times 10^8)^2 = 4.5 \times 10^{13} \text{ J}$$

19. (c)

20. (b) : For ${}^{7}_{3}\text{Li}$ nucleus,

Mass defect, $\Delta M = 0.042$ u
$\because$ 1 u = 931.5 MeV/c^2
$\therefore$ $\Delta M = 0.042 \times 931.5$ MeV/c^2 = 39.1 MeV/c^2
Binding energy, $E_b = \Delta M c^2$

$$= \left(39.1 \frac{\text{MeV}}{c^2}\right) c^2 = 39.1 \text{ MeV}$$

Binding energy per nucleon,

$$E_{bn} = \frac{E_b}{A} = \frac{39.1 \text{ MeV}}{7} \approx 5.6 \text{ MeV}$$

21. (c) : $ZM_p + (A - Z)M_n - M(A, Z)$

$$= \text{mass defect} = \frac{B.E}{c^2}$$

$$\Rightarrow \quad M(A, Z) = ZM_p + (A - Z)M_n - \frac{B.E}{c^2}$$

22. (a)

23. (d) : For nuclei having $A > 56$ binding energy per nucleon gradually decreases.

24. (c) : Mass defect $= 2M_P + 2M_N - M_{He}$
$= 2 \times 1.0073 + 2 \times 1.0087 - 4.0015 = 0.0305$
$\Rightarrow$ Binding energy = (931 × mass defect) MeV
$= 931 \times 0.0305$ MeV = 28.4 MeV

25. (a) : The nuclei of light elements have a lower binding energy than that for the elements of intermediate mass. They are therefore less stable; consequently the fusion of the light elements results in more stable nucleus.

26. (a) **27. (a)**

28. (b) : From binding energy curve, the curve reaches peak for ${}_{26}\text{Fe}^{56}$.

29. (c) : 1 a.m.u = 931 MeV

30. (a) : Average binding energy/nucleon in nuclei is of the order of 8 MeV.

31. (c) : Nuclear force is the same between any two nucleons.

32. (c) : Nuclear forces are short range forces.

33. (b) : Alpha particle is a positively charged particle. It is identical to the nucleus of the helium ($_2He^4$) atom, so it contains 2 protons and 2 neutrons.

34. (d) : Given, $t_{1/2} = 2.2 \times 10^9$ s
and rate of radioactive disintegration,

$$\frac{dN}{dt} = 10^{10}\ \text{s}^{-1}$$

$$\therefore\ \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{2.2\times10^9} = 3.15\times10^{-10}\ \text{s}^{-1}$$

Now, we know that, $N = N_0 e^{-\lambda t}$

$$\Rightarrow\ \frac{dN}{dt} = -\lambda N_0 e^{-\lambda t} = -\lambda N$$

$$\Rightarrow\ 10^{10} = 3.15\times10^{-10}\times N \Rightarrow N = 3.17\times10^{19}$$

35. (a) : Number of nuclei remaining,
$N = 600 - 450 = 150$
According to the law of radioactive decay,

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$; where N_0 is the number of nuclei initially.

$$\therefore\ \frac{150}{600} = \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$; where $T_{1/2}$ = half life.

$$\text{or}\ \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$

$$\Rightarrow\ t = 2T_{1/2} = 2\times 10 \text{ minutes} = 20 \text{ minutes}$$

36. (*) : The number of radioactive nuclei 'N' at any time t is given as

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

where N_0 is number of radioactive nuclei in the sample at some arbitrary time $t = 0$ and λ is the radioactive decay constant.

Given: $\lambda_A = 8\lambda$, $\lambda_B = \lambda$, $N_{0A} = N_{0B} = N_0$

$$\therefore\ \frac{N_B}{N_A} = \frac{e^{-\lambda t}}{e^{-8\lambda t}}\ \text{or}\ \frac{1}{e} = e^{-\lambda t}e^{8\lambda t} = e^{7\lambda t}$$

$$\Rightarrow\ -1 = 7\lambda t\ \text{or}\ t = \frac{-1}{7\lambda}$$

*Negative value of time is not possible.

So given ratio in question should be $\frac{N_B}{N_A} = e$

37. (d) : N_0 = Nuclei at time $t = 0$
N_1 = Remaining nuclei after 40% decay
$= (1 - 0.4)\ N_0 = 0.6\ N_0$
N_2 = Remaining nuclei after 85% decay
$= (1 - 0.85)\ N_0 = 0.15\ N_0$

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

Hence, two half life is required between 40% decay and 85% decay of a radioactive substance.

$\therefore$ Time taken $= 2t_{1/2} = 2\times 30$ min $= 60$ min

38. (c) : If $\vec{p}_{Th}$ and $\vec{p}_{He}$ are the momenta of thorium and helium nuclei respectively, then according to law of conservation of linear momentum

$$0 = \vec{p}_{Th} + \vec{p}_{He}\ \text{or}\ \vec{p}_{Th} = -\vec{p}_{He}$$

Negative sign shows that both are moving in opposite directions.
But in magnitude

$$p_{Th} = p_{He}$$

If m_{Th} and m_{He} are the masses of thorium and helium nuclei respectively, then
Kinetic energy of thorium nucleus is $K_{Th} = \frac{p_{Th}^2}{2m_{Th}}$ and that of helium nucleus is

$$K_{He} = \frac{p_{He}^2}{2m_{He}}\ \therefore\ \frac{K_{Th}}{K_{He}} = \left(\frac{p_{Th}}{p_{He}}\right)^2\left(\frac{m_{He}}{m_{Th}}\right)$$

But $p_{Th} = p_{He}$ and $m_{He} < m_{Th}$

$\therefore\ K_{Th} < K_{He}$ or $K_{He} > K_{Th}$

Thus the helium nucleus has more kinetic energy than the thorium nucleus.

39. (d) : Binding energy of ^7_3Li nucleus
$= 7\times 5.60$ MeV $= 39.2$ MeV
Binding energy of ^4_2He nucleus
$= 4\times 7.06$ MeV $= 28.24$ MeV
The reaction is

$$^7_3Li + {}^1_1H \longrightarrow 2(^4_2He) + Q$$

$$\therefore\ Q = 2(\text{BE of } ^4_2He) - (\text{BE of } ^7_3Li)$$

$= 2\times 28.24$ MeV $- 39.2$ MeV
$= 56.48$ MeV $- 39.2$ MeV $= 17.28$ MeV

40. (c) :

	X	$\rightarrow$ Y
Number of nuclei at $t = 0$	N_0	0
Number of nuclei after time t	$N_0 - x$	x

As per question, $\frac{N_0 - x}{x} = \frac{1}{7}$

$$7N_0 - 7x = x\ \text{or}\ x = \frac{7}{8}N_0$$

$\therefore$ Remaining nuclei of isotope X

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

So three half lives would have been passed.

$\therefore\ t = nT_{1/2} = 3\times 1.4\times 10^9$ years $= 4.2\times 10^9$ years

Hence, the age of the rock is 4.2×10^9 years.

41. (d) : There is requirement of three half lives so age of the rock
$t = nT_{1/2} = 3\times 20$ years $= 60$ years

42. (b) : For a given energy, γ-rays has highest penetrating power and α-particles has least penetrating power.

43. (d) : Let after t s amount of the A_1 and A_2 will become equal in the mixture.

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

where n is the number of half-lives

For A_1, $N_1 = N_{01}\left(\frac{1}{2}\right)^{t/20}$

For A_2, $N_2 = N_{02}\left(\frac{1}{2}\right)^{t/10}$

According to question, $N_1 = N_2 \Rightarrow \frac{40}{2^{t/20}} = \frac{160}{2^{t/10}}$

$2^{t/10} = 4(2^{t/20})$ or $2^{t/10} = 2^2\, 2^{t/20}$

$\Rightarrow 2^{t/10} = 2^{\left(\frac{t}{20}+2\right)}$ or $\frac{t}{10} = \frac{t}{20} + 2$ or $\frac{t}{10} - \frac{t}{20} = 2$

or $\frac{t}{20} = 2$ or $t = 40$ s

44. (b) : According to radioactive decay law

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

where N_0 = Number of radioactive nuclei at time $t = 0$

N = Number of radioactive nuclei left undecayed at any time t

λ = decay constant

At time t_2, $\frac{2}{3}$ of the sample had decayed

$\therefore\ N = \frac{1}{3}N_0 \quad \Rightarrow \quad \frac{1}{3}N_0 = N_0 e^{-\lambda t_2}$ ...(i)

At time t_1, $\frac{1}{3}$ of the sample had decayed,

$\therefore\ N = \frac{2}{3}N_0 \quad \Rightarrow \quad \frac{2}{3}N_0 = N_0 e^{-\lambda t_1}$ ...(ii)

Divide (i) by (ii), we get

$\frac{1}{2} = \frac{e^{-\lambda t_2}}{e^{-\lambda t_1}} \Rightarrow \frac{1}{2} = e^{-\lambda(t_2 - t_1)} \Rightarrow \lambda(t_2 - t_1) = \ln 2$

$t_2 - t_1 = \frac{\ln 2}{\lambda} \Rightarrow T_{1/2} = 50$ days

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

where n is number of half lives

$\therefore\ \frac{1}{16} = \left(\frac{1}{2}\right)^n$ or $\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$ or $n = 4$

Let the age of rock be t years.

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

or $t = nT_{1/2} = 4 \times 50$ years $= 200$ years

46. (b) : Momentum of emitted photon

$= p_{\text{photon}} = \frac{h\upsilon}{c}$

From the law of conservation of linear momentum,

$p_{\text{nucleus}} = p_{\text{photon}} \Rightarrow Mv = \frac{h\upsilon}{c}$

where v is the recoil speed of the nucleus

or $v = \frac{h\upsilon}{Mc}$ ...(i)

The recoil energy of the nucleus

$= \frac{1}{2}Mv^2 = \frac{1}{2}M\left(\frac{h\upsilon}{Mc}\right)^2 = \frac{h^2\upsilon^2}{2Mc^2}$ (Using(i))

47. (c) : When an alpha particle $\left({}^4_2\text{He}\right)$ is emitted, the mass number and the atomic number of the daughter nucleus decreases by four and two respectively. When a beta particle (β^-) is emitted, the atomic number of the daughter nucleus increases by one but the mass number remains the same.

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

48. (c) :

	P	Q
No. of nuclei, at $t = 0$	$4N_0$	N_0
Half- life	1 min	2 min
No. of nuclei after time t	N_P	N_Q

Let after t min the number of nuclei of P and Q are equal.

$\therefore\ N_P = 4N_0\left(\frac{1}{2}\right)^{t/1}$ and $N_Q = N_0\left(\frac{1}{2}\right)^{t/2}$

As $N_P = N_Q$

$\therefore\ 4N_0\left(\frac{1}{2}\right)^{t/1} = N_0\left(\frac{1}{2}\right)^{t/2}$ or $4 = \frac{2^t}{2^{t/2}}$

or $4 = 2^{t/2}$ or $2^2 = 2^{t/2}$ or $\frac{t}{2} = 2$ or $t = 4$ min

After 4 minutes, both P and Q have equal number of nuclei.

$\therefore$ Number of nuclei of R

$= \left(4N_0 - \frac{N_0}{4}\right) + \left(N_0 - \frac{N_0}{4}\right) = \frac{15N_0}{4} + \frac{3N_0}{4} = \frac{9N_0}{2}$

49. (d) : According to activity law

$R = R_0 e^{-\lambda t}$ ...(i)

According to given problem,

$R_0 = N_0$ counts per minute, $R = \frac{N_0}{e}$ counts per minute

$t = 5$ minutes

Substituting these values in equation (i), we get

$\frac{N_0}{e} = N_0 e^{-5\lambda}$ or $e^{-1} = e^{-5\lambda}$

$5\lambda = 1$ or $\lambda = \frac{1}{5}$ per minute

At $t = T_{1/2}$, the activity R reduces to $\frac{R_0}{2}$

where $T_{1/2}$ = half life of a radioactive sample

$T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{\log_e 2}{\left(\frac{1}{5}\right)} = 5\log_e 2$ minutes

50. (c) : $A_1 = \lambda N_1$ at time t_1, $A_2 = \lambda N_2$ at time t_2

Therefore, number of nuclei decayed during time interval $(t_1 - t_2)$ is

$$N_1 - N_2 = \frac{[A_1 - A_2]}{\lambda}$$

51. (d) : ${}^{A}_{Z}X \xrightarrow{\beta} {}^{A}_{Z+1}Y \xrightarrow{\alpha} {}^{A-4}_{Z-1}B^* \xrightarrow{\gamma} {}^{A-4}_{Z-1}B$

First X decays by β^- emission emitting $\bar{\upsilon}$, antineutrino simultaneously. Y emits α resulting in the excited level of B which in turn emits a γ ray.

$\therefore$ β, α, γ is the answer.

52. (c) : ${}^{A}_{Z}X \xrightarrow{2\beta^-} {}_{Z+2}^{A}Y_1 \xrightarrow{\alpha} {}^{A-4}_{Z}Y_2$

The resultant daughter is an isotope of the original parent nucleus.

53. (a) : $X_1 = N_0 e^{-\lambda_1 t}$; $X_2 = N_0 e^{-\lambda_2 t}$

$$\frac{X_1}{X_2} = e^{(-\lambda_1 + \lambda_2)t} \Rightarrow e^{-1} = e^{-(\lambda_1 - \lambda_2)t}$$

$$\therefore \quad t = \left|\frac{1}{\lambda_1 - \lambda_2}\right| = \frac{1}{(5\lambda - \lambda)} = \frac{1}{4\lambda}$$

54. (c) : $\lambda_A = 5\lambda$, $\lambda_B = \lambda$, At $t = 0$, $(N_0)_A = (N_0)_B$

At any time t,

$$\frac{N_A}{N_B} = \left(\frac{1}{e}\right)^2$$

According to radioactive decay, $\frac{N}{N_0} = e^{-\lambda t}$

$$\therefore \quad \frac{N_A}{(N_0)_A} = e^{-\lambda_A t} \quad \text{... (i)}$$

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

Divide (i) by (ii), we get

$$\frac{N_A}{N_B} = e^{-(\lambda_A - \lambda_B)t} \quad \text{or,} \quad \frac{N_A}{N_B} = e^{-(5\lambda - \lambda)t}$$

$$\text{or,} \quad \left(\frac{1}{e}\right)^2 = e^{-4\lambda t} \quad \text{or,} \quad \left(\frac{1}{e}\right)^2 = \left(\frac{1}{e}\right)^{4\lambda t}$$

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

55. (a) : In beta minus (β^-) decay, a neutron is transformed into a proton and an electron is emitted with the nucleus along with an antineutrino.

$n \longrightarrow p + e^- + \bar{\nu}$, where $\bar{\nu}$ is the antineutrino.

56. (b) : According to activity law, $R = R_0 e^{-\lambda t}$

$$\therefore \quad R_1 = R_0 e^{-\lambda t_1} \text{ and } R_2 = R_0 e^{-\lambda t_2}$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{R_0 e^{-\lambda t_1}}{R_0 e^{-\lambda t_2}} = e^{-\lambda t_1} e^{\lambda t_2} = e^{-\lambda(t_1 - t_2)}$$

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

57. (c) : Energy released, E = Energy equivalent of mass defect (Δm)

Δm = mass of product – mass of reactant

$E = c - a - b$

58. (d) : Using $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

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

The total time in which radium change to 25 g is
= 2 × 1600 = 3200 yr

59. (a) : At $t = 0$, $M_0 = 10$ g and $t = 2\tau = 2\left(\frac{1}{\lambda}\right)$

$$M = M_0 e^{-\lambda t} = 10e^{-\lambda\left(\frac{2}{\lambda}\right)} = 10\left(\frac{1}{e}\right)^2 = 1.35 \text{ g}$$

60. (a)

61. (c) : Number of initial active nuclei = 4×10^{16}

Number of decayed nuclei after 10 days (half life)

$$= \frac{4 \times 10^{16}}{2} = 2 \times 10^{16}$$

Remaining number of nuclei after 10 days
$= 4 \times 10^{16} - 2 \times 10^{16} = 2 \times 10^{16}$

$\therefore$ Number of decayed nuclei in next 10 days

$$= \frac{2 \times 10^{16}}{2} = 1 \times 10^{16}$$

Similarly, number of decayed nuclei in next 10 days = 0.5×10^{16}

$\therefore$ Total number of nuclei decayed after 30 days
$= 2 \times 10^{16} + 1 \times 10^{16} + 0.5 \times 10^{16} = 3.5 \times 10^{16}$

62. (d) : The nuclear reaction is

$${}_8O^{16} + {}_1H^2 \rightarrow {}_7N^{14} + {}_2He^4$$

So when a deuteron is bombarded on ${}_8O^{16}$ nucleus then an α-particle (${}_2He^4$) is emitted and the product nucleus is ${}_7N^{14}$.

63. (a) : α-rays are positively charged particles.

64. (a) : ${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{4}_{2}He + {}^{7}_{3}Li$

65. (b) : $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$; $n \rightarrow$ no.of decays

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

Time for 8 half life = 100 hours

66. (c) **67. (a)** **68. (d)**

69. (b, d) : 1α reduce the mass number by 4 units and atomic number by 2 units, while 1β only increase the atomic number by 1 unit.

70. (c)

71. (a) : For A, 80 min. = 4 half lives

Number of atoms left $= \frac{N_0}{16}$

For B, 80 min. $\cong$ 2 half lives

Number of atoms left $= \frac{N_0}{4}$. Required ratio = 1 : 4.

72. (b) : γ-ray are most penetrating radiations.

73. (b) : On emission of one α-particle, atomic number decreases by 2 units and mass number decrease by 4 units. While the emission of β-particle does not effect the mass number and atomic number increases by 1 unit.
Here, decrease in mass number = 200 – 168 = 32.
$\therefore$ Number of α-particles = 32/4 = 8.
$\therefore$ Number of β-particles = 16 – 10 = 6.

74. (b) : No. of nucleon on reactant side = 4
Binding energy for one nucleon = x_1
Binding energy for 4 nucleons = $4x_1$
Similarly on product side binding energy = $4x_2$
Now, Q = change in binding energy = $4(x_2 - x_1)$

75. (a) : Half-life time = 30 minutes; Rate of decrease (N) = 5 per second and total time = 2 hours = 120 minutes.
Relation for initial and final count rate,

$$\frac{R}{R_0} = \left(\frac{1}{2}\right)^{\text{time/half-life}} = \left(\frac{1}{2}\right)^{120/30} = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$$

Therefore $R_0 = 16 \times R = 16 \times 5 = 80\ s^{-1}$

76. (a) : α-particle = $_2He^4$. It contains $2p$ and $2n$.

77. (d) : $\dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^{6400/1600} = \left(\dfrac{1}{2}\right)^4 = \dfrac{1}{16}$

78. (b) : $_6C^{12} + {_0n^1} \rightarrow {_6C^{13}} \rightarrow {_7N^{13}} + {_{-1}\beta^0}$ + Energy

79. (d) : Number of half lives, $n = \dfrac{t}{T} = \dfrac{6400}{800} = 8$

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

80. (a) : From step (ii), B has 2 units of charge more than C.
From step (i), A loses 2 units of charge by emission of alpha particle. Hence, A and C are isotopes as their charge number is same.

81. (c) : Curie is a unit of radioactivity.

82. (d) : In two half lives, the activity becomes one fourth.
Activity on 1 - 8 - 91 was 2 micro curie.
$\therefore$ Activity before two months,
4 × 2 micro-Curie = 8 micro curie

83. (d) : Two successive β decays increase the charge number by 2.

84. (a) : $_{92}U^{235} + {_0n^1} \longrightarrow {_{36}Kr^{89}} + 3n_0^1 + {_ZX^A}$
$92 + 0 = 36 + Z$
$\Rightarrow$ $Z = 56$
Now, $235 + 1 = 89 + 3 + A$
$\Rightarrow$ $A = 144$
So, $_{56}Ba^{144}$ is generated.

85. (a) : As $^2_1H + {^2_1H} \longrightarrow {^4_2He}$
Here, $\Delta M = 0.02866$ u
$\therefore$ The energy liberated per u is $= \dfrac{\Delta M \times 931}{4}$ MeV

$$= \frac{0.02866 \times 931}{4}\ \text{MeV} = \frac{26.7}{4}\ \text{MeV} = 6.675\ \text{MeV}$$

86. (c) : According to Einstein's mass energy relation

$$E = mc^2 \quad \text{or} \quad m = \frac{E}{c^2}$$

Mass decay per second

$$= \frac{\Delta m}{\Delta t} = \frac{1}{c^2}\frac{\Delta E}{\Delta t} = \frac{P}{c^2} = \frac{1000 \times 10^3\ \text{W}}{(3 \times 10^8\ \text{m/s})^2} = \frac{10^6}{9 \times 10^{16}}\ \text{kg/s}$$

Mass decay per hour

$$= \frac{\Delta m}{\Delta t} \times 60 \times 60 = \left(\frac{10^6}{9 \times 10^{16}}\ \text{kg/s}\right)(3600\ \text{s})$$

$= 4 \times 10^{-8}$ kg $= 40 \times 10^{-6}$ g = 40 μg

87. (c) : Extremely high temperature needed for fusion make kinetic energy large enough to overcome coulomb repulsion between nuclei.

88. (a) : $_1H^2 + {_1H^2} \rightarrow {_2He^4} + \Delta E$
The binding energy per nucleon of a deuteron = 1.1 MeV
$\therefore$ Total binding energy = 2 × 1.1 = 2.2 MeV
The binding energy per nucleon of a helium nuclei = 7 MeV
$\therefore$ Total binding energy = 4 × 7 = 28 MeV
Hence, energy released
$\Delta E = (28 - 2 \times 2.2) = 23.6$ MeV

89. (c)

90. (c)

91. (c) : In nuclear fusion the mass of end product or resultant is always less than the sum of initial product, the rest is liberated in the form of energy, like in Sun energy is liberated due to fusion of two hydrogen atoms.

92. (c)

93. (a)

94. (d) : In nuclear fission, the chain reaction is controlled in such way that only one neutron, produced in each fission, causes further fission. Therefore some moderator is used to slow down the neutrons. Heavy water is used for this purpose.

95. (b) : Fission rate

$$= \frac{\text{total power}}{\dfrac{\text{energy}}{\text{fission}}} = \frac{5}{200 \times 1.6 \times 10^{-13}} = 1.56 \times 10^{11}\ s^{-1}$$

96. (a)

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