13.NUCLEI

Single Correct Answer Type

1. The radioactivity of a sample is R_1 at a time T_1 and R_2 at a time T_2. If the half-life of the specimen is T, the number of atoms that have disintegrated in the time $(T_2 - T_1)$ is proportional to

a) $R_1T_1 = R_2T_2$ b) $R_1 - R_2$ c) $\frac{(R_1 - R_2)}{T}$ d) $(R_1 - R_2)T$

2. The half life period of a radioactive element X is same as the mean life time of another radioactive element Y. Initially both them have the same number of atoms. Then

a) X and Y have the same decay rate initially b) X and Y decay at the same rate always c) Y will decay at a faster rate than X d) X will decay at a faster rate than Y

3. Consider the following reaction

$^1H_2 + {}^1H_2 \rightarrow {}_1He^4 + Q$

If $m({}_1H^2) = 2.0141$ u; $m({}_2He^4) = 4.0024$ u, the energy Q released (in MeV) in this fusion reaction is

a) 12 b) 6 c) 24 d) 48

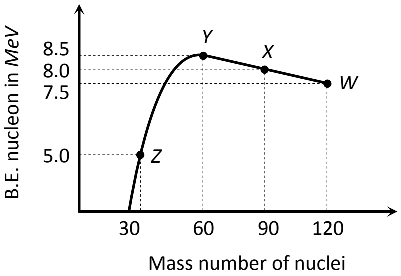
4. Which of the following is a correct statement?

a) Beta rays are same as cathode rays b) Gamma rays are high-energy neutrons c) Alpha particles are singly ionized helium atoms d) Protons and neutrons have exactly the same mass

5. 90% of a radioactive sample is left undecayed after time t has elapsed. What percentage of the initial sample will decay in a total time $2t$?

a) 20% b) 19% c) 40% d) 38%

6. Binding energy per nucleon verses mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is



a) $Y \rightarrow 2Z$ b) $W \rightarrow X + Z$ c) $W \rightarrow 2Y$ d) $X \rightarrow Y + Z$

7. The binding energies of nuclei X and Y are E_1 and E_2, respectively. Two atoms of X fuse to give one atom of Y and an energy Q is released. Then,

a) $Q = 2E_1 - E_2$ b) $Q = E_2 - 2E_1$ c) $Q < 2E_1 - E_2$ d) $Q > E_2 - 2E_1$

8. A radioactive sample of U^{238} decays to Pb through a process for which half life is $4.5 \times 10^9 years$. The ratio of number of nuclei of Pb to U^{238} after a time of $1.5 \times 10^9 years$ (given $2^{1/3} = 1.26$)

a) 0.12 b) 0.26 c) 1.2 d) 0.37

9. What is the power output of ${}_{92}U^{235}$ reactor if it takes 30 days to use up 2 kg of fuel and if each fission gives 185 MeV of usable energy? Avogadro's number $= 6.02 \times 10^{26}$ per kilomole

a) 45 megawatt b) 58.46 megawatt c) 72 megawatt d) 92 megawatt

10. In hydrogen spectrum, the wavelength of Hα line is 656 nm, whereas in the spectrum of a distant galaxy, Hα line wavelength is 706 nm. Estimated speed of the galaxy with respect to earth is

a) 2×10^8m s b) 2×10^7m s c) 2×10^6m s d) 2×10^5m s

11. After 280 days, the activity of a radioactive sample is 6000 dps. The activity reduces to 3000dps after another 140 days. The initial activity of the sample(in dps) is

a) 6000 b) 9000 c) 3000 d) 24000

12. The binding energies per nucleon of deuteron $({}_1H^2)$ and helium $({}_2He^4)$ atoms are 1.1 MeV and 7 MeV. If two deuteron atoms react to form a single helium atom, then the energy released is

a) 13.9 MeV b) 26.9 MeV c) 23.9 MeV d) 19.2 MeV

13. In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. the correct option is

a) $E(^{236}_{92}U) > E(^{137}_{53}I + E(^{97}_{39}Y + 2E(n)$
b) $E(^{236}_{92}U) < E(^{137}_{53}I + E(^{97}_{39}Y + 2E(n)$
c) $E(^{236}_{92}U) > E(^{140}_{56}\mathrm{B} + E(^{94}_{36}\mathrm{K} + 2E(n)$
d) $E(^{236}_{92}U) < E(^{140}_{56}\mathrm{B} + E(^{94}_{36}\mathrm{K} + 2E(n)$

14. N_1 atoms of a radioactive element emit N_2 beta particles per second. The decay constant of the element is (in s^{-1})

a) $\frac{N_1}{N_2}$ b) $\frac{N_2}{N_1}$ c) $N_1 \ln(2)$ d) $N_2 \ln(2)$

15. The binding energy of an electron in the ground state of He-atom is $E_0 = 24.6$ eV. The energy required to remove both the electrons from the atom is

a) 24.6 eV b) 79.0 eV c) 54.4 eV d) None of these

16. A nucleus $^A_Z\mathrm{X}$ emits an α-particle. The resultant nucleus emits a β^+ particle. The respective atomic and mass numbers of the final nucleus will be

a) $Z-3, A-4$ b) $Z-1, A-4$ c) $Z-2, A-4$ d) $Z, A-2$

17. Order of magnitude of density of uranium nucleus is $[m_p = 1.67 \times 10^{-27}\mathrm{kg}]$

a) 10^{20} kg b) 10^{17} kg c) 10^{14} kg d) 10^{11} kg

18. The half-life period of a radioactive element X is same as the mean lifetime of another radioactive element Y. Initially, both of them have the same number of atoms. Then,

a) X and Y have the same decay rate initially
b) X and Y decay at the same rate always
c) Y will decay at a faster rate than X
d) X will decay at a faster rate than Y

19. A newly prepared radioactive nuclide has a decay constant λ of $10^{-6}\mathrm{s}^{-1}$. What is the approximate half-life of the nuclide?

a) 1 hour b) 1 day c) 1 week d) 1 month

20. A star initially has 10^{40} deuterons. It produces energy via the processes $^2_1\mathrm{H} + {}^2_1\mathrm{H} \rightarrow {}^3_1\mathrm{H} + \mathrm{p}$ and $^2_1\mathrm{H} + {}^3_1\mathrm{H} \rightarrow {}^4_2\mathrm{H} + \mathrm{n}$

If the average power radiated by the star is 10^{16} W, the deuteron supply of the star is exhausted in a time of the order of

[Given: $M(^2\mathrm{H}) = 2.014$ u, $M(\mathrm{n}) = 1.008$ u, $M(\mathrm{p}) = 1.008$ u and $M(^4\mathrm{He}) = 4.001$ u]

a) 10^6 s b) 10^8 s c) 10^{12} s d) 10^{16} s

21. A radioactive nucleus A finally transforms into a stable nucleus B. Then, A and B may be

a) Isobars b) Isotones c) Isotopes d) None of these

22. As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom $(Z = 3)$ is

a) 1.51 b) 13.6 c) 40.8 d) 122.4

23. Masses of two isobars $_{29}\mathrm{Cu}^{64}$ and $_{30}\mathrm{Zn}^{64}$ are 63.9298 u and 63.9292 u, respectively. It can be concluded from these data that

a) Both the isobars are stable
b) Zn^{64} is radioactive, decaying to Cu^{64} through β-decay
c) Cu^{64} is radioactive, decaying to Zn^{64} through γ-decay
d) Cu^{64} is radioactive, decaying to Zn^{64} through β-decay

24. Binding energy per nucleon for C^{12} is 7.68 MeV and for C^{13} is 7.74 MeV. The energy required to remove a neutron from C^{13} is

a) 5.49 MeV b) 8.46 MeV c) 9.45 MeV d) 15.49 Me

25. A radioactive sample S1 having an activity of $5\mu Ci$ has twice the number of nuclei as another sample S2 which has an activity of $10\mu Ci$. The half lives of S1 and S2 can be

a) 20 years and 5 years, respectively
b) 20 years and 10 years, respectively
c) 10 years each
d) 5 years each

26. The luminous dials of watches are usually made by mixing a zinc sulphide phosphor with an α-particle emitter. The mass of radium (mass number 226, half-life 1620 years) that is needed to produce an average of 10 α-particles per second for this purpose is

a) 2.77 mg b) 2.77 g c) 2.77×10^{-23} g d) 2.77×10^{-13} kg

27. Calculate the binding energy of a deuteron atom, which consists of a proton and a neutron, given that the atomic mass of the deuteron is 2.014102 u

a) 0.002388 b) 2.014102 c) 2.16490 d) 2.224 MeV

28. A radioactive substance X decays into another radioactive substance Y. Initially, only X was present. λ_x and λ_y are the disintegration

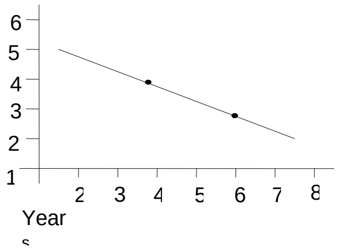
constants of X and Y. N_y will be maximum when

a) $\frac{N_y}{N_x - N_y} = \frac{\lambda_y}{\lambda_x - \lambda_y}$ b) $\frac{N_x}{N_x - N_y} = \frac{\lambda_x}{\lambda_x - \lambda_y}$ c) $\lambda_y N_y = \lambda_x N_x$ d) $\lambda_y N_x = \lambda_x N_y$

29. A proton and a neutron are both shot at $100\ \mathrm{ms}^{-1}$ towards a ${}^{12}_{6}\mathrm{C}$ nucleus. Which particle, if either, is more likely to be absorbed by the nucleus?

a) The proton b) The neutron c) Both particles are about equally likely to be absorbed d) Neither particle will be absorbed

30. To determine the half- life of radioactive element, a student plots graph of $\ln\left|\frac{dN\ (t)}{dt}\right|$ *versus* t. Here $\frac{dN\ (t)}{dt}$ is the rate of radioactive decay at time t. If the number of radioactive nuclei of this element decreases by a factor of p after 4.16 yr, the value of p is



a) 8 b) 7 c) 4 d) 8.5

31. A star initially has 10^{40} deutrons. It produces energy via the processes ${}_1\mathrm{H}^2 + {}_1\mathrm{H}^2 \rightarrow {}_1\mathrm{H}^2 + \mathrm{p}$ and ${}_1\mathrm{H}^2 + {}_1\mathrm{H}^3 \rightarrow {}_2\mathrm{He}^4 + \mathrm{n}$

If the average power radiated by the star is 10^{16} W, the deuteron supply of the star is exhausted in a time of the order of

[The mass of the nuclei are as follows: $\mathrm{M(H^2) = 2.014\ a.m.u..M(n) = 1.008\ a.m.u..}$ $\mathrm{M(p) = 1.007\ a.m.u..M(He^4) =}$ $\mathrm{4.001\ a.m.u..}$]

a) 10^6 s b) 10^8 s c) 10^{12} s d) 10^{16} s

32. After an interval of one day, 1/16th initial amount of a radioactive material remains in a sample. Then, its half-life is

a) 6 h b) 12 h c) 1.5 h d) 3 h

33. In the following atoms and molecules for the transition from $n = 2$ to $n = 1$, the spectral line of minimum wavelength will be produced by

a) Hydrogen atom b) Deuterium atom c) Uni-ionized helium d) De-ionized lithium

34. ${}^{238}\mathrm{U}$ decays with a half-life of 4.5×10^9 years, the decay series eventually ending at ${}^{206}\mathrm{Pb}$, which is stable. A rock sample analysis shows that the ratio of the number of atoms of ${}^{206}\mathrm{Pb}$ and ${}^{238}\mathrm{U}$ is 0.0058. Assuming that all the ${}^{206}\mathrm{Pb}$ is produced by the decay of ${}^{238}\mathrm{U}$ and that all other half-lives on the chain are negligible, the age of the rock sample is $(\ln 1.0058 = 5.78 \times 10^{-3})$

a) 38×10^8 years b) 38×10^6 years c) 19×10^8 years d) 19×10^6 years

35. Samples of two radioactive nuclides, X and Y, each have equal activity A at time $t = 0$. X has a half-life of 24 years and Y a half-life of 16 years. The samples are mixed together. What will be the total activity of the mixture at $t = 48$ years?

a) $\frac{1}{2}A_0$ b) $\frac{1}{4}A_0$ c) $\frac{3}{16}A_0$ d) $\frac{3}{8}A_0$

36. In a problem 43, number of atoms decayed between time interval t_1 and t_2 are

a) $\frac{\ln(2)}{\lambda}(R_1$ b) $R_1 e^{-\lambda t_2} - R_2 e^{-\lambda t}$ c) $\lambda(R_1 - R_2)$ d) $\left(\frac{R_1 - R_2}{\lambda}\right.$

37. ${}^{22}\mathrm{Ne}$ nucleus, after absorbing energy, decays into two α-particles and an unknown nucleus. The unknown nucleus is

a) Nitrogen b) Carbon c) Boron d) Oxygen

38. In an α-decay, the kinetic energy of α-particle is 48 MeV and Q value of the reaction is 50 MeV. The mass number of the mother nucleus is (assume that daughter nucleus is in ground state)

a) 96 b) 100 c) 104 d) None of these

39. If 10% of a radioactive substance decays in every 5 years, then the percentage of the substance that will have decayed in 20 years will be

a) 40% b) 50% c) 65.6% d) 34.4%

40. Half-life of a radioactive substance A is two times the half-life of another radioactive substance B. Initially, the number of A and B are N_A and N_B, respectively. After three half-lives of A, number of nuclei of both are equal. Then, the ratio N_A/N_B is

a) 1/4 b) 1/8 c) 1/3 d) 1/6

41. If a star can convert all the He nuclei completely into oxygen nuclei, the energy released per oxygen nuclei is (Mass of the nucleus is 4.0026 amu and mass of oxygen nucleus is 15.9994 amu)

a) 7.6MeV b) 56.12MeV c) 10.24MeV d) 23.9MeV

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

a) 1:16 b) 4:1 c) 1:4 d) 1:1

43. The activity of a radioactive sample is 1.6 curie, and its half-life is 2.5 days. Its activity after 10 days will be

a) 0.8 curie b) 0.4 curie c) 0.1 curie d) 0.16 curie

44. What is the age of an ancient wooden piece if it is known that the specific activity of C^{14} nuclide in it amounts to 3/5 of that in fresh trees? Given: the half of C nuclide is 5570 years and $\log_e(5/3) = 0.5$

a) 0 years b) 2000 years c) 3000 years d) 4000 years

45. A sample of radioactive material decays simultaneously by two processes A and B with half-lives $\frac{1}{2}$ and $\frac{1}{4}$ h, respectively. For first half hour it decays with the process A, next one hour with the process B, and for further half an hour with both A and B. If originally there were N_0 nuclei, find the number of nuclei after 2 h of such decay

a) $\frac{N_0}{(2)^8}$ b) $\frac{N_0}{(2)^4}$ c) $\frac{N_0}{(2)^6}$ d) $\frac{N_0}{(2)^5}$

46. A radioactive element X converts into another stable element Y. Half-life of X is 2 h. Initially, only X is present. After time t, the ratio of atoms of X and Y is found to be 1: 4. Then t in hours is

a) 2 b) 4 c) Between 4 and 6 d) 6

47. Binding energy per nucleon of ${}_1H^2$ and ${}_2He^4$ are 1.1 MeV and 7.0 MeV, respectively. Energy released in the process ${}_1H^2 + {}_1H^2 = {}_2He^4$ is

a) 20.8 MeV b) 16.6 MeV c) 25.2 MeV d) 23.6 MeV

48. A hydrogen like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. The value of n will be

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

49. ${}^{49}_{19}$K isotope of potassium has a half-life of 1.4×10^9 yr and decays to form stable argon, ${}^{40}_{18}$Ar. A sample of rock has been taken which contains both potassium and argon in the ratio 1:7, i.e.,

$$\frac{\text{Number of potassium} - 40 \text{ atoms}}{\text{Number of argon} - 40 \text{ atom}} = \frac{1}{7}$$

Assuming that when the rock was formed no argon-40 was present in the sample and none has escaped subsequently, determine the age of the rock

a) 4.2×10^9 years b) 9.8×10^9 years c) 1.4×10^9 years d) 10×10^9 years

50. During a nuclear fusion reaction

a) A heavy nucleus breaks into two fragments by itself b) A light nucleus bombarded by thermal neutrons breaks up c) A heavy nucleus bombarded by thermal neutrons breaks up d) Two light nuclei combine to give a heavier nucleus and possibly other products

51. The initial activity of a certain radioactive isotope was measured as 16000 counts $\min^{-1}$. Given that the only activity measured was due to this isotope and that its activity after 12 h was 2100 counts $\min^{-1}$, its half-life, in hours, is nearest to [Given $\log_e(7.2) = 2$)]

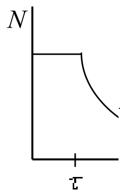
a) 9.0 b) 6.0 c) 4.0 d) 3.0

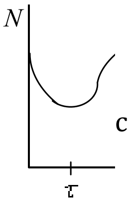
52. Some radioactive nucleus may emit

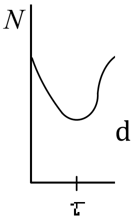
a) Only one α, β or γ at a time b) All the three α, β and γ one after another c) All the three α, β and γ simultaneously d) Only α and β simultaneously

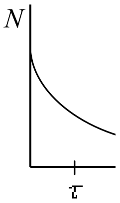
53. A radioactive sample consists of two distinct species having equal number of atoms initially. The mean lifetime of one species is τ and that of the other is 5τ. The decay products in both cases are stable. A plot is made of the total number of radioactive nuclei as a function of

time. Which of the following figures best represents the form of this plot?

a)


b)


c)


d)


54. Atomic mass number of an element is 232 and its atomic number is 90. The end product of this radioactive element is an isotope of lead (atomic mass 208 and atomic number 82). The number of α- and β-particles emitted are
a) $\alpha = 3, \beta = 3$ b) $\alpha = 6, \beta = 4$ c) $\alpha = 6, \beta = 0$ d) $\alpha = 4, \beta = 6$

55. The compound unstable nucleus $^{236}_{92}\mathrm{U}$ often decays in accordance with the following reaction $^{236}_{92}\mathrm{U} \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{94}_{38}\mathrm{Sr} +$ order particles
In the nuclear reaction presented above, the 'other particle' might be
a) An alpha particle, which consist of two protons and two neutrons b) Two protons c) One proton and one neutron d) Two neutrons

56. In which of the following processes, the number of protons in the nucleus increase?
a) α-decay b) β^--decay c) β^+-decay d) k-capture

57. Consider α-particles, β-particles and γ-rays, each having an energy of 0.5 MeV. In increasing order of penetrating powers, the radiations are:
a) α, β, γ b) α, γ, β c) β, γ, α d) γ, β, α

58. If in nature there may not be an element for which the principle quantum number $n > 4$, then the total possible number of elements will be
a) 60 b) 32 c) 4 d) 64

59. A freshly prepared radioactive source of half-life 2 h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with the source is
a) 6 h b) 12 h c) 24 h d) 128 h

60. In the nuclear reaction given by $_2\mathrm{He}^4 + {}_7\mathrm{N}^{14} \rightarrow {}_1\mathrm{H}^1 + \mathrm{X}$, the nucleus X is
a) Nitrogen of mass 16 b) Nitrogen of mass 17 c) Oxygen of mass 16 d) Oxygen of mass 17

61. The fraction of a radioactive material which remains active after time t is $9/16$. The fraction which remains active after time $t/2$ will be
a) $\frac{4}{5}$ b) $\frac{7}{8}$ c) $\frac{3}{5}$ d) $\frac{3}{4}$

62. Which of the following is in the increasing order for penetrating power
a) α, β, γ b) β, α, γ c) γ, α, β d) γ, β, α

63. Assuming that about 20 MeV of energy is released per fusion reaction
$_1\mathrm{H}^2 + {}_1\mathrm{H}^2 \rightarrow + {}_2\mathrm{He}^4 + \mathrm{E} + \text{other particles}$
Then the mass of $_1\mathrm{H}^2$ consumed per day in a fusion reactor of power 1 megawatt will approximately be
a) 0.001 g b) 0.1 g c) 10.0 g d) 1000 g

64. A radioactive sample S_1 having an activity of 5μCi has twice the number of nuclei as another sample S_2 which has an activity of 10 μCi. The half lives of S_1 and S_2 can be
a) 20 yr and 5 yr ,respectively b) 20 yr and 10 yr ,respectively c) 10 yr each d) 5 yr each

65. Consider two arbitrary decay equations and mark the correct alternative(s) given below:
1. $^{230}_{92}\mathrm{U} \rightarrow n + {}^{229}_{92}\mathrm{U}$
2. $^{230}_{92}\mathrm{U} \rightarrow p + {}^{229}_{91}\mathrm{U}$
Given: $M({}^{230}_{92}\mathrm{U}) = 230.033927$ u, $M({}^{229}_{92}\mathrm{U}) = 229.03349$ u, $m_n = 1.008665$ u, $M({}^{229}_{91}\mathrm{Pa}) = 229.032089, m_p = 1.007825$, 1 a. m. u $= 931.5$ MeV
a) Only decay (i) is possible b) Only decay (ii) is possible c) Both the decays are possible d) Neither of the two decays is possible

66. 1.00 kg of ^{235}U undergoes fission process. If energy released per event is 200 MeV, then the total energy released is
a) 5.12×10^{24} M b) 6.02×10^{23} M c) 5.12×10^{26} d) 6.02×10^{26} M

67. A sample of a 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

68. The activity of a radioactive element decreases to one-third of the original activity I_0 in a period of nine years. After a further lapse of nine years, its activity will be

a) I_0 b) $(2/3)I_0$ c) $(I_0/9)$ d) $(I_0/6)$

69. During a negative beta decay

a) An atomic electron is ejected
b) An electron which is already present within the nucleus is ejected
c) A neutron in the nucleus decays emitting an electron
d) A part of the binding energy of the nucleus is converted into an electron

70. The binding energy per nucleon of O^{16} is $7.97 MeV$ and that of O^{17} is $7.75\ MeV$. The energy (in MeV) required to remove a neutron from O^{17} is

a) 3.52 b) 3.64 c) 4.23 d) 7.86

71. Given a sample of *Radium*-226 having half-life of 4 days. Find the probability, a nucleus disintegrates after 2 half lives

a) 1 b) 1/2 c) 1.5 d) 3/4

72. The equation $4{}_1^1\text{H} \rightarrow {}_2^4\text{H}e^2 + 2e^- + 26\text{ MeV}$ represents

a) β-decay b) γ-decay c) Fusion d) Fission

73. A neutron of energy 1 MeV and mass 1.6×10^{-27} kg passes a proton at such a distance that the angular momentum of the neutron relative to the proton approximately equals 10^{-33} Js. The distance of closest approach neglecting the interaction between particles is

a) 0.44 nm b) 0.44 mm c) 0.44 Å d) 0.44 fm

74. There are two ratio nuclei A and B. A is an alpha emitter and B a beta emitter. Their disintegration constants are in the ratio of 1:2. What should be the ratio of number of atoms of A and B at any time t so that probabilities of getting alpha and beta particles are same at that instant?

a) 2:1 b) 1:2 c) e d) e^{-1}

75. The following deuterium reactions and corresponding reaction energies are found to occur

${}^{14}\text{N}\,(\text{d, p})\ {}^{15}\text{N}\quad Q = 8.53\text{ MeV}$
${}^{15}\text{N}\,(\text{d}, \alpha)\ {}^{13}\text{C}\quad Q = 7.58\text{ MeV}$
${}^{13}\text{C}\,(\text{d}, \alpha)\ {}^{11}\text{B}\quad Q = 5.16\text{ MeV}$

The rotation ${}^{14}\text{N}(\text{d, p})\ {}^{15}\text{N}$ represents the reaction ${}^{14}\text{N} + \text{d} \rightarrow {}^{15}\text{N} + \text{p}$
${}_2^4\text{He} = 4.0026\text{ a.m.u.}$, ${}_1^2\text{He} = 2.014\text{ a.m.u.}$, ${}_1^1\text{H} = 1.0078\text{ a.m.u.}$, n $=$1.0087 a.m.u. (1 a.m.u. $=$ 931 MeV)
The Q values of the reaction ${}^{11}\text{B}(\alpha, \text{n})\ {}^{14}\text{N}$ is

a) 0.5 eV b) 0.5 MeV c) 0.05 MeV d) 0.05 eV

76. A radioactive sample decays by 63% of its initial value in 10 s. It would have decayed by 50% of its initial value in

a) 7 s b) 14 s c) 0.7 s d) 1.4 s

77. Assuming that about 200 MeV of energy is released per fission of ${}_{92}\text{H}^{235}$ nuclei, the mass of U^{235} consumed per day in a fission reactor of power 1 megawatt will be approximately

a) 10^{-2} g b) 1 g c) 100 g d) 10,000 g

78. In a sample of rock; the ratio of ${}^{206}\text{Pb}$ to ${}^{238}\text{U}$ nuclei is found to be 0.5. The age of the rock is (given half-life of U^{238} is 4.5×10^9 years)

a) 2.25×10^9 year b) $4.5 \times 10^9 \ln 3$ year c) $4.5 \times 10^9 \frac{\ln\left(\frac{3}{2}\right)}{\ln 2}$ year d) $2.25 \times 10^9 \ln\left(\frac{3}{2}\right)$ year

79. The binding energy of deuteron ${}_1^2H$ is $1.112\ MeV$ per nucleon and an α-particle ${}_2^4He$ has a binding energy of $7.047\ MeV$ per nucleon. Then in the fusion reaction ${}_1^2H + {}_1^2H \rightarrow {}_2^4He + Q$, the energy Q released is

a) $1\ MeV$ b) $11.9\ MeV$ c) $23.8\ MeV$ d) $931\ MeV$

80. The half-life of ${}^{131}\text{I}$ is 8 days. Given a sample of ${}^{131}\text{I}$ at time $t = 0$, we can assert that

a) No nucleus will decay before $t = 4$ days
b) No nucleus will decay before $t = 8$ days
c) All nuclei will decay before $t = 16$ days
d) A given nucleus may decay at any time after $t = 0$

81. In the fusion reaction ${}_1^2\text{He} + {}_1^2\text{H} \rightarrow {}_2^3\text{He} + {}_0^1\text{n}$, the masses of deuteron, helium and neutron expressed in a.m.u. are 2.015, 3.017 and 1.009, respectively. If 1 kg of deuterium undergoes complete fusion, find the amount of total energy released (1 a.m.u. $= 931.5\text{ meV}/c^2$)

a) $\approx 6.02 \times$ b) $\approx 5.6 \times$ c) $\approx 9.0 \times$ d) $\approx 0.9 \times$

10^{13} J 10^{13} J 10^{13} J 10^{13} J

82. Uranium ores contain one radium-226 atom for every 2.8×10^6 uranium-238 atoms. Calculate the half-life of ${}_{92}U^{238}$, given that the half-life of ${}_{88}Ra^{226}$ is 1600 years (${}_{88}Ra^{226}$ is a decay product of ${}_{92}U^{238}$)

a) 1.75×10^3 years b) $1600 \times \frac{238}{92}$ years c) 4.5×10^9 years d) 1600×238 years

83. Atomic masses of two isobars ${}^{64}_{29}Cu$ and ${}^{64}_{30}Zn$ are 63.9298 u and 63.9292 u, respectively. It can be concluded from this data that

a) Both the isobars are stable b) ${}^{64}Zn$ is radioactive, decaying to ${}^{64}Cu$ through β-decay c) ${}^{64}Cu$ is radioactive, decaying to ${}^{64}Zn$ through β-decay d) ${}^{64}Cu$ is radioactive, decaying to ${}^{64}Zn$ through γ-decay

84. The half-life period of RaB(${}_{82}Pb^{214}$) is 26.8 min. The mass of one curie of RaB is

a) 3.71×10^{10} g b) 3.71×10^{-10} g c) 8.61×10^{10} g d) 3.064×10^{-8} g

85. A nucleus with atomic number Z and neutron number N undergoes two decay processes. The result is a nucleus with atomic number $Z - 3$ and neutron number $N - 1$. Which decay processes took place?

a) Two β^- decays b) Two β^+ decays c) An α-decay and a β^- decay d) An α-decay and a β^+ decay

86. ${}_{92}U^{238}$ absorbs a neutron. The product emits an electron. This product further emits an electron. The result is

a) ${}_{94}Pu^{239}$ b) ${}_{90}Pu^{239}$ c) ${}_{93}Pu^{237}$ d) ${}_{94}Pu^{237}$

87. The percentage of quantity of a radioactive material that remains after 5 half-lives will be

a) 31% b) 3.125% c) 0.3% d) 1%

88. A stationery Thorium nucleus ($A = 220, Z = 90$) emits an alpha particle with kinetic energy E_α. What is the kinetic energy of the recoiling nucleus?

a) $\frac{E_\alpha}{108}$ b) $\frac{E_\alpha}{110}$ c) $\frac{E_\alpha}{55}$ d) $\frac{E_\alpha}{54}$

89. An element A decays into an element C by a two-step process:

$A \rightarrow B + He^4_2$ and $B \rightarrow C + 2e^0_{-1}$

a) A and C are b) A and C are c) B and C are d) A and B are

isotopes isobars isotopes isobars

90. A 5×10^{-4} Å photon produces an electron-positron pair in the vincinity of a heavy nucleus. Rest energy of electron is 0.511 MeV. If they have the same kinetic energies, the energy of each particle is nearly

a) 1.2 MeV b) 12 MeV c) 120 MeV d) 1200 MeV

91. The electron emitted in beta radiation originates from

a) Inner orbits of atoms b) Free electrons existing in a nuclei c) Decay of a neutron in a nucleus d) Photon escaping from the nucleus

92. The minimum frequency of a γ-ray that causes a deuteron to disintegrate into a proton and a neutron is ($m_d = 2.0141$ a.m.u., $m_p = 1.0078$ a.m.u., $m_n = 1.0087$ a.m.u)

a) 2.7×10^{20} H b) 5.4×10^{20} H c) 10.8×10^{20} H d) 21.6×10^{20} H

93. Let E_1 and E_2 be the binding energies of two nuclei A and B. It is observed that two nuclei of A combine together to form a B nucleus. This observation is correct only if

a) $E_1 > E_2$ b) $E_2 > E_1$ c) $E_2 > 2E_1$ d) Nothing can be said

94. If mass of $U^{235} = 235.12142$ a.m.u., mass of $U^{236} = 236.1205$ a.m.u. and mass of neutron $= 1.008665$ a.m.u., then the energy required to remove one neutron from the nucleus of U^{236} is nearly about

a) 75 MeV b) 6.5 MeV c) 1 eV d) Zero

95. In fission, the percentage of mass converted into energy is about

a) 10% b) 1% c) 0.1% d) 0.01%

96. The energy released in a typical nuclear fusion reaction is approximately

a) 25 MeV b) 200 MeV c) 800 MeV d) 1050 Me

97. Mark out the incorrect statement

a) A free neutron can transform itself into photon b) A free proton can transform itself into neutron c) In beta minus decay, the electron originates from nucleus d) All of the above

98. For uranium nucleus how does its mass vary with volume?

a) $m \propto V$ b) $m \propto 1/V$ c) $m \propto \sqrt{V}$ d) $m \propto V^2$

99. An element X decays, first by positron emission and then two α-particles are emitted in successive radioactive decay. If the product nucleus has a mass number 229 and atomic number 89, the mass number and atomic number of element X are

a) 237, 93 b) 237, 94 c) 221, 84 d) 237, 92

100. At any instant, the ratio of the amounts of two radioactive substances is 2:1. If their half-lives be, respectively, 12 h and 16 h, then after two days, what will be the ratio of the substances?

a) 1:1 b) 2:1 c) 1:2 d) 1:4

101. If the decay or disintegration constant of a radioactive substance is λ, then its half life and mean life are respectively

a) $\frac{1}{\lambda}$ and $\frac{\log_e 2}{\lambda}$ b) $\frac{\log_e 2}{\lambda}$ and $\frac{1}{\lambda}$ c) $\lambda \log_e 2$ and $\frac{1}{\lambda}$ d) $\frac{\lambda}{\log_e 2}$ and $\frac{1}{\lambda}$

102. Rank the following nuclei in order from largest to smallest value of the binding energy per nucleon: (i) $^{4}_{2}\mathrm{He}$, (ii) $^{52}_{24}\mathrm{Cr}$, (iii) $^{152}_{62}\mathrm{Sm}$, (iv) $^{100}_{80}\mathrm{Hg}$, (v) $^{252}_{92}\mathrm{Cf}$

a) $E_{(v)} > E_{(iv)} > E_{(iii)} > E_{(ii)} > E_{(i)}$ b) $E_{(i)} > E_{(ii)} > E_{(iii)} > E_{(iv)} > E_{(v)}$ c) $E_{(ii)} > E_{(iii)} > E_{(iv)} > E_{(v)} > E_{(i)}$ d) $E_{(i)} = E_{(ii)} = E_{(iii)} = E_{(iv)} = E_{(v)}$

103. Plutonium has atomic mass 210 and a decay constant equal to $5.8 \times 10^{-8}\mathrm{s}^{-1}$. The number of α-particles emitted per second by 1 mg Plutonium is

(Avogadro's constant $= 6.0 \times 10^{23}$)

a) 1.7×10^{9} b) 1.7×10^{11} c) 2.9×10^{11} d) 3.4×10^{9}

104. Neutron decay in the free space is given as follows: ${}_0\mathrm{n}^1 \rightarrow {}_1\mathrm{H}^1 + {}_{-1}\mathrm{e}^0 + [\,]$

Then, the parenthesis represents

a) Photon b) Graviton c) Neutrino d) Antineutrino

105. U-235 can decay by many ways, let us here consider only two ways A and B. In decay of U-235 by means of A, the energy released per fission is 210 MeV while in B it is 186 MeV. Then, the uranium 235 sample is more likely to decay by

a) Scheme A b) Scheme B c) Equally likely for both schemes d) It depends on half-life of schemes A and B

106. The decay constant of a radioactive sample is λ. The half-life and mean-life of the sample are, respectively, given by

a) $1/\lambda$ and $(\ln 2)/\lambda$ b) $(\ln 2)\lambda$ and $1/\lambda$ c) $\lambda(\ln 2)$ and $1/\lambda$ d) $\lambda/(\ln 2)$ and $1/\lambda$

107. The half-life of $^{131}\mathrm{I}$ is 8 days. Given a sample of $^{131}\mathrm{I}$ at time $t = 0$, we can assert that

a) No nucleus will decay before $t = 4$ days b) No nucleus will decay before $t = 8$ days c) all nuclei will decay before $t = 16$ days d) A given nucleus may decay at any time after $t = 0$

108. In the disintegration series

$$^{238}_{92}\mathrm{U} \xrightarrow{\alpha} \mathrm{X} \xrightarrow{\beta^-} {}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{Y}$$

The values of Z and A, respectively, will be

a) 92, 326 b) 88, 230 c) 90, 234 d) 91, 234

109. The nuclear radius of ${}_8\mathrm{O}^{16}$ is 3×10^{-15} m. If an atomic mass unit is 1.67×10^{-27} kg, then the nuclear density is approximately?

a) 2.35×10^{17} g b) 2.35×10^{17} kg c) 2.35×10^{17} g d) 2.35×10^{17} kg

110. There are two radioactive substances A and B. Decay constant of B is two times that of A. Initially, both have equal number of nuclei. After n half-lives of A, rates of disintegration of both are equal. The value of n is

a) 1 b) 2 c) 4 d) All of these

111. $$A \xrightarrow{\lambda} B \xrightarrow{2\lambda} C$$

$T = 0$ N_0 0 0

T N_1 N_2 N_3

The ratio of N_1 to N_2 when N_2 is maximum is

a) At no time this is possible b) 2 c) 1/2 d) $\frac{\ln 2}{2}$

112. Two radioactive materials X_1 and X_2 have decay constants 10λ and λ, respectively. If initially they have the same number of nuclei, the ratio of the number of nuclei of X_1 to that of X_2 will be $1/e$ after a time

a) $\frac{1}{10\lambda}$ b) $\frac{1}{11\lambda}$ c) $\frac{11}{10\lambda}$ d) $\frac{1}{9\lambda}$

113. Number of nuclei of a radioactive substance are 1000 and 900 at times $t = 0$ and time $t = 2$ s. Then, number of nuclei at time $t = 4$ s will be

a) 800 b) 810 c) 790 d) 700

114. Gold $^{198}_{79}$Au undergoes β^- decay to an excited state of $^{198}_{80}$Hg. If the excited state decays by emission of a γ-photon with energy 0.412 MeV, the maximum kinetic energy of the electron emitted in the decay is (This maximum occurs when the antineutrino has negligible energy. The recoil energy of the $^{198}_{80}$Hg nucleus can be ignored. The masses of the neutral atoms in their ground states are 197.968225 u for $^{198}_{79}$Au and 197.966752 u for $^{198}_{79}$Hg.)

a) 0.412 Me b) 1.371 Me c) 0.959 Me d) 1.473 Me

115. The mean life time of a radionuclide, if its activity decreases by 4% for every 1 h, would be [product is non-radioactive, i.e., stable]

a) 25 h b) 1.042 h c) 2 h d) 30 h

116. A radioactive nucleus decay by two different processes. The mean value period for the first process is t_1 and that for the second process is t_2. The effective mean value period for the two processes is

a) $\frac{t_1 + t_2}{2}$ b) $t_1 + t_2$ c) $\sqrt{t_1 t_2}$ d) $\frac{t_1 t_2}{t_1 + t_2}$

117. A radioactive isotope is being produced at a constant rate X. Half-life of the radioactive substance is Y. After some time, the number of radioactive nuclei become constant. The value of this constant is

a) $\frac{XY}{\ln(2)}$ b) XY c) (XY) ln(2d)$\frac{X}{Y}$

118. Four physical quantities are listed in Column I. Their values are listed in Column II in a random order

Column I	Column II
p. Thermal energy of air molecules at room temperature	(i)0.02 eV
q. Binding energy of heavy nuclei per nucleon	(ii) 2 eV
r. X-ray photon energy	(iii)10 keV
s. Photon energy of visible light	(iv)7 MeV

The correct matching of Column I and Column II is given by

a) p → i, q → iv, r → iii, s → ii b) p → i, q → iii, r → ii, s → iv c) p → ii, q → i, r → iii, s → iv d) p → ii, q → iv, r → i, s → iii

119. A certain radioactive material can undergo three different types of decay, each with a different decay constant λ, 2λ and 3λ. Then, the effective decay constant λ_{eff} is

a) 6λ b) 4λ c) 2λ d) 3λ

120. The wavelength of the first spectral line in the Balmer series of hydrogen atom is 6561 Å. The wavelength of the second spectral line in the Balmer series of singly ionized helium atom is

a) 1215 Å b) 1640 Å c) 2430 Å d) 4687 Å

121. The ratio of molecular mass of two radioactive substances is $\frac{3}{2}$ and the ratio of their decay constants is $\frac{4}{3}$. Then, the ratio of their initial activity per mole will be

a) 2 b) $\frac{8}{9}$ c) $\frac{4}{3}$ d) $\frac{9}{8}$

122. An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (in eV) required to remove both the electrons from a neutral helium atom is

a) 79.0 b) 51.8 c) 49.2 d) 38.2

123. If $_{92}\text{U}^{238}$ changes to $_{85}\text{At}^{210}$ by a series of α- and β-decays, the number of α- and β-decays undergone is

a) 7 and 5 b) 7 and 7 c) 5 and 7 d) 7 and 9

124. The probability of survival of a radioactive nucleus for one mean life is

a) $\frac{1}{e}$ b) $1 - \frac{1}{e}$ c) $\frac{\ln 2}{e}$ d) $1 - \frac{\ln 2}{e}$

125. A radioactive nuclide is produced at the constant rate of n per second (say, by bombarding a target with neutrons). The expected number N of nuclei in existence t s after the number is N_0 is given by

a) $N = N_0 e^{-\lambda t}$ b) $N = \frac{n}{\lambda} + N_0 e^{-\lambda t}$ c) $N = \frac{n}{\lambda} + \left(N_0 - \frac{n}{\lambda}\right) e^{-\lambda t}$ d) $N = \frac{n}{\lambda} + \left(N_0 + \frac{n}{\lambda}\right) e^{-\lambda t}$

126. Beta rays emitted by a radioactive material are

a) Electromagnetic radiatio b) The electrons orbiting c) Charged particles emitted by the d) Neutral particles ns around the nucleus nucleus

127. A radio isotope ‘X’ has a half-life of 10 s. Find the number of nuclei in the sample (if initially there are 1000 isotopes which are falling from rest from a height of 3000 m) when it is at a height of 1000 m from the reference plane

a) 50 b) 250 c) 29 d) 100

128. Half-life of a radio active substance A is 4 days. The probability that a nucleus will decay in two half-lives is

a) $\frac{1}{4}$ b) $\frac{3}{4}$ c) $\frac{1}{2}$ d) 1

129. The half-life of radioactive radon is 3.8 days. The time at the end of which 1/20th of the radon sample will remain undecayed is (given $\log_{10} e = 0.4343$)

a) 3.8 days b) 16.5 days c) 33 days d) 76 days

130. In the case of thorium ($A = 232$ and $Z = 90$), we obtain an isotope of lead ($A = 208$ and $Z = 82$) after some radioactive disintegration. The number of α- and β-particles emitted are, respectively,

a) 6, 3 b) 6, 4 c) 5, 5 d) 4, 6

131. What would be the energy required to dissociate completely 1 g of Ca-40 into its constituent particles?
Given: Mass of proton = 1.007277 a. m. u.,
Mass of neutron =1.00866 a. m. u.
Mass if Ca-40 = 39.97545 a. m. u
(take 1 a. m. u. = 931 MeV)

a) 4.813×10^{24} M b) 4.813×10^{24} e c) 4.813×10^{23} M d) None of the above

132. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer is)

a) 802 nm b) 823 nm c) 1882 nm d) 1648 nm

133. The activity of a radioactive substance is R_1 at time t_1 and R_2 at time $t_2 (> t_1)$. Its decay constant is λ. Then

a) $R_1 t_1$ b) $R_2 = R_1 e^{\lambda(t_1}$ c) $\frac{R_1 - R_2}{t_2 - t_1}$ =constant d) $R_2 = R_1 e^{\lambda(t}$

134. The nuclear radius of a nucleus with nucleon number 16 is 3×10^{-15}m. Then, the nuclear radius of a nucleus with nucleon number 128 is

a) 3×10^{-15} m b) 1.5×10^{-15} m c) 6×10^{-15} m d) 4.5×10^{-15}

135. A heavy nucleus having mass number 200 gets disintegrated into two small fragments of mass numbers 80 and 120. If binding energy per nucleon for parent atom is 6.5 MeV and for daughter nuclei is 7 MeV and 8 MeV, respectively, then the energy released in the decay will be

a) 200 MeV b) −200 Me c) 220 MeV d) 180 MeV

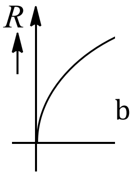
136. Why is a ${}^{4}_{2}$He nucleus stable than a ${}^{4}_{3}$Li nucleus?

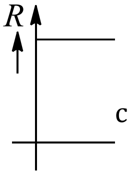
a) The strong nuclear force is larger when the neutron to proton ratio is higher
b) The laws of nuclear physics forbid a nucleus from containing more protons than neutrons
c) Forces other than the strong nuclear force make the lithium nucleus less stable
d) None of the above

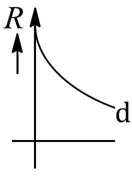
137. The half-life of At is 100 μs. The time taken for the radioactivity of a sample of At to decay to 1/16th of its initial value is

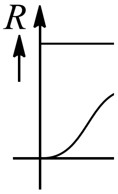
a) 400 μs b) 6.3 μs c) 40 μs d) 300 μs

138. A radioactive nucleus ‘X’ decays to a stable nucleus ‘Y’. Then, time graph of rate of formation of ‘Y’ against time ‘t’ will be:

a) 

b) 

c) 

d) 

139. A radioactive substance is being consumed at a constant rate of 1 s^{-1}. After what time will the number of radioactive nuclei become 100. Initially, there were 200 nuclei present

a) 1 s b) $\frac{1}{\ln(2)}$ s c) ln(2) s d) 2 s

140. A nucleus moving with velocity $\vec{v}$ emits an α-particle. Let the velocities of the α-particle and the remaining nucleus be $\vec{v_1}$ and $\vec{v_2}$ and their masses be m_1 and m_2, then

a) $\vec{v}, \vec{v}_1$ and b) None of c) $\vec{v}_1 + \vec{v}_2$ d) $m_1 \vec{v}_1 +$

$\vec{v}_2$ must be parallel to each other
the two of $\vec{v}, \vec{v}_1$ and $\vec{v}_2$ should be parallel to each other
must be parallel to $\vec{v}$
$m_2\vec{v}_2$ must be parallel to $\vec{v}$

141. Certain radioactive substance reduces to 25% of its value in 16 days. Its half-life is
a) 32 days b) 8 days c) 64 days d) 28 day

142. The half-life of a certain radioactive isotope is 32 h. What fraction of a sample would remain after 16 h?
a) 0.25 b) 0.71 c) 0.29 d) 0.75

143. A helium atom, a hydrogen atom and a neutron have masses of 4.003 u, 1.008 u and 1.009 u (unified atomic mass units), respectively. Assuming that hydrogen atoms and neutrons can fuse to form helium, what is binding energy of a helium nucleus?
a) 2.01 u b) 3.031 u c) 1.017 u d) 0.031 u

144. The rest mass of a deuteron is equivalent to an energy of 1876 MeV, that of a proton to 939 MeV and that of a neutron to 940 MeV
A deuteron may disintegrate to a proton and a neutron if it
a) Emits an X-ray photon of energy 2 MeV
b) Captures an X-ray photon of energy 2 MeV
c) Emits an X-ray photon of energy 3 MeV
d) Captures an X-ray photon of energy 3 MeV

145. The activity of a radioactive element decreases to one-third of the original activity A_0 in a period of 9 years. After a further lapse of 9 years, its activity will be
a) A_0 b) $\frac{2}{3}A_0$ c) $\frac{A_0}{9}$ d) $\frac{A_0}{6}$

146. There are n number of radioactive nuclei in a sample that undergoes beta decay. If from the sample, n' number of β-particles are emitted every 2 s, then half-life of nuclei is
a) $n'/2$ b) $0.693 \times (2n/n')$ c) $0.693\ \ln(/n')$ d) $0.693 \times n/n'$

147. A radioactive nucleus undergoes a series of decays according to the scheme
$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$
If the mass number and atomic number of A are 180 and 72, respectively, then what are these number for A_4?
a) 172 and 69 b) 174 and 70 c) 176 and 69 d) 176 and 70

148. When an atom undergoes β^+ decay,
a) A neutron 'changes into' a proton
b) A proton 'changes into' a neutron
c) A neutron 'changes into' an antiproton
d) A proton 'changes into' an antineutron

149. From a newly formed radioactive substance (Half life 2 $hours$), the intensity of radiation is 64 times the permissible safe level. The minimum time after which work can be done safely from this source is
a) 6 $hours$ b) 12 $hours$ c) 24 $hours$ d) 128 $hour$

150. Stationery nucleus ^{238}U decays by a emission generating a total kinetic energy T:
$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\alpha$
What is the kinetic energy of the α-particle?
a) Slightly less than $T/2$
b) $T/2$
c) Slightly less than T
d) Slightly greater than T

151. A freshly prepared radioactive source of half-life 2 h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is
a) 6 h b) 12 h c) 24 h d) 28 h

152. The fission of a heavy nucleus gives, in general, two smaller nuclei, two or three neutrons, some β-particles, and some γ-radiation. It is always true that the nuclei produced
a) Have a total rest-mass that is greater off the greater part of the original nucleus
b) Have large kinetic energies that carry off the greater part of the energy released
c) Travel in exactly opposite directions
d) Have neutron-to-proton ratios that are too low for stability

153. Fast neutrons can easily be slowed down by
a) The use of lead shieldin
b) Passing them through
c) Elastic collision with
d) Applyin g a strong

g water heavy nuclei electric field

154. The rate of decay of a radioactive element at any instant is 10^3 disintegrations s^{-1}. If the half-life of the elements is 1 s, then the rate of decay after 1 s will be

a) $500\ s^{-1}$ b) $1000\ s^{-1}$ c) $250\ s^{-1}$ d) $2000\ s^{-1}$

155. Which of the following statements is incorrect for nuclear forces?

a) These are strongest in dependent b) They are charge dependent c) They are effective only for short ranges d) They result from interaction of every nucleon with the nearest limited number of nucleons

156. A radioactive nucleus is being produced at a constant rate α per second. Its decay constant is λ. If N_0 are the number of nuclei at time $t = 0$, then maximum number of nuclei possible are

a) $\frac{\alpha}{\lambda}$ b) $N_0\frac{\alpha}{\lambda}$ c) N_0 d) $\frac{\alpha}{\lambda} + N_0$

157. In the nuclear reaction

$_1H^2 + {}_1H^2 \rightarrow {}_2H^3 + {}_0n^1$

If the mass of the deuterium atom $= 2.014741$ a. m. u., mass of $_2He^3$ atom =3.016977 a.m.u. and mass of neutron =1.008987 a.m.u., then the Q value of the reaction is nearly

a) 0.00352 b) 3.27 MeV c) 0.82 MeV d) 2.45 MeV

158. An α-particle of 5 MeV energy strikes with a nucleus of uranium at stationary at an scattering angle of 180°. The nearest distance upto which α-particle reaches the nucleus will be of the order of

a) 1 Å b) $10^{-10} cm$ c) $10^{-12} cm$ d) $10^{-15} cm$

159. A radionuclide A_1 with decay constant λ_1 transform into a radioactive A_2 with decay constant λ_2. Assuming that at the initial moment the preparation contained only the radioactive A_1, then the time interval after which the activity of the radioactive A_2 reaches its maximum value is

a) $\frac{\ln(\lambda_2/\lambda_1)}{\lambda_2 - \lambda_1}$ b) $\frac{\ln(\lambda_1/\lambda_2)}{\lambda_2 - \lambda_1}$ c) $\ln(\lambda_2 - \lambda_1)$ d) None of these

160. Consider one of fission reactions of ^{235}U by thermal neutrons $^{235}_{92}U + n \rightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2n$. The fission fragments are however unstable and they undergo successive β-decay until $^{94}_{38}Sr$ becomes $^{94}_{40}Zr$ and $^{140}_{54}Xe$ becomes $^{140}_{58}Ce$. The energy released in this process is [Given $m(^{235}U) = 235.439$, $m(n) = 1.00866$ u, $m(^{94}Zr) = 93.9064$ u, $m(^{140}Ce) = 139.9055$ u, 1 u = 931 MeV

a) 156 MeV b) 208 MeV c) 456 MeV d) Cannot be computed

161. A free nucleus of mass 24 a. m. u. emits a gamma photon (when initially at rest). The energy of the photon is 7 MeV. The recoil energy of the nucleus in keV is

a) 2.2 b) 1.1 c) 3.1 d) 2.2

162. The half-life of radium is 1500 years. In how many years will 1 g of pure radium be reduced to one centigram?

a) 3.927×10^2 years b) 9.972×10^2 years c) 99.927×10^2 years d) 0.927×10^2 years

163. If the Q value of an endothermic reaction is 11.32 MeV, then the minimum energy of the reactant nuclei to carry out the reaction is (in laboratory frame of reference)

a) 11.32 Me b) Less than 11.32 Me c) Greater than 11.32 Me d) Data is insufficient

164. If a nucleus such ^{226}Ra that is initially at rest undergoes alpha decay, then which of the following statements is true?

a) The alpha particle has more kinetic energy than the daughter nucleus b) The alpha particle has less kinetic energy than the daughter nucleus c) The alpha particle and daughter nucleus both have same kinetic energy d) We cannot say anything about kinetic energy of alpha particle and daughter nucleus

165. Two radioactive materials X_1 and X_2 have

decay constants 10λ 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 of X_2 will be $1/e$ after a time

a) $\frac{1}{10\lambda}$ b) $\frac{1}{11\lambda}$ c) $\frac{11}{10\lambda}$ d) $\frac{1}{9\lambda}$

166. On an average, a neutron loses half of its energy per collision with a quasi-free proton. To reduce a 2 MeV neutron to a thermal neutron having energy 0.04 eV, the number of collisions required is nearly

a) 50 b) 52 c) 26 d) 15

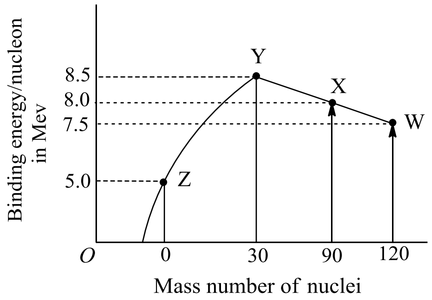
167. A container is filled with a radioactive substance for which the half-life is 2 days. A week later, when the container is opened, it contains 5 g of the substance. Approximately how many grams of the substances were initially placed in the container?

a) 40 b) 60 c) 80 d) 100

168. In a sample of a radioactive substance, what fraction of the initial nuclei will remain undecayed after a time $t = T/2$, where $T =$ half-life of radioactive substance?

a) $\frac{1}{\sqrt{2}}$ b) $\frac{1}{2\sqrt{2}}$ c) $\frac{1}{4}$ d) $\frac{1}{\sqrt{2}-1}$

169. Binding energy per nucleon vs. mass number curve for nuclei is shown in W,X,Y and Z are four nuclei indicated on the curve. The process that would release energy is



a) $Y \rightarrow 2Z$ b) $W \rightarrow X + Z$ c) $W \rightarrow 2Y$ d) $X \rightarrow Y + Z$

170. A certain radioactive element has half-life of 4 days. The fraction of material that decays in 2 days is

a) $1/2$ b) $1/\sqrt{2}$ c) $\sqrt{2}$ d) $(\sqrt{2} - 1)/\sqrt{2}$

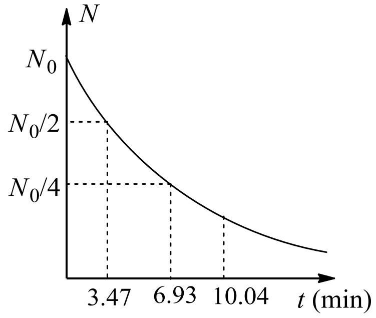
171. The half-life of a radioactive decay is x times its mean life. The value of x is

a) 0.3010 b) 0.6930 c) 0.6020 d) $\frac{1}{0.6930}$

172. The half-life of radium is 1620 years and its atomic weight is 226. The number of atoms that will decay from its 1 g sample per second will be

a) 3.6×10^{10} b) 3.6×10^{12} c) 3.1×10^{15} d) 31.1×10^{15}

173. A radioactive sample undergoes decay as per the following graph. At time $t = 0$, the number of undecayed nuclei is N_0. Calculate the number of nuclei left after 1 h



a) N_0/e^8 b) N_0/e^{10} c) N_0/e^{12} d) N_0/e^{14}

Multiple Correct Answers Type

174. Let m_p be the mass of proton, m_n the mass of a neutron, M_1 the mass of a $^{20}_{10}$Ne nucleus and M_2 the mass of a $^{40}_{20}$Ca nucleus. Then,

a) $M_2 = 2M_1$ b) $M_2 > 2M_1$ c) $M_2 < 2M_1$ d) $M_1 < 10(m_p + m_p)$

175. Mark out the correct statement(s)

a) In both fission and fusion processes, the mass of reactant nuclide is greater than the mass of product nuclide
b) In fission process, BE per nucleon of reactant nuclide is less than the binding energy per nucleon of product nuclide
c) In fusion process, BE per nucleon of reactant nuclide is less than the binding energy per nucleon of product nuclide
d) In fusion process, BE per nucleon of reactant nuclide is greater than the binding energy per nucleon of product nuclide

176. An electron in hydrogen atom first jumps from second excited state to first excited state and then from first excited state to ground state. Let the ratio of wavelength, momentum and energy of photons emitted in these two cases be a, b and c respectively. Then

a) $a = \frac{9}{4}$ b) $b = \frac{5}{27}$ c) $c = 5/27$ d) $c = \frac{1}{a}$

177. For a certain radioactive substance, it is observed that after 4 h, only 6.25% of the original sample is left undecayed. If follows that`1

a) The half-life of the sample is 1 h
b) The mean life of the sample is $\frac{1}{\ln 2}$ h
c) The decay constant of the sample is in $\ln(2)\mathrm{h}^{-1}$
d) After a further 4 h, the amount of the substance left over would by only 0.39% of the original amount

178. In Bohr's model of the hydrogen atom

a) The radius of the n^{th} orbit is proportional to n^2
b) The total energy of the electron in n^{th} orbit is inversely proportional to n
c) The angular momentum of electron in an n^{th} orbit is an integral multiple of $\frac{h}{2\pi}$
d) The magnitude of potential energy of the electron in any orbit is greater than its kinetic energy

179. The phenomenon of nuclear fission can be carried out both in a controlled and in an uncontrolled way. Out of the following the correct statements vis-à-vis these phenomena are:

a) The fission energy released per reaction is much more than conventional nuclear reactions and one of the products of the reaction is that very particle which initiates the reaction
b) It is the 'surface to volume' ratio of the sample of nuclear fuel used which determines whether or not the reaction would sustain itself as a 'chain reaction'
c) The 'control rods' in a nuclear reactor must be made of a material that absorbs neutrons effectively
d) The energy released per fission as well as energy released per unit mass of the fuel in nuclear fission are both greater than the corresponding quantities for nuclear fusion

180. A radioactive substance emits

a) Electromagnetic radiation
b) Electrons revolving around the nucleus
c) Charged particles
d) Neutral particles

181. During β-decay (beta minus), the emission of antineutrino particle is supported by which of the following statement(s)?

a) Angular momentum conservation holds good in any nuclear reaction
b) Linear momentum conservation holds good in any nuclear reaction
c) The KE of emitted β-particle is varying continuously to a maximum value
d) None of the above

182. A radioactive sample has initial concentration N_0 of nuclei. Then,

a) The number of undecayed nuclei present in the sample decays exponentially with time
b) The activity (R) of the sample at any instant is directly proportional to the number of undecayed nuclei present
c) The number of decayed nuclei grows exponentially with time
d) The number of decayed nuclei grows linearly with time

in the sample at that time

183. From the following equations, pick out the possible nuclear fusion reaction:

a) $_6C^{13} + {}_1H^1 \rightarrow {}_6C^{14} + 4.3$ Me

b) $_6C^{12} + {}_1H^1 \rightarrow {}_7C^{13} + 2$ MeV

c) $_7C^{14} + {}_1H^1 \rightarrow {}_8O^{15} + 7.3$ Me

d) $_{92}U^{235} + {}_0n^1 \rightarrow {}_{54}Xe^{1} + {}_{38}Sr^{94} + {}_0n^1 + {}_0n^1 + y + 200$ M

184. Two samples A and B of same radioactive nuclide are prepared. Sample A has twice the initial activity of sample B. For this situation, mark out the correct statement(s)

a) The half-lives of both the samples would be same

b) The half-lives of the samples are different

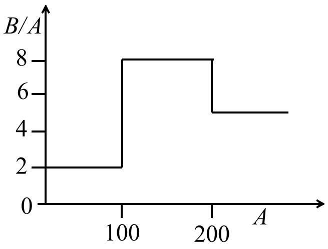
c) After each has passed through 5 half-lives, the ratio of activity of A to B is 2:1

d) After each has passed through 5 half-lives, ratio of activities of A to B is 64:1

185. An O^{16} nucleus is spherical and has a radius R and a volume $V = \frac{4}{3}\pi R^3$. According to the empirical observations, the volume of the $_{54}X^{128}$ nucleus assumed to be spherical is V' and radius is R'. Then

a) $V' = 8V$ b) $V' = 2V$ c) $R' = 2R$ d) $R' = 8R$

186. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure. Use this plot to choose the correct choice(s) given below



a) Fusion of two nuclei with mass numbers lying in the range of $1 < A < 50$ will release energy

b) Fusion of two nuclei with mass numbers lying in the range of $51 < A < 100$ will release energy

c) Fission of a nucleus lying in the mass range of $100 < A < 200$ will release energy when broken into two equal fragments

d) Fission of a nucleus lying in the mass range of $200 < A < 260$ will release energy when broken into two equal fragments

187. It has been found that nuclides with 2, 8, 20, 50, 82, and 126 protons or neutrons are exceptionally stable. These numbers are referred to as the magic numbers and their existence has led us to

a) The idea of periodicity in nuclear properties similar to the periodicity of chemical elements in periodic table

b) The so-called 'liquid drop model of the nucleus'

c) The so-called 'shell model of the nucleus'

d) Have a convenient explanation of 'nuclear fission'

188. Which of the following statement(s) is (are) correct?

a) The rest mass of a stable nucleus is greater than the sum of the rest masses of its separated nucleons

b) The rest mass of a stable nucleus is greater than the sum of the rest masses of its separated nucleons

c) In nuclear fission, energy is released by fusing two nuclei of medium mass (approximately 100 a. m. u.)

d) In nuclear fission, energy is released by fragmentation of a very heavy nucleus

189. Mark out the correct statement (s)

a) Higher binding

b) If the binding

c) Binding energy

d) Binding energy

energy per nucleon means the nucleus is more stable	energy of nucleus were zero, then it would spontaneously break apart	of a nucleus can be negative	of a nucleus is always positive

190. Which of the following isotopes is used for treatment for cancer?

a) K^{40} b) Co^{60} c) Sr^{90} d) I^{131}

191. Choose the correct statements from the following:

a)	b)	c)	d)
Like other light nuclei, the $_2He^4$ nuclei also have a low value of the binding energy per nucleon	The binding energy per nucleon decreases for nuclei with small as well as large atomic number	The energy required to remove one neutron from $_3Li^7$ to transform it into the isotope $_3Li^6$ is 5.6 MeV, which is the same as the binding energy per nucleon of $_3Li^6$	When two deuterium nuclei fuse together, they give rise to a tritium nucleus accompanied by a release of energy

192. A nuclide A undergoes α-decay and another nuclide B undergoes β-decay. Then,

a)	b)	c)	d)
All of the α-particles emitted by A will have almost the same speed	The α-particles emitted by B will have widely different speeds	All the β-particles emitted by B will have almost the same speed	The β-particles emitted by B may have widely different speeds

193. Atomic weight of Boron is 10.81 and it has two isotopes $_5B^{10}$ and $_5B^{11}$. Then the ratio would be

a) 19: 81 b) 10: 11 c) 15: 16 d) 81: 12

194. In an electron transition inside a hydrogen atom, orbital angular momentum may change by (h =Planck constant)

a) h b) $\frac{h}{\pi}$ c) $\frac{h}{2\pi}$ d) $\frac{h}{4\pi}$

195. Mark out the correct statement(s)

a)	b)	c)	d)
In alpha decay, the energy released is shared between alpha particle and daughter nucleus in the form of kinetic energy and share of alpha particle is more than that of the daughter nucleus	In beta decay, the energy released is in the form of kinetic energy of beta particles	In beta minus decay, the energy released is shared between electron and antineutrino	In gamma decay, the energy released is in the form of energy carried by photons termed as gamma rays

196. If A, Z and N denote the mass number, the atomic number, and the neutron number for a given nucleus, we can say that

a)	b)	c)	d)
$N = Z + A$	Isobars have the same A but different Z and N	Isotopes have the same Z but different N and A	Isotopes have the same N but different A and Z

197. In a nuclear reactor

a)	b)	c)	d)
The chain	The thick	Heavy water	Out of U^{238} and

reaction is kept under control by rods of cadmium, which reduces the rate	concrete shield is used to slow down the speed of fast neutrons	(or graphite) moderate the activity of the reactor	U^{235} natural uranium has less than 1% of U^{235}

198. The decay constant of a radioactive substance is 0.173 year^{-1}. Therefore,

a) Nearly 63% of the radioactive substance will decay in (1/0.173)year
b) Half-life of the radioactive substance is (1/0.173)year
c) One-fourth of the radioactive substance will be left after 8 years
d) All of the above

199. It is observed that only 0.39% of the original radioactive sample remains undecayed after eight hours. Hence

a) The half-life of that substance is 1 h
b) The mean-life of the substance is [1/(log 2)] h
c) Decay constant of the substance is (log 2)h^{-1}
d) If the number of radioactive nuclei of this substance at a given instant is 10, then the number left after 30 min would be 7.5

200. Mark the correct statement(s)

a) For an exothermic reaction, if Q value is +12.56 MeV and the KE of incident particle is 2.44 MeV, then the total KE of products of reaction is 15.00 MeV
b) For an exothermic reaction, if Q value is +12.56 MeV and the KE of incident particle is 2.44 MeV, then the total KE of products of reaction is 12.56 MeV
c) For an endothermic reaction, if we give the energy equal to $|Q|$ value of reaction, then the reaction will be carried out
d) For an exothermic reaction, the BE per nucleon of products should be greater than the BE per nucleon of reactants

201. The energy, the magnitude of linear momentum and orbital radius of an electron in a hydrogen atom corresponding to the quantum number n are E, P and $r$respectively. Then according to Bohr's theory of hydrogen atom,

a) $P\,r$ is proportional to n
b) P/E is proportional to n
c) Er is constant for all orbits
d) EPr is proportional to $1/n$

Assertion - Reasoning Type

This section contain(s) 0 question(s) numbered 202 to 201. Each question contains STATEMENT 1(Assertion) and STATEMENT 2(Reason). Each question has the 4 choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

a) Statement 1 is True, Statement 2 is True; Statement 2 **is** correct explanation for Statement 1
b) Statement 1 is True, Statement 2 is True; Statement 2 **is not** correct explanation for Statement 1
c) Statement 1 is True, Statement 2 is False
d) Statement 1 is False, Statement 2 is True

202

Statement 1: Neutrons penetrate matter more readily as compared to protons

Statement 2: Neutrons are slightly more massive than protons

203

Statement 1: According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic

Statement 2: According to electromagnetic theory an accelerated particle continuously emits radiation

204

Statement 1: Balmer series lies in the visible region of electromagnetic spectrum.

Statement 2: $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$, where $n = 3, 4, 5$

205

Statement 1: The ionizing power of β-particle is less compared to α-particles but their penetrating power is more

Statement 2: The mass of β-particle is less than the mass of α-particle

206

Statement 1: It is not possible to use ^{35}Cl as the fuel for fusion energy

Statement 2: The binding energy of ^{35}Cl is too small

207

Statement 1: Hydrogen atom consists of only one electron but its emission spectrum has many lines

Statement 2: Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found

208

Statement 1: 1 amu is equivalent to 931 MeV.

Statement 2: Energy equivalent (E) or mass (m) is $E = mc^2$

209

Statement 1: Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate

Statement 2: According to classical physics all moving electrons radiate

210

Statement 1: On a decay, daughter nucleus shifts two places to the left from the parent nucleus.

Statement 2: An alpha particle carries four units of mass.

211

Statement 1: The binding energy per nucleon, for nuclei with atomic mass number $A > 100$, decreases with A

Statement 2: The nuclear forces are weak for heavier nuclei

212

Statement 1: Light nuclei are most stable if $N = Z$, while heavy nuclei are more stable if $N > Z$. [$N \rightarrow$ number of neutrons, $Z \rightarrow$ number of protons]

Statement 2: As the number of protons increases in a nucleus, the Coulomb's repulsive, force increases, which tends to break the nucleus apart. So, to keep the nucleus stable, more number of neutrons are needed which are neutral in nature

213

Statement 1: $_{Z}X^{4}$ undergoes 2 α-decays, 2 β-decays (negative β) and 2 γ-decays. As a result, the daughter product is $_{Z-2}Y^{A-B}$

Statement 2: In α-decay, the mass number decreases by 4 unit and atomic number decreases by 2 unit. In β-decay (negative β), the mass number remains unchanged and atomic number increases by 1 unit. In γ-decay, mass number and atomic number remain unchanged

214

Statement 1: Isobars are the element having same mass number but different atomic number

Statement 2: Neutrons and protons are present inside nucleus

215

Statement 1: Density of all the nuclei is same

Statement 2: Radius of nucleus is directly proportional to the cube root of mass number

216

Statement 1: Electron capture occurs more often than positron emission in heavy elements

Statement 2: Heavy elements exhibit radioactivity

217

Statement 1: The ionisation potential of hydrogen to be 13.6 eV, the ionised potential of doubly ionized lithium is 122.4 eV.

Statement 2: Energy in nth state of hydrogen atom is $E_n = -\frac{13.6}{n^2}$

218

Statement 1: Heavy nuclides tend to have more number of neutrons than protons

Statement 2: In heavy nuclei, as there is coloumbic repulsion between protons, so excess of neutrons are preferable

219

Statement 1: All nuclei are not of same size

Statement 2: Size depends on atomic mass

220

Statement 1: The mass of β-particles when they are emitted is higher than the mass of electrons obtained by other mean

Statement 2: β-particle and electron, both are similar particles

221

Statement 1: Cobalt-60 is useful in cancer therapy

Statement 2: Cobalt-60 is source of γ-radiations capable of killing cancerous cell

222

Statement 1: $4{}_1^1\text{H} \rightarrow {}_2^4\text{He}^{2+} + 2e^{+} +$ 26 MeV,represents fusion.

Statement 2: The above case is a β −decay.

223

Statement 1: The fission of a heavy nucleus is always accompanied with the neutrons along with two product nuclei

Statement 2: For a lighter stable nuclide, the $\frac{N}{Z}$ ratio has to be slightly greater than 1

224

Statement 1: Radioactive nuclei emits β^{-1} particles

Statement 2: Electrons exist inside the nucleus

225

Statement 1: A certain radioactive substance has a half-life period of 30 days. Its disintegration constant is 0.0231 day $^{-1}$

Statement 2: The decay constant is related with half-life $\lambda = \frac{0.6931}{T}$

226

Statement 1: ${}_{38}\text{Sr}^{90}$ from the radioactive fall out from a nuclear bomb ends up in the bones of human beings through the milk consumed by them. It causes impairment of the production of red blood cells

Statement 2: The energy β −particle emitted in the decay of ${}^{90}\text{Sr}$ damage to bone marrow

227

Statement 1: The ratio of time taken for light emission from an atom to that for release of nuclear energy in fission is 1 : 100.

Statement 2: Time taken of the light emission from an atom is of the order of 10^{-8}s.

228

Statement 1: Electrons in the atom are held due to coulomb forces

Statement 2: The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force

229

Statement 1: Amongst alpha, beta and gamma rays, α-particle has maximum penetrating power

Statement 2: The alpha particle is heavier than beta and gamma rays

230

Statement 1: Radioactivity of 10^8 undecayed radioactive nuclei of half life of 50 days is equal to that of 1.2×10^8 number of undecayed nuclei of some other material with half life of 60 days

Statement 2: Radioactivity is proportional to half-life

231

Statement 1: The positively charged nucleus of an atom has a radius of almost $10^{-15} m$

Statement 2: In α-particle scattering experiment, the distance of closest approach for α-particles is $\simeq 10^{-15} m$

232

Statement 1: ^{90}Sr from the radioactive fall out from a nuclear bomb ends up in the bones of human beings through the milk consumed by them. It causes impairment of the production of red blood cells.

Statement 2: The energetic β −particles emitted in the decay of ^{90}Sr damage the bone marrow.

233

Statement 1: In alpha decay of different radioactive nuclides, the energy of alpha particles has been compared. It is found that as the energy of alpha particle increases the half-life of the decay goes on decreasing

Statement 2: More is the energy in any decay process, more is the probability of decaying the nuclide which leads to faster rate of decay

234

Statement 1: (A) Fission of $^{235}_{92}$U is brought about by thermal neutron, whereas that of $^{238}_{92}$U is brought about by a fast neutron.

Statement 2: $^{235}_{92}$Uis an even-odd nucleus, whereas $^{238}_{92}$U is an even-even nucleus.

235

Statement 1: For the scattering of α-particles at large angles, only the nucleus of the atom is responsible

Statement 2: Nucleus is very heavy in comparison to electrons

236

Statement 1: The mass of a nucleus can be either less than or more than the sum of the masses of nucleons present in it

Statement 2: The whole mass of the atom is considered in the nucleus

237

Statement 1: The amount of energy required to remove an average nucleon from different nuclei having different mass numbers is approximately the same, while to remove an average electron from atoms having different mass numbers widely varying amounts of energies are required

Statement 2: Nucleons in a nucleus are bounded by short-range nuclear force while in a electrons in an atom are bounded by long-range Coulomb's forces

238

Statement 1: The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law

Statement 2: Rutherford did α-particle scattering experiment

239

Statement 1: Half-life of a certain radioactive element is 100 days. After 200 days, fraction left undecayed will be 50%

Statement 2: $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$, where symbols have usual meaning.

240

Statement 1: A nucleus having energyE_1 decays be β^- emission to daughter nucleus having energy E_2, but the β^- rays are emitted with a continuous energy spectrum having end point energy $E_1 - E_2$.

Statement 2: To conserve energy and momentum in $\beta -$ decay at least three particles must take part in the transformation.

241 This question contains statements I and statements II of the four choices given after the statements, choose the one that best describes the two statements.

Statement 1: Energy is released when heavy nuclei undergo fission of light nuclei undergo fusion.

Statement 2: For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z.

242

Statement 1: The nucleus $^A_Z X$ is having atomic mass as well as its mass number as A

Statement 2: Mass number of an element is an integer that specifies an isotope and has no units, while atomic mass is generally not an integer

243

Statement 1: To determine the age of certain very old organic samples, dating of the sample with radioactive isotopes having larger half-life is a better choice than with radioactive isotopes having smaller half-lives

Statement 2: The activity of a radioactive sample having smaller half-life is negligibly small after a very long time and hence makes it next to impossible to get detected

244

Statement 1: ${}_Z X^A$undergoes 2α $-$decays, 2β $-$decays and 2γ $-$decays and the daughter product is ${}_{Z-2}Y^{A-8}$

Statement 2: In α-decay the mass number decreases by 4 and atomic number decrease by 2. In β-decay the mass number remains unchanged, but atomic number increases by 1 only

245

Statement 1: Energy is released in nuclear fission

Statement 2: Total binding energy of the fission fragments is larger than the total binding energy of the parent nucleus

246

Statement 1: If the half-life of a radioactive substance is 40 days then 25% substance decays in 20 days

Statement 2: $N = N_0 = \left(\frac{1}{2}\right)^n$ where $n = \frac{\text{Time elapsed}}{\text{half−life period}}$

Matrix-Match Type

This section contain(s) 0 questions. Each question contains Statements given in 2 columns which have to be matched. Statements in **columns I** have to be matched with Statements in **columns II**.

247. Column II gives certain systems undergoing a process. Column I suggests changes in some of the parameters related to the system. Match the statements in Column I to the appropriate process(es) from Column II

	Column-I		**Column- II**
(A)	The energy of the system is increased	(p)	System : A capacitor, initially unchanged Process : It is connected to a battery
(B)	Mechanical energy is provided to the system, which is converted into energy of random motion of its parts	(q)	System : A gas in an adiabatic container fitted with an adiabatic piston Process : The gas is compressed by pushing the piston
(C)	Internal energy of the system is converted into its mechanical energy	(r)	System : A gas in rigid container Process : The gas gets cooled due to colder atmosphere surrounding it
(D)	Mass of the system is decreased	(s)	System : A heavy nucleus, initially at rest Process : The nucleus fissions into two fragments of nearly equal masses and some neutrons are emitted
		(t)	System : A resistive wire loop Process : The loop is placed in a time varying magnetic field perpendicular to its plane

Codes :

	A	**B**	**C**	**D**
(a)	P,q,s, t	q	s	s
(b)	q	s	s	p,q,s,t
(c)	s	q	p,q,s,t	s
(d)	s	p,q,s,t	q	s

248. In Column I consider each process just before and just after it occurs. Initial system is isolated from all other bodies. Consider all product particles (even those having rest mass zero) in the system. Match the system in Column I with the result they produce in Column II:

	Column-I		**Column- II**
(A)	Spontaneous radioactive decay of a uranium nucleus initially at rest as given by reaction $^{238}_{92}\mathrm{U} \to {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He} + \cdots$	(p)	Number of proton is increased
(B)	Fusion reaction of two hydrogen nuclei as given by reaction $^{1}_{1}\mathrm{H} \to {}^{1}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} + \cdots$	(q)	Momentum is conserved
(C)	Fission of U^{235} nucleus initiated by a thermal neutron as given by reaction $^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \to {}^{144}_{56}\mathrm{Ba} + {}^{89}_{36}\mathrm{K} + 3\,{}^{1}_{0}\mathrm{n} + \cdots$	(r)	Mass is converted to energy or vice versa
(D)	β-decay (negative beta decay)	(s)	Charge is conserved

Codes :

	A	**B**	**C**	**D**
(a)	P,r,s	r,s	p,s	s,p
(b)	r,s	p,s	s,p	s,r

(c)	q,r,s	q,r,s	q,r,s	p,r,s
(d)	p,s	p,r,s	r,s	q,r,s

249. In Column I some of the nuclear reactions are given. Match this with the energy involved in these reactions in Column II

Column-I	**Column- II**
(A) ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + \mathrm{E}_1$	(p) 3.3 MeV
(B) ${}^{3}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \mathrm{E}_2$	(q) 18.3 MeV
(C) ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \mathrm{E}_3$	(r) 4 MeV
(D) ${}^{3}_{2}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{1}\mathrm{H} + \mathrm{E}_4$	(s) 17.6 MeV
	(t) 200 MeV

Codes :

	A	**B**	**C**	**D**
(a)	p	q	r	s
(b)	s	p	q	r
(c)	q	r	s	p
(d)	r	s	p	q

250. Four physical quantities are given in Column I and their order of values in Column II. Match approximately

Column-I	**Column- II**
(A) Thermal energy of air molecules at room temperature	(p) 0. 02 eV
(B) Binding energy of heavy nuclei per nucleon	(q) 2 eV
(C) X-ray photon energy	(r) 10 KeV
(D) Photon energy of visible light	(s) 7 MeV

Codes :

	A	**B**	**C**	**D**
(a)	p	s	r	q
(b)	s	r	q	p
(c)	r	q	p	s
(d)	q	p	s	r

251.

Column-I	**Column- II**
(A) Stability of nucleus decided by	(p) $-$ve
(B) Four radioactive substance spontaneously decays because its	(q) Binding energy per nucleon is minimum
(C) For the stable orbit or bound orbit, total energy is	(r) Neutron-proton ratio
(D) Stopping potential	(s) Packing fraction
	(t) Mass defect

Codes :

	A	**B**	**C**	**D**
(a)	R,s	s,t	q	t,r
(b)	r,s,t	q	p	p
(c)	q	t,r	s,t	r,s,t
(d)	t,r	r,s,t	p,	q

252.

Column-I	**Column- II**
(A) Nuclear fusion	(p) Satisfies $E = mc^2$
(B) Nuclear fission	(q) Generally possible for nuclei with low atomic number
(C) β-decay	(r) Generally possible for nuclei with higher atomic number and unstable
(D) Exothermic nuclear reaction	(s) Essentially proceeds by weak nuclear forces
	(t) Significant momentum conservation

Codes :

	A	B	C	D
(a)	P,r	s	q,s	p,q,t
(b)	s	q,s	p,q,t	p,r
(c)	p,q,t	p,r,	s	q,s
(d)	q,s	p,q,t	p,r	s

253.

Column-I	**Column- II**
(A) Photoelectric effect	(p) Photon
(B) Wave	(q) Frequency
(C) X-rays	(r) K capture
(D) Nucleus	(s) γ-rays

Codes :

	A	B	C	D
(a)	q	r	s	p
(b)	r	s	p	q
(c)	s	q	p	r
(d)	p	q	r	s

254.

Column-I	**Column- II**
(A) Binding energy per nucleon for middle order of element is	(p) Shell model
(B) Nuclear force depends on	(q) 8.8 MeV
(C) For nuclear fission, $\frac{Z^2}{A}$ is	(r) 2.5 ev
(D) Magic numbers 2, 8, 20, 28, 50, 82, 126 are explained by	(s) Spin of nucleons
	(t) Greater than 15

Codes :

	A	B	C	D
(a)	p	s	t	p
(b)	s	t	p	p
(c)	t	p	p	s
(d)	p	t	s	p

255. Match the Column I of properties with Column II of reactions

Column-I	**Column- II**
(A) Mass of products formed is less than the original mass of the system in	(p) α-decay
(B) Binding energy per nucleon increase in	(q) β-decay
(C) Mass number is conserved in	(r) Nuclear fission
(D) Charge number is conserved in	(s) Nuclear fusion

Codes :

	A	B	C	D
(a)	P,q,r	r,s	q,s	p,s
(b)	p,q,r, s	p,q,r,s	p,q,r,s	p,q,r,s
(c)	p,q	q,s	p,s	q,p
(d)	q,s	p,s	p,q	r,s

Linked Comprehension Type

This section contain(s)0 paragraphs. Based upon each paragraph, multiple choice questions have to be answered. Each question has at least 4 choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

Paragraph for Question Nos. 256 - 255

According to Bohr's theory of hydrogen atom, electrons revolve around the nucleus in stationary orbits. The radius of stationery orbits $r \propto n^2$. Velocity of electron in stationary orbits $v \propto \frac{1}{n}$ and total energy of electron in stationary orbits $-E \propto$

$\frac{1}{n^2}$. Energy emitted when an electron jumps from outer orbit n_2 to inner $n_1$is,

$hv = E_2 - E_1 = Rhc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

where R =Rydberg constant

$= 1.097 \times 10^7 \mathrm{m}^{-1}$

256. Total energy of electron in first stationary orbit of hydrogen atom is -13.6 eV. The energy in second stationery orbit would be

a) 13.6 eV b) 8.6 eV c) -13.6 eV d) -3.4 eV

Paragraph for Question Nos. 257 - 257

Atomic number (Z) of an element is the number of protons present in the nucleus of an atom of the element.Mass number (A) is total number of protons and neutrons present in the nucleus of the atom of the element. The size of nucleus is given by $R = R_0 A^{1/3}$,where R_0 =a constant

$= 1.2 \times 10^{-15}$m. Nuclear density ρ = $\frac{3m}{4\pi R_0^3}$ =constant

$= 2.29 \times 10^{77} \mathrm{kgm}^{-3}$

257. Number of neutrons in a gold nucleus with $A = 197$ and $Z = 79$ is

a) 79 b) 197 c) 118 d) None of these

Paragraph for Question Nos. 258 - 258

Nuclei of a radioactive element X are being produced at a constant rate K and this element decays to a stable nucleus Y with a decay constant λ and half-life $T_{1/2}$. At time $t = 0$, there are N_0 nuclei of the element X

258. The number N_{X} of nuclei of X at time $t = T_{1/2}$ is

a) $\frac{K + \lambda N_0}{2\lambda}$ b) $(2\lambda N_0 - \mathrm{K})\frac{1}{\lambda}$ c) $\left[\lambda N_0 + \frac{K}{2}\right]\frac{1}{\lambda}$ d) Data insufficient

Paragraph for Question Nos. 259 - 259

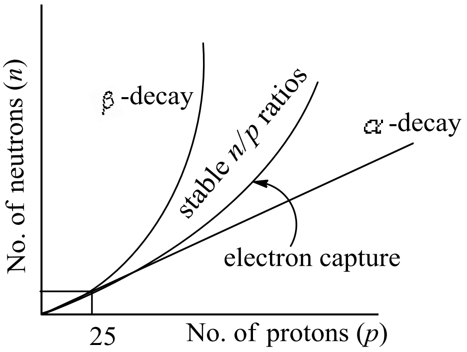
A radionuclide with decay constant λ is being produced in a nuclear reactor at a rate $q_0 t$ per second, where q_0 is a positive constant and t is the time. During each decay, E_0 energy is released. The production of radionuclide starts at time $t = 0$

259. Which differential equation correctly represents the above process?

a) $\frac{dN}{dt} + \lambda N = q_0 t$ b) $\frac{dN}{dt} - \lambda N = q_0 t$ c) $\frac{dN}{dt} + q_0 t = \lambda N$ d) $\frac{dN}{dt} + q_0 t = -\lambda N$

Paragraph for Question Nos. 260 - 260

Various rules of thumb have been proposed by the scientific community to explain the mode of radioactive decay by various radioisotopes. One of the major rules is called the n/p ratio. If all the known isotopes of the elements are plotted on a graph of number of neutrons (n) versus number of protons (p), it is observed that all isotopes lying outside of a ‘stable’ n/p ratio region are radioactive as shown in



The graph exhibits straight line behavior with unit slope up to $p = 25$. Above $p = 25$, those isotopes with an n/p ratio lying below the stable region usually undergo electron capture while those with n/p ratios lying above the stable region usually undergo beta decay. Very heavy isotopes $(p > 83)$ are unstable because of their relatively large nuclei and they undergo alpha decay. Gamma ray emission does not involve the release of a particle. It represents a change in an atom from a higher energy level to a lower energy level

260. How would the radioisotope of magnesium with atomic mass 27 undergo radioactive decay?

a) Electron capture b) Alpha decay c) Beta decay d) Gamma ray emission

Paragraph for Question Nos. 261 - 261

The radionuclide ^{56}Mn is being produced in a cyclotron at a constant rate P by bombarding a manganese target with deuterons. ^{56}Mn has a half-life of 2.5 h and the target contains large number of only the stable manganese isotopes ^{56}Mn. The reaction that produces ^{56}Mn is

$^{56}\mathrm{Mn} + \mathrm{d} \rightarrow {}^{56}\mathrm{Mn} + \mathrm{p}$

After being bombarded for a long time, the activity of ^{56}Mn becomes constant, equal to $13.86 \times 10^{10} \text{s}^{-1}$. (Use $\ln 2 = 0.693$; Avagardo number $= 6 \times 10^{2}$; atomic weight of $^{56}\text{Mn} = 56 \text{ g mol}^{-1}$.)

261. At what constant rate P, ^{56}Mn nuclei are being produced in the cyclotron during the bombardment?

a) 2×10^{11} n
b) 13.86×10^{10} n
c) 9.6×10^{10} n
d) 6.93×10^{10} n

Paragraph for Question Nos. 262 - 262

Many unstable nuclei can decay spontaneously to a nucleus of lower mass but different combination of nucleons. The process of spontaneous emission of radiation is called radioactivity. Three types of radiations are emitted by radioactive substance Radioactive decay is a statistical process. Radioactivity is independent of all external conditions

The number of decays per unit time or decay rate is called activity. Activity exponentially decreases with time. Mean lifetime is always greater than half-life time

262. Choose the correct statement about radioactivity:

a) Radioactivity is a statistical process
b) Radioactivity is independent of high temperature and high pressure
c) When a nucleus undergoes α- or β-decay, its atomic number changes
d) All of these

Paragraph for Question Nos. 263 - 263

All nuclei consist of two types of particles-protons and neutrons. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron-proton ratio or mass defect or binding energy per nucleus or packing fraction. Shape of nucleus is calculated by quadrupole moment. Spin of nucleus depends on even or odd mass number. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centered at the nucleus. Magnetic moment of the nucleus is measured in terms of the nuclear magnetons

263. The correct statements about nuclear force is/are

a) Charge independent
b) Short-range force
c) Non-conservative force
d) Spin-dependent force

Paragraph for Question Nos. 264 - 264

When subatomic particles undergo reactions, energy is conserved, but mass is not necessarily conserved. However, a particle's mass 'contributes' to its total energy, in accordance with Einstein's famous equation, $E = mc^2$

In this equation, E denotes the energy a particle carries because of its mass. The particle can also have additional energy due to its motion and its interaction with order particles

Consider a neutron at rest, and well separated from other particles. It decays into a proton, an electron, and an undetected third particle:

Neutron → proton + electron+???

The table below summarizes some data from a single neutron decay. An MeV (mega electron volt) is a unit energy. Column 2 shows the rest mass of the particle times the speed of light squared

Particle	**Mass $\times$ c^2(MeV)**	**Kinetic energy (MeV)**
Neutron	940.97	0.00
Proton	939.67	0.01
electron	0.51	0.39

264. Assuming the table contains no major errors, what can we conclude about the (mass × c^2) of the undetected third particle?

a) It is 0.79 MeV
b) It is 0.39 MeV
c) It is less than or equal to 0.79 MeV; but we cannot be more precise
d) It is less than or equal to 0.39 MeV; but we cannot be more precise

Paragraph for Question Nos. 265 - 265

The compound unstable nucleus $^{236}_{92}\text{U}$ often decays in accordance with the following reaction:

$^{236}_{92}\text{U} \rightarrow {}^{140}_{54}\text{Xe} + {}^{94}_{38}\text{Sr} +$ other particles

During the reaction, the uranium nucleus 'fission' (splits) into the two smaller nuclei. The reaction is energetically favorable because the small nuclei have higher nuclear binding energy per nucleon

(although the lighter nuclei have lower total nuclear binding energies, because they contain fewer nucleons)
Inside a nucleus, the nucleons (protons and neutrons) attract each other with a 'strong nuclear' force. All nucleons exert approximately the same strong nuclear force on each other. This force holds the nucleus together. Importantly, the strong nuclear force becomes important only when the protons and neutrons are very close together at intranuclear distances

265. In the nuclear reaction presented above, the 'other particles' might be

a) An alpha particle, which consists of two protons and neutrons
b) Two protons
c) One proton and one neutron
d) Two neutrons

Paragraph for Question Nos. 266 - 266

A beam of alpha particles is incident on a target of lead. A particular alpha particle comes in 'head-on' to a particular lead nucleus and stops 6.50×10^{-14} m away from the center of the nucleus.(The point is well outside the nucleus.) Assuming that the lead nucleus, which has 82 protons, remains at rest. The mass of alpha particle is 6.64×10^{-27}kg

266. Calculate the electrostatic potential energy at the instant when the alpha particle stops?

a) 36.3 MeV
b) 45.0 MeV
c) 3.63 MeV
d) 40.0 MeV

Paragraph for Question Nos. 267 - 267

A nucleus, kept at rest in free space, break up into two smaller nuclei of masses m and $2m$. Total energy generated in this fission is E. The bigger part is radioactive, emits five gamma ray photons in the direction opposite to its velocity, and finally comes to rest. Now, answer the following questions: (given:$h = 6.6 \times 10^{-34}$ J s, $m = 1.00 \times 10^{-26}$kg, $E = 3.63 \times 10^{-8}$mc^2, $c = 3 \times 10^8$ ms^{-1}

267. Fractional loss of mass in the fission is

a) 1.21×10^{-8}
b) 2.56×10^{-8}
c) 1.73×10^{-8}
d) 3.52×10^{-8}

Paragraph for Question Nos. 268 - 268

The results of activity measurements on a radioactive sample are given in the table below.

Time (h)	Decays (s^{-1})
0	20000
0.5	14800
1.0	11000
1.5	8130
2.0	6020
2.5	4460
3.0	3300
4.0	1810
5.0	1000
6.0	550
7.0	300

268. The half-life of the radioactive nuclei is nearly ($\ln 2 = 0.693, \ln 3 = 1.0986$)

a) 2.5 h
b) 7 h
c) 5 h
d) 1.2 h

Paragraph for Question Nos. 269 - 269

Scientists are working hard to develop nuclear fusion reactor. Nuclei of heavy hydrogen, ${}_1^2H$, known as deuteron and denoted by D, can be thought of as a candidate for fusion reactor. The D-D reaction is ${}_1^2H + {}_1^2H \rightarrow {}_2^3He + n +$ energy. In the core of fusion reactor, a gas of heavy hydrogen is fully ionized into deuteron nuclei and electrons. This collection of ${}_1^2H$ nuclei and electrons is known as plasma. The nuclei move randomly in the reactor core and occasionally come close enough for nuclear fusion to take place. Usually, the temperatures in the reactor core are too high and no material wall can be used to confine the plasma. Special techniques are used which confine the plasma for a time t_0 before the particles fly away from the core. If n is the density (number/volume) of deuterons, the product nt_0 is called Lawson number. In one of the criteria, a reactor is termed successful if Lawson number is greater than $5 \times 10^{14} s/cm^3$. It may be helpful to use the following : Boltzmann constant $k = 8.6 \times 10^{-5} eV/K; e^2 = 1.44 \times 10^{-9}\ eVm$

269. In the core of nuclear fusion reactor, the gas becomes plasma because of

a) Strong nuclear force acting between the deutero
b) Coulomb force acting between the deuterons
c) Coulomb force acting between deuterons-electron
d) The high temperature maintained inside the

ns	pairs	reactor core

Paragraph for Question Nos. 270 - 270

When a particle is restricted to move along x-axis between $x = 0$ and $x = a$, where a is nanometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus, the energy of the particle can be denoted by a quantum number n' taking values 1, 2, 3, …… ($n = 1$, called the ground state) corresponding to the number of loops in the standing wave.

Use the model described above to answer the following three questions for a particle moving in the line $x = 0$ to $x = a$.

Take $h = 6.6 \times 10^{-34} J\ s$ and $e = 1.6 \times 10^{-19} C$

270. The allowed energy for the particle for a particular value of n is proportional to

a) a^{-2} b) $a^{-3/2}$ c) a^{-1} d) a^2

Paragraph for Question Nos. 271 - 271

In a mixture of $H - He^+$ gas (He^+ is singly ionized He atom), H atoms and He^+ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He^+ ions (by collisions). Assume that the Bohr model of atom is exactly valid

271. The quantum number n of the state finally populated in He^+ ions is

a) 2 b) 3 c) 4 d) 5

Paragraph for Question Nos. 272 - 272

The key feature of Bohr's theory of spectrum of hydrogen atom is the quantization of angular momentum when an electron is revolving around a proton. We will extend this to a general rotational motion to find quantized rotational energy of a diatomic molecule assuming it to be rigid. The rule to be applied is Bohr's quantization condition

272. A diatomic molecule has moment of inertia I. By Bohr's quantization condition its rotational energy in the n^{th} level ($n = 0$ is not allowed) is

a) $\frac{1}{n^2}\left(\frac{h^2}{8\pi^2 I}\right)$ b) $\frac{1}{n}\left(\frac{h^2}{8\pi^2 I}\right)$ c) $n\left(\frac{h^2}{8\pi^2 I}\right)$ d) $n^2\left(\frac{h^2}{8\pi^2 I}\right.$

Paragraph for Question Nos. 273 - 273

The β-decay process, discovered around 1900, is basically the decay of a neutron (n), in the laboratory, a proton (p) and an electron (e^-) are observed as the decay products of the neutron therefore, considering the decay of a neutron as a two-body decay process, it was predicted theoretically that the kinetic energy of the electron should be a constant. But experimentally, it was observed that the electron kinetic energy has a continuous spectrum. Considering a three-body decay process, $i.e. n \rightarrow p + e^- + \bar{\nu}_e$, around 1930, Pauli explained the observed electron energy spectrum. Assuming the anti-neutrino ($\bar{\nu}_e$) to be massless and possessing negligible energy, and neutron to be at rest, momentum and energy conservation principles are applied. From this calculation, the maximum kinetic energy of the electron is $0.8 \times 10^6 eV$. The kinetic energy carried by the proton is only the recoil energy

273. What is the maximum energy of the anti-neutrino

a) Zero b) Much less than $0.8 \times 10^6 eV$ c) Nearly $0.8 \times 10^6 eV$ d) Much larger than $0.8 \times 10^6 eV$

Integer Answer Type

: ANSWER KEY :

1)	d	2)	c	3)	c	4)	a
5)	b	6)	c	7)	b	8)	b
9)	b	10)	b	11)	d	12)	c
13)	a	14)	b	15)	b	16)	a
17)	b	18)	c	19)	c	20)	c
21)	c	22)	d	23)	d	24)	b
25)	a	26)	d	27)	d	28)	c
29)	b	30)	a	31)	c	32)	a
33)	d	34)	b	35)	d	36)	d
37)	b	38)	b	39)	d	40)	b
41)	c	42)	c	43)	c	44)	d
45)	a	46)	c	47)	d	48)	b
49)	a	50)	d	51)	c	52)	a
53)	d	54)	b	55)	d	56)	b
57)	c	58)	a	59)	b	60)	d
61)	d	62)	a	63)	b	64)	a
65)	d	66)	c	67)	a	68)	c
69)	c	70)	c	71)	d	72)	c
73)	d	74)	a	75)	c	76)	a
77)	b	78)	c	79)	c	80)	d
81)	c	82)	c	83)	c	84)	d
85)	d	86)	a	87)	b	88)	d
89)	a	90)	b	91)	c	92)	b
93)	c	94)	b	95)	c	96)	a
97)	a	98)	a	99)	b	100)	a
101)	b	102)	c	103)	b	104)	d
105)	a	106)	b	107)	d	108)	d
109)	b	110)	a	111)	b	112)	d
113)	b	114)	c	115)	a	116)	d
117)	a	118)	a	119)	a	120)	a
121)	c	122)	a	123)	b	124)	a
125)	c	126)	c	127)	b	128)	b
129)	b	130)	b	131)	a	132)	b
133)	b	134)	c	135)	c	136)	c
137)	a	138)	c	139)	c	140)	d
141)	b	142)	b	143)	d	144)	d
145)	c	146)	b	147)	a	148)	b
149)	b	150)	c	151)	b	152)	b
153)	b	154)	a	155)	b	156)	a
157)	b	158)	c	159)	d	160)	b
161)	b	162)	b	163)	c	164)	a
165)	d	166)	c	167)	c	168)	a
169)	c	170)	d	171)	b	172)	a
173)	c	174)	c,d	175)	a,b,c	176)	a,c,d
177)	a,b,c,d	178)	a,c,d	179)	a,b,c	180)	a,c

181)	a,b,c	182)	a,b,c	183)	a,b,c	184)	a,c
185)	a,c	186)	b,d	187)	a,c	188)	a,d
189)	a,b,d	190)	b	191)	b,c	192)	a,d
193)	a	194)	b,c	195)	a,c,d	196)	b,c,d
197)	a,d	198)	a,c	199)	a,b,c	200)	a,d
201)	a,b,c,d	202)	b	203)	e	204)	a
205)	b	206)	c	207)	b	208)	a
209)	b	210)	a	211)	c	212)	a
213)	a	214)	b	215)	a	216)	b
217)	a	218)	a	219)	a	220)	b
221)	a	222)	c	223)	a	224)	c
225)	a	226)	a	227)	b	228)	c
229)	e	230)	c	231)	a	232)	b
233)	a	234)	b	235)	a	236)	e
237)	a	238)	b	239)	d	240)	c
241)	a	242)	d	243)	a	244)	a
245)	b	246)	d	247)	a	248)	c
249)	d	250)	a	251)	b	252)	c
253)	d	254)	a	255)	b	256)	d
257)	c	258)	a	259)	a	260)	c
261)	b	262)	d	263)	a,b,c,d	264)	d
265)	d	266)	c	267)	a	268)	d
269)	d	270)	a	271)	c	272)	d
273)	c	274)	4	275)	0	276)	8
277)	2	278)	2	279)	7	280)	1
281)	6	282)	6				

: HINTS AND SOLUTIONS :

Single Correct Answer Type

1 **(d)**

$R_1 = N_1\lambda, R_2 = N_2\lambda$

Also,

$T = \frac{\log_e 2}{\lambda}$ or $\lambda = \frac{\log_e 2}{T}$

$\therefore R_1 - R_2 = (N_1 - N_2)\lambda$

$= (N_1 - N_2)\frac{\log_e 2}{T}$

$\therefore \ (N_1 - N_2) = \frac{(R_1 - R_2)T}{\log_e 2}$

i.e., $(N_1 - N_2) \propto (R_1 - R_2)T$

2 **(c)**

$\left(T_{1/2}\right)_x = (t_{\text{mean}})_y$

$\Rightarrow \frac{0.693}{\lambda_x} = \frac{1}{\lambda_y} \Rightarrow \lambda_x = 0.693\lambda_y$ or $\lambda_x < \lambda_y$

Also rate of decay $= \lambda N$

Initially number of atoms (N) of both are equal but since $\lambda_y > \lambda_x$, therefore, y will decay at a faster rate than x

3 **(c)**

${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_1\text{He}^4 + \text{Q}$

$\Delta m = m({}_2\text{He}^4) - 2m\ ({}_1\text{H}^2)$

$\Delta m = 4.0024 - 2(2.0141)$

$\Delta m = -0.0258$ u

Now, $Q = c^2\Delta m$

Or $= (0.0258)(931.5)$MeV

Or ≈ 24 MeV

4 **(a)**

Both the beta rays and the cathode rays are made up of electrons. So, only option (a) is correct

Gamma rays are electromagnetic waves

Alpha particles are doubly ionized helium atoms

Protons and neutrons have approximately the same mass

Therefore, (b), (c) and (d) are wrong options

5 **(b)**

90% of the sample is left undecayed after time t

$\therefore \frac{9}{10}N_0 = N_0 e^{-\lambda t}$

$\lambda = \frac{1}{t}\ln\left(\frac{10}{9}\right)$ (i)

After time $2t$,

$N_c = N_0 e^{-\lambda(2t)} = N_0 e^{-\frac{1}{t}\left[\ln\left(\frac{10}{9}\right)\right]2t}$ (ii)

$N = N_0 e^{-\ln\left(\frac{10}{9}\right)^2} = N_0\left(\frac{9}{10}\right)^2 \approx 81\%$ of N_0 (iii)

Therefore, 19% of initial value will decay in time $2t$

6 **(c)**

Energy is released in a process when total binding energy (B.E.) of the nucleus is increased or we can say when total $B.E.$ of products is more than the reactants. By calculation we can see that only in case of option (c), this happens

Given $W \rightarrow 2Y$

$B.E.$ of reactants $= 120 \times 7.5 = 900\ MeV$

and $B.E.$ of products $= 2 \times (60 \times 8.5) = 1020\ MeV$

$i.e., B.E.$ of products $> B.E.$ of reactants

7 **(b)**

During fusion, binding energy of daughter nucleus is always greater than the total binding energy of the parent nuclei. The difference of binding energies is released. Hence,

$Q = E_2 - 2E_1$

8 **(b)**

Here $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{1/3}$

Where $n =$ Number of half lives $= \frac{1}{3}$

$\Rightarrow \frac{N}{N_0} = \frac{1}{1.26} \Rightarrow \frac{N_U}{N_{Pb} + N_U} = \frac{1}{1.26}$

$\Rightarrow N_{Pb} = 0.26\ N_U \Rightarrow \frac{N_{Pb}}{N_U} = 0.26$

9 **(b)**

Number of atoms in 2 kg fuel

$\frac{2}{235} = 6.02 \times 10^{26} = 5.12 \times 10^{24}$

Fission rate = Number of atoms fissioned in one second

$= \frac{5.12 \times 10^{24}}{30 \times 24 \times 60 \times 60}$

$= 1.975 \times 10^{18}\text{s}^{-1}$

Each fission gives 185 MeV. Hence, energy obtained in one second,

$P = 185 \times 1.975 \times 10^{18}\text{MeV s}^{-1}$

$= 185 \times 1.975 \times 10^{18} \times 1.6 \times 10^{-19}\text{J s}^{-1}$

10 **(b)**

According to Doppler's effect of light, the wavelength shift is given by

$\Delta\lambda = \frac{V}{c} \times \lambda$

$\Rightarrow V = \frac{\Delta\lambda \times c}{\lambda} = \frac{(706 - 656)}{656} \times 3 \times 10^8$

$= 2 \times 10^7\text{m s}^{-1}$

11 **(d)**

Activity reduces from 6000dps to 3000dps in 140 days. It implies that half-life of the radioactive sample is 140 days. In 280 days (or two half-lives)activity will remain $\frac{1}{4}$th of the initial activity . Hence the initial activity of the sample is

$$4 \times 6000 \text{ dps} = 24000 \text{ dps}$$

12 **(c)**

Total binding energy of helium atom ($_2\mathrm{He}^4$) is

$4 \times 7 = 28$ MeV

Total binding energy of deuteron $_1\mathrm{H}^2(1\mathrm{p} + 1\mathrm{n})$ is

$2 \times 1.1 = 2.2$ MeV

Hence, binding energy of 2 deuterons is

$2 \times 2.2 = 4.4$ MeV

So, the energy released in forming helium nucleus from two deuterons is

$28 - 4.4$ MeV $= 23.6$ MeV

13 **(a)**

Rest mass of parent nucleus should be greater than the rest mass of daughter nuclei.

14 **(b)**

Activity of a radioactive substance,

$R = \lambda N$

$\therefore \ \lambda = \frac{R}{N}$

Here, $R = N_2$ particles per second and $N = N_1$

$\therefore \ \lambda = \frac{N_2}{N_1}$

15 **(b)**

The total energy required to make the electron free from nucleus is the sum of the energy required to separate the electrons from the influence of each other and the energy required to separate the electrons from the influence of nucleus i.e.,

Total required energy = BE of electron in He atom + ionization energy of He atom

$= (24.6 + 13.6 \times 2^2)\mathrm{eV}$

$= (24.6 + 54.4)\mathrm{eV} = 79$ eV

16 **(a)**

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

$^{A-4}_{Z-2}\mathrm{Y} \rightarrow e^+ + \ ^{A-4}_{Z-3}\mathrm{Y}'$

During β^+ emission

$_{\mathrm{T}}\mathrm{p}^1 \rightarrow \ _0\mathrm{n}^1 + \beta^+$

The proton changes into neutron. So, charge number decreases by 1 but mass number remains unchanged

17 **(b)**

Nuclear density of an atom of mass number A,

$$D = \frac{\text{mass}}{\text{volume}} = \frac{A(1.67 \times 10^{-27})}{\frac{4}{3}\pi[1.25 \times 10^{-15}\ A^{1/3}]^3}$$

$$\left[\because V = \frac{4}{3}\pi R^3, R = R_0 A^{1/3}, R_0 = 1.25 \times 10^{-15}\right]$$

$\therefore D = 2 \times 10^{17}$ kg m^{-3}

18 **(c)**

$(t_{1/2})_{\mathrm{x}} = (t_{\mathrm{mean}})_{\mathrm{y}}$

$\frac{0.693}{\lambda_x} = \frac{1}{\lambda_y}$

$\lambda_x = 0.693\ \lambda_y$

$\lambda_{\mathrm{x}} < \lambda_{\mathrm{y}}$

Or Rate of decay $= \lambda N$

Initially, number of atoms (N) of both are equal but since $\lambda_{\mathrm{y}} < \lambda_{\mathrm{x}}$, therefore, Y will decay at a faster rate than X

19 **(c)**

Decay constant, $\lambda = 10^{-6}\ \mathrm{s}^{-1}$. The half-life $T_{1/2}$ is thus given by

$T_{1/2} = \frac{0.639}{\lambda} = \frac{0.639}{10^{-6}} = 0.693 \times 10^6$ s

$= 192.5$ h ≈ 8 days $= 1.14$ week

≈ 1 week

20 **(c)**

The net reaction is

$3(\,^2_1\mathrm{H}) \rightarrow \ ^4_2\mathrm{He} + \mathrm{n} + \mathrm{p}$

$$Q = [3 \times m(\,^2\mathrm{H}) + m(\,^4\mathrm{He}) - m(\mathrm{n}) - m(\mathrm{p})] \times 931 \text{ MeV}$$

$= 3.87 \times 10^{-12}$ J

This is energy produced by the consumption of 3 deuteron atoms. So, the total energy released by 10^{40} deuteron is

$\frac{3.87 \times 10^{-12}}{3} \times 10^{40} = 1.29 \times 10^{28}$ J

Let total supply of deuteron in star be exhausted in t seconds. Then,

$10^{16} \times t = 1.29 \times 10^{28}$

$\Rightarrow t = 1.29 \times 10^{12}$ s

21 **(c)**

A and B can be isotopes if number of β-decays is two times the number of α-decays

22 **(d)**

$E = -Z^2 \times 13.6\ eV = -9 \times 13.6\ eV = -122.4\ eV$

So ionization energy $= +122.4\ eV$

23 **(d)**

The mass defect for ^{64}Zn is more than that for ^{64}Cu. So, Zn is more stable. Therefore, ^{64}Cu is radioactive and will decay to ^{64}Zn through β^--decay as follows

$^{29}_{64}\mathrm{Cu} \ \rightarrow \ ^{64}_{30}\mathrm{Zn} \ \rightarrow \ ^{0}_{-1}\mathrm{e}$

Alternative solution:

By the conservation of charge and nucleons, only potential is feasible

24 **(b)**

The difference in the binding energies is the energy required to add an extra neutron

25 **(a)**

Given that $\lambda_1 N_1 = 5\mu Ci;\ \lambda_2 N_2 = 10\mu Ci;\ \lambda_2 N_2 = 2\lambda_1 N_1$

Also $N_1 = 2N_2$; Then $\lambda_2 N_2 = 2\lambda_1(2N_2) \Rightarrow \lambda_2 = 4\lambda_1$

26 **(d)**

$$\left|\frac{dN}{dt}\right| = \lambda N$$

Number of radium nuclei in m g $= \frac{N_A m}{226}$

Decay constant, $\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{1620 \times 3.16 \times 10^7}$

$$\left|\frac{dN}{dt}\right| = 10 = \frac{6.02 \times 10^{23} m}{226} \times \frac{0.693}{1620 \times 3.16 \times 10^7}$$

$$\therefore m = \frac{10 \times 226 \times 1620 \times 3.16 \times 10^7}{6.02 \times 10^{23} \times 0.693}$$

$= 2.77 \times 10^{-10}$g

$= 2.77 \times 10^{-13}$ kg

27 **(d)**

Atomic mass $M(\mathrm{H})$ of hydrogen and nuclear mass (M_n) are

$M(\mathrm{H}) = 1.007825$ u and $M_\mathrm{n} = 1.008665$ u

Mass defect,

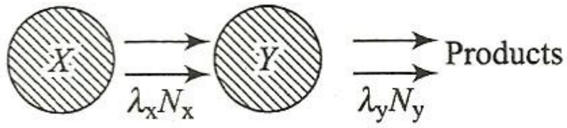
$\Delta m = [M(\mathrm{H}) + M_\mathrm{n} - M(\mathrm{D})]$

$M(\mathrm{D})$ = mass of deuteron $= 2.016490$ u $-$ 2.014102 u $= 0.002388$ u

As 1 u corresponds to 931.494 MeV energy, therefore, mass defect corresponds to energy,

$E_\mathrm{b} = 0.002388 \times 931.5 = 2.224$ MeV

28 **(c)**



Net rate of formation of Y at any time t is

$$\frac{dN_y}{dt} = \lambda_x N_x - \lambda_y N_y$$

N_y is maximum when

$$\frac{dN_y}{dt} = 0$$

Or $\lambda_x N_x = \lambda_y N_y$

29 **(b)**

Once the neutron gets sufficiently close to the nucleus, the strong nuclear force sucks it in. Same happens with the proton except it is electrostatically repelled by the six protons already inside the carbon nucleus. The repulsion prevents a 100 ms^{-1} proton from getting close enough to the nucleus. Therefore, the answer is (b)

30 **(a)**

$\left|\frac{dN}{dt}\right|$ = |Activity of radioactive substance|

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

Taking log both sides

$$\ln\left|\frac{dN}{dt}\right| = \ln(\lambda N_0) - \lambda t$$

Hence, $\ln\left|\frac{dN}{dt}\right|$ *versus* t graph is a straight line with slope-λ.

From the graph we can see that,

$$\lambda = \frac{1}{2} = 0.5\ yr^{-1}$$

Now applying the equation

$$N = N_0\, e^{-\lambda t} = N_0\, e^{-0.5 \times 4.16}$$
$$= N_0 e^{-2.08} = 0.125\, N_0$$
$$= \frac{N_0}{8}$$

ie, nuclei decreases by a factor of 8.

Hence the answer is 8.

31 **(c)**

The given reactions are

${}_1\mathrm{H}^2 + {}_1\mathrm{H}^2 \rightarrow {}_1\mathrm{H}^3 + \mathrm{p}$

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

$3\ {}_1\mathrm{H}^2 \rightarrow {}_2\mathrm{He}^4 + \mathrm{n} + \mathrm{p}$

Mass defect,

$\Delta m = (3 \times 2.014 - 4.001 - 1.007 - 1.008)$ a.m.u.

$= 0.026$ a.m.u.

Energy released $= 0.026 \times 931$ MeV

$= 0.026 \times 931 \times 1.6 \times 10^{-13}$ J

$= 3.87 \times 10^{-12}$ J

This is the energy produced by the consumption of three deuteron atoms. Therefore, total energy released by 10^{40} deuterons is

$$\frac{10^{40}}{3} \times 3.87 \times 10^{-12}\ \mathrm{J} = 1.29 \times 10^{28}\ \mathrm{J}$$

The average power radiated is $P = 10^6$ W or 10^{16} J s^{-1}

Therefore, total time to exhaust all deuteron of the star will be

$$t = \frac{1.29 \times 10^{28}}{10^{16}} = 1.29 \times 10^{12}\ \mathrm{s} \approx 10^{12}\ \mathrm{s}$$

32 **(a)**

$$N = \frac{N_0}{2^{t/T}}$$

$$\frac{N_0}{16} = \frac{N_0}{2^{t/T}}$$

$2^{t/T} = 16 = 2^4$ or $\frac{t}{T} = 4$

Or $T = \frac{t}{T} = \frac{24}{4}$ h $= 6$ h

33 **(d)**

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

For di-ionised lithium the value of Z is maximum

34 **(b)**

After a time t, a sample ^{238}U originally consisting of N atoms will have decayed to $Ne^{-\lambda t}$. The number of ^{206}Pb atoms,

$$N_{\text{Pb}} = N(1 - e^{-\lambda t})$$

$$\therefore \frac{N_{\text{Pb}}}{N_{\text{u}}} = N\frac{(1 - e^{-\lambda t})}{Ne^{-\lambda t}} = 0.0058$$

$$e^{\lambda t} - 1 = 0.0058 \Rightarrow e^{\lambda t} = 1.0058$$

$$\therefore t = \frac{1}{\lambda}\ln(1.0058) = \frac{(4.5 \times 10^9 \text{years})}{\ln 2}\ln(1.0058)$$

$$= 0.0376 \times 10^9 \text{ years} = 38 \times 10^6 \text{ years}$$

35 **(d)**

X has activity A_0 at $t = 0$ and its half-life is 24 years

Y has activity A_0 at $t = 0$ and its half-life is 16 years

At $t = 48$ years, activity of X $= \frac{1}{4}\text{A}_0$

(2 half-lives have elapsed)

At $t = 48$ years, activity of $Y = \frac{1}{8}A_0$

(3 half-lives have elapsed)

Thus, total activity of the mixtures of X and Y at $t = 48$ years is

$$\frac{1}{4}A_0 + \frac{1}{8}A_0 = \frac{3}{8}A_0$$

36 **(d)**

$$R_1 = \lambda N_1 \Rightarrow N_1 = \frac{R_1}{\lambda}$$

and $R_2 = \lambda N_2 \Rightarrow N_2 = \frac{R_2}{\lambda}$

Therefore, number of atoms decayed

$$= N_1 - N_2\left(\frac{R_1 - R_2}{\lambda}\right)$$

37 **(b)**

$$^{22}_{10}\text{Ne} \to {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} + {}^{14}_{6}\text{X}$$

The new element X has a atomic number 6.

Therefore, the element is carbon

38 **(b)**

Let ${}^{A}_{Z}X \to {}^{A-4}_{A-2}Y + {}^{4}_{2}\text{He}$

$$K_\alpha = \frac{m_y}{m_y + m_\alpha}Q$$

$$\therefore K_\alpha = \frac{A-4}{A}Q$$

Or $48 = \frac{A-4}{A} \times 50 \Rightarrow A = 100$

39 **(d)**

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

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

$$\lambda t = \log_e \frac{N_0}{N}$$

$$t = \frac{1}{\lambda}\log_e \frac{N_0}{N}$$

$$t \propto \log_e \frac{N_0}{N}$$

$$5 \propto \log_e \frac{100}{90}$$

and $20 \propto \log_e \frac{N_0}{N}$

Dividing,

$$\frac{5}{20} = \frac{\log_{10}\frac{100}{90}}{\log_{10}\frac{N_0}{N}}$$

Or $\log_{10}\frac{N_0}{N} = 4\log_{10}\frac{10}{9}$

Or $\frac{N_0}{N} = \left(\frac{10}{9}\right)^4 \Rightarrow \frac{N}{N_0} = 0.6561$

Percentage of substance decayed is

$(1 - 0.6561) \times 100 = 34.39$

40 **(b)**

Three half-lives of A is equivalent to six half-lives of B

Hence,

$$N_A\left(\frac{1}{2}\right)^3 = N_B\left(\frac{1}{2}\right)^6$$

Or $\frac{N_A}{N_B} = \frac{1}{8}$

41 **(c)**

$4({}_2\text{He}^4) = {}_8\text{O}^{16}$

Mass defect,

$$\Delta m = \{4(4.0026) - 15.9994\} \text{ amu}$$
$$= 0.01 \text{ lamu}$$

$\therefore$ Energy released per oxygen nuclei

$$= (0.011)(931.48) \text{ MeV}$$
$$= 10.24 \text{ MeV}$$

42 **(c)**

We know that

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

For A,

$$N = N_0\left(\frac{1}{2}\right)^{n_A} = N_0\left(\frac{1}{2}\right)^4 = \frac{N_0}{16}$$

$$\left[\because n_A = \frac{t}{T_A} = \frac{80}{20} = 4\right]$$

For B,

$$N_B = N_0\left(\frac{1}{2}\right)^{n_B} = N_0\left(\frac{1}{2}\right)^2 = \frac{N_0}{4}$$

$\therefore \frac{N_A}{N_B} = \frac{1}{4}$ or $N_A : N_B = 1 : 4$

43 **(c)**

Since four half-lives have elapsed

$$A = \frac{A_0}{2^4} = \frac{A_0}{16} = \frac{1.6}{16} \text{ curie} = 0.1 \text{ curie}$$

44 **(d)**

$$\frac{3}{5}N_0 = N_0 e^{-\lambda t}$$

$$\Rightarrow e^{\lambda t} = \frac{5}{3}$$

$\log_e e^{\lambda t} = \log_e \frac{5}{3}$ or $\lambda t = \log_e \frac{5}{3}$

Or $t = \frac{1}{\lambda}\log_e \frac{5}{3}$

$$= \frac{T}{0.693} \times 0.5 \quad \left[\because T = \frac{0.693}{\lambda}\right]$$

$$= \frac{5570 \times 0.5}{0.693} \text{ years} = 4018.7 \text{ years}$$

$= 4000$ years

45 **(a)**

After first half hours,

$$N = N_0 \frac{1}{2}$$

For $t = \frac{1}{2}$h to $t = 1\frac{1}{2}$h, 1 h = four half-lives

Hence, $N = \left(N_0 \frac{1}{2}\right)\left[\frac{1}{2}\right]^4 = N_0\left(\frac{1}{2}\right)^5$

For $t = \frac{1}{2}$ to $t = 2$ h

$$\left[\text{for both A and B}, \frac{1}{t_{1/2}} = \frac{1}{t_{1/2}} + \frac{1}{t_{1/4}} = 2 + 4 = 6 \right.$$
$$\left. \Rightarrow t_{1/2} = \frac{1}{6}\right]$$

$\frac{1}{2}$h= three half-lives

$$\therefore N = \left[\left(N_0 \frac{1}{2}\right)^5\right]\left(\frac{1}{2}\right)^3 = N_0\left(\frac{1}{2}\right)^8$$

46 **(c)**

Let N_2 be the number of atoms of X at time $t = 0$. Then, at $t = 4$ h (two half-lives)

$N_x = \frac{N_0}{4}$ and $N_y = \frac{3N_0}{4}$

$$\therefore \frac{N_x}{N_y} = \frac{1}{3} = 0.33$$

At $t = 6$ h (three half-lives)

$N_x = \frac{N_0}{8}$ and $N_y = \frac{7N_0}{8}$ or $\frac{N_x}{N_y} = \frac{1}{7} \approx 0.142$

The given ratio $\frac{1}{4}$ lies between $\frac{1}{3}$ and $\frac{1}{7}$

Therefore, t lies between 4 h and 6 h

47 **(d)**

Energy released would be

$\Delta E =$ total binding energy of $_2\mathrm{He}^4 - 2 \times$ (total binding energy of $_1\mathrm{He}^4$)

$= 4 \times 7.0 - 2(1.1)(2)$

$= 23.6$ MeV

48 **(b)**

Let ground state energy (in eV) be E_1

Then from the given condition

$$E_{20} - E_1 = 204eV$$

Or $\frac{E_1}{4n^2} - E_1 = 204eV$

$\Rightarrow E_1\left(\frac{1}{4n^2} - 1\right) = 204eV \quad$ ...(i)

and $E_{2n} - E_n = 40.8eV$

$\Rightarrow \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1\left(-\frac{3}{4n^2}\right) = 40.8eV \quad$ ...(ii)

From equation (i) and (ii)

$$\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow n = 2$$

49 **(a)**

At present,

$$\frac{\text{Number of K atoms}}{\text{Number of Ar atom}} = \frac{1}{7}$$

Let age of rock be n half-lives of K-nuclide. Then,

$$\left(\frac{1}{2}\right)^n = \frac{\text{Number of K} - \text{atoms present now}}{\text{Number of K} - \text{atom present initially}}$$
$$= \frac{1}{1+7}$$

Where number of K atoms present initially = number of K atoms + number of Ar atoms present now

$\therefore n = 3$

So, age of rock is 3 half-lives of K nuclides, i.e., 4.2×10^9 years

51 **(c)**

$A = A_0 e^{-\lambda t}; 2100 = 16000\, e^{-12\lambda} \Rightarrow e^{12\lambda} = 7.6$

$$\Rightarrow 12\lambda = \log_e 7.6 = 2 \Rightarrow \lambda = \frac{2}{12} = \frac{1}{6}$$

$$\therefore T = \frac{0.6931 \times 6}{1} = 4$$

52 **(a)**

No radioactive substance emits both α and β particles simultaneously. Some substances emit α −particles and some other emits β −particles, γ −rays are emitted along with both α and β −particles

53 **(d)**

$N_1 = N_0 e^{-\frac{t}{\tau}}$ (i) and $\tau = \frac{1}{\lambda_1}$

$N_2 = N_0 e^{-\lambda_2 t} = N_0 e^{-\frac{1}{5\tau}}$ (ii) and $5\tau = \frac{1}{\lambda_2}$

Adding (i) and (ii), we get

$N = N_1 + N_2 = N_0(e^{-t/\tau} + e^{-t/5\tau})$

1. Is not the correct option as there is a time τ for which N is constant, which means for time τ there is no process of radioactivity which does not makes sense

2. and (c) show intermediate increase in the number of radioactive atoms which is impossible as N will only decrease exponentially. Hence, the correct option is

(d)

54 **(b)**

Number of α-particles emitted $= \frac{232-208}{4} = 6$

Decrease in charge number due to α-emission = 12

But actual decrease in charge number

$= 90 - 82 = 8$

Clearly, four β-particles are emitted

55 **(d)**

Nuclear reactions conserve total charge, and also conserve the total approximate mass. The other particles in the reaction will have mass

$= 236 - 140 - 94 = 2$

The other particles are two neutrons. Hence, (a) is not correct.

For nuclei, number of protons tells the charge. So, the other particles must have charge Z such that

$92 = 54 + 38 + Z$

$\therefore Z = 0$

Therefore, the other particles have a total atomic mass 2 and total charge 0. Hence, only (d) is correct

56 **(b)**

For α decay: ${}_{\mathrm{x}}\mathrm{A}^{\mathrm{y}} \rightarrow {}_{\mathrm{x}-2}\mathrm{B}^{\mathrm{y}-4} + \alpha$

For β^- decay: ${}_{\mathrm{x}}\mathrm{A}^{\mathrm{y}} \rightarrow {}_{\mathrm{x}+1}\mathrm{B}^{\mathrm{y}} + {}_{-1}\beta^0$

For β^+ decay: ${}_{\mathrm{x}}\mathrm{A}^{\mathrm{y}} \rightarrow {}_{\mathrm{x}-1}\mathrm{B}^{\mathrm{y}} + {}_{+1}\beta^0$

For k-capture, there will be no change in the number of protons. Hence, only case in which number of protons increases is β^- decay

57 **(c)**

The penetrating power is dependent on velocity. For a given energy, the velocity of γ-radiation is highest and α-particle is least

58 **(a)**

For $n = 1$, maximum number of states $= 2n^2 = 2$ and for $n = 2, 3, 4$, maximum number of states would be 8, 18, 32 respectively, Hence number of possible elements

$= 2 + 8 + 18 + 32 = 60$

59 **(b)**

$$\frac{A}{A_0} = \frac{N}{N_0}$$

Let safe level activity be A, initial activity $= 64A$

Hence,

$$\frac{N}{N_0} = \frac{A}{A_0} = \frac{A}{64A} = \frac{1}{64}$$

Or $\left(\frac{1}{2}\right)^n = \frac{1}{64}$ or $n = 6$

Hence,

$$\frac{t}{T} = n = 6$$

$\because T = 2$ h

$\therefore t = 12$ h

60 **(d)**

Use mass balance and balance of atomic number

61 **(d)**

$$\frac{9}{16} = \left(\frac{1}{2}\right)^{\frac{t}{T}}$$

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

$$\left(\frac{N}{N_0}\right)^2 = \left(\frac{1}{2}\right)^{t/T} \text{ or } \left(\frac{N}{N_0}\right)^2 = \frac{9}{16}$$

Or $\frac{N}{N_0} = \frac{3}{4}$

Note the special technique used in the problem

62 **(a)**

Penetration power of γ is 100 times of β, while that of β is 100 times of α

63 **(b)**

$P = 10^6$ W

Time = 1 day $= 24 \times 36 \times 10^2$s

Energy produced,

$U = Pt = 10^6 \times 24 \times 36 \times 10^2$ s

$= 24 \times 36 \times 10^8$ J

Energy released per fusion reaction is

20 MeV $= 32 \times 10^{-13}$ J

Energy released per atom of ${}_1\mathrm{H}^2$ is

32×10^{-13}J

Number of ${}_1\mathrm{H}^2$ atoms used is

$$\frac{24 \times 36 \times 10^8}{32 \times 10^{-12}} = 22 \times 10^{21}$$

Mass of 6×10^{23} atoms =2 g

Mass of 27×10^{21} atoms $= \frac{2}{6\times10^{23}} = 27 \times 10^{21} =$ 0.1 g

64 **(a)**

Activity of $S_1 = \frac{1}{2}$ (activity of S_2)

Or $\lambda_1 N_1 = \frac{1}{2}(\lambda_2 N_2)$

Or $\frac{\lambda_1}{\lambda_2} = \frac{N_2}{2N_1}$

Or $\frac{T_1}{T_2} = \frac{2N_1}{N_2}$

Given $N_1 = 2N_2$

$$\therefore \quad \frac{T_1}{T_2} = 4$$

65 **(d)**

For decay (i):

$$Q = [230.033927 - 229.033496 - 1.008665] \times 931.5$$

$= -7.7$ MeV

For decay (ii):

$$Q = [230.033927 - 229.032089 - 1.007825] \times 931.5$$

$$= -5.6 \text{ MeV}$$

As Q is negative for both the decays, so none of the decays is allowed

66 **(c)**

The number of nuclei in 1 kg ^{235}U is

$$N = \frac{N_A}{235} \times (1 \times 10^3)$$

$$N = \frac{6.023 \times 10^{23}}{235} \times 10^3 = 2.56 \times 10^{24} \text{ nuclei}$$

Total energy released is

$$E = N \times 200 \text{ MeV}$$

$$= 5.12 \times 10^{26} \text{MeV}$$

67 **(a)**

Let $t = 0, M_0 = 10$ g

$$t = 2\tau = 2\left(\frac{1}{\lambda}\right)$$

Then,

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

$$= 10\left(\frac{1}{e}\right)^2 = 1.35 \text{ g}$$

68 **(c)**

$$\frac{A}{I_0} = \left(\frac{1}{3}\right)^2 = \frac{1}{9} \text{ or } A = \frac{I_0}{9}$$

69 **(c)**

Following nuclear reaction takes place

$${}_0\text{n}^{-1} \Rightarrow {}_1\text{H}^1 + {}_{-1}\text{e}^0 + \bar{\nu}$$

70 **(c)**

The equation is $O^{17} \rightarrow_0 n^1 + O^{16}$

$\therefore$ Energy required = B.E. of O^{17} − B.E. of O^{16}

$= 17 \times 7.75 - 16 \times 7.97 = 4.23\ MeV$

71 **(d)**

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

Probability $= 1 - \frac{N}{N_0} = 1 - \frac{1}{4} = \frac{3}{4}$

72 **(c)**

$4\,{}_1^1\text{H}^+ \rightarrow {}_2^4\text{He}^{2+} + 2e^- + 26$ MeV represents a fusion reaction

73 **(d)**

If d is the distance of closest approach given, then the angular momentum $= mvd = 10^{-33}$ J s

$$E = \frac{1}{2}mv^2 = 1 \text{ MeV} = 1.6 \times 10^{-13}\text{J}$$

Momentum,

$$p = \sqrt{2m_\text{n}E} = \sqrt{2 \times 1.6 \times 10^{-27} \times 1.6 \times 10^{-13}}$$

$$= 1.6\sqrt{2} \times 10^{-20} \text{ kg m s}^{-1}$$

$$= \frac{1}{1.6\sqrt{2}} \times 10^{-13} = \frac{100}{1.6\sqrt{2}} \text{ fm} = 0.44 \text{ fm}$$

74 **(a)**

$$\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$$

Probabilities of getting α- and β-particles are same. Thus, rates of disintegration are equal

$\therefore\ \lambda_A N_A = \lambda_B N_B$

Or $\frac{N_A}{N_B} = \frac{\lambda_B}{\lambda_A} = 2$

75 **(c)**

The Q value of the first reaction implies that

${}^{14}\text{N} + \text{d} = {}^{15}\text{N} = \text{p} + 8.53$ MeV

Where ^{14}N represents the mass of ^{14}N nucleus in energy units. This can be rearranged to give

${}^{14}\text{N} - {}^{15}\text{N} = \text{p} - \text{d} + 8.53$ MeV

The second reaction similarly implies as

${}^{15}\text{N} - {}^{13}\text{C} = \alpha - \text{d} + 7.58$ MeV

And the third reaction gives

${}^{13}\text{C} - {}^{11}\text{B} = \alpha - \text{d} + 5.16$ MeV

Adding these three equations, we have

${}^{14}\text{N} - {}^{11}\text{B} = \text{p} + 2\alpha - 3\text{d} + 21.27$ MeV

${}^{11}\text{B}(\alpha, \text{n})\,{}^{14}\text{N} = {}^{11}\text{B} - {}^{14}\text{N} + \alpha - \text{n}$

$= 3\text{d} - \alpha - \text{p} - \text{n} - 21.27$ MeV

Now,

$$3\text{d} - \alpha - \text{p} - \text{n} = (3 \times 2.014 - 4.0020 - 1.0078 - 1.0087)\text{a.m.u.}$$

$$= 0.0229\text{a.m.u.}$$

$\therefore Q = (0.0229 \times 931 - 21.27)\text{MeV} = 0.05$ MeV

76 **(a)**

Given, $N_2 = \frac{N_0}{e} = N_0 e^{-\lambda t} \Rightarrow t = \frac{1}{\lambda} = 10$ s

$$\therefore T_{1/2} = \frac{\ln 2}{\lambda} = 0.693 \times 10 \approx 7 \text{ s}$$

77 **(b)**

Power P of fission reactor,

$P = 10^6\text{W} = 10^6 \text{ J s}^{-1}$

Time $= t = 1$ day $= 24 \times 36 \times 10^2$s

Energy produced, $U = Pt$

Or $U = 10^6 \times 24 \times 36 \times 10^2$

$= 24 \times 36 \times 10^8$ J

Energy released per fission of U^{235} is

$200 \text{ MeV} = 32 \times 10^{-12}$J

Number of U^{235} atoms used is

$$\frac{24\times 36\times 10^{8}}{32\times 10^{-12}} = 27\times 10^{20}$$

Mass of 6×10^{23} atoms of $\mathrm{U}^{235} = 235\ \mathrm{g}$

Mass of 27×10^{20} atoms of U^{235} is

$$\left(\frac{235}{6\times 10^{23}}\right)(27\times 10^{20}) = 1.058\ \mathrm{g} = 1\ \mathrm{g}$$

78 **(c)**

Suppose an initial radioactive I decays to a final product F with a half-life $T_{1/2}$

At any time, $N_1 = N_0 e^{-\lambda t}$

$$\frac{N_\mathrm{F}}{N_\mathrm{I}} = \frac{N_0 - N_\mathrm{I}}{N_\mathrm{I}} = \left(\frac{N_0}{N_\mathrm{I}} - 1\right)$$

$$\frac{N_0}{N_\mathrm{I}} = \left(1 + \frac{N_\mathrm{F}}{N_\mathrm{I}}\right) = 1 + 0.5 = 1.5$$

$$e^{\lambda t} = 1.5 \Rightarrow \lambda t = \ln 1.5$$

$$\therefore \frac{T_{1/2}\ln(1.5)}{\ln 2} = 4.5\times 10^{9}\frac{\ln\left(\frac{3}{2}\right)}{\ln 2}\ \text{year}$$

79 **(c)**

Energy equivalent to $_1H^2 = 2\times 1.112 = 2.224\ MeV$

Energy equivalent to $_2He^4 = 4\times 7.047 = 28.188\ MeV$

From the equation, energy released

$= 28.188 - 2\times 2.224 = 23.74\ MeV \approx 24\ MeV$

80 **(d)**

Number of nuclei decreases exponentially,

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

Rate of decay, $-\frac{dN}{dt} = \lambda N$

Therefore, decay process lasts upto $t = \infty$.

Therefore, a given nucleus may decay at any time after $t = 0$

81 **(c)**

Mass defect,

$\Delta m = 2(2.015) - (3.017 + 1.009) = 0.004\ \mathrm{a.m.u.}$

As $1\ \mathrm{a.m.u.} = 931.5\ \mathrm{MeV}/c^2$, energy released will be $0.004\times 931.5\ \mathrm{MeV} = 3.726\ \mathrm{MeV}$

Energy released per deuteron is

$$\frac{3.726}{2} = 1.863\ \mathrm{MeV}$$

Number of molecules in 1 kg deuterons is

$$\frac{6.02\times 10^{26}}{2} = 3.01\times 10^{26}$$

Therefore, energy released per kg of deuterium fusion

$= (3.01\times 10^{26}\times 1.863)$

$= 5.6\times 10^{26}\mathrm{MeV} \approx 9.0\times 10^{13}\ \mathrm{J}$

82 **(c)**

$N_1\lambda_1 = N_2\lambda_2$

$$T = \frac{0.693}{\lambda}$$

Hence,

$$2.8\times 10^{6}\times \frac{0.693}{T_1(\mathrm{U})}$$

$$= 1\times \frac{0.693}{T_2(\mathrm{Ra})}$$

$\therefore T_1(\mathrm{U}) = 1600\times 2.8\times 10^{6}$

$= 4.48\times 10^{9}$ years

$\approx 4.5\times 10^{6}$ years

83 **(c)**

Expected atomic mass of Cu must be less than that of zinc, but it is not so. So, it means Cu is radioactive and unstable and decays to Zn through β-decay

84 **(d)**

Here, $T = 26.8\ \mathrm{min} = 26.8\times 60\ \mathrm{s}$

$\therefore$ Decay constant,

$$\lambda = \frac{0.693}{T} = \frac{0.693}{26.8\times 60}$$

$= 4.32\times 10^{-4}\mathrm{s}^{-1}$

Now, 1 curie is equal to 3.71×10^{10} disintegrations per second $= 3.71\times 10^{10}$

If N be the number of atoms in one curie, then

$$-\frac{dN}{dt} = \lambda N$$

Or $3.71\times 10^{10} = 431\times 10^{-4}\ \mathrm{N}$

$$\therefore N = \frac{3.71\times 10^{10}}{4.31\times 10^{-4}} = 8.607\times 10^{13}$$

Further, atomic weight of RaB = 214 and Avogadro's number $= 6.025\times 10^{23}$

Mass of one atom $= \frac{214}{6.025\times 10^{23}}$

Mass of N atoms $= \left(\frac{214}{6.025\times 10^{23}}\right)\times(8.607\times 10^{13})$

$= 3.064\times 10^{-8}\mathrm{g}$

85 **(d)**

Two protons and two neutrons are lost in an α-decays, so Z and N each decrease by 2. A β^+ decay changes a proton to a neutron, so Z decreased by 1 and N increases by 1. The net result is Z decreases by 3 and N decreases by 1

$${}^{A}_{Z}\mathrm{X} \xrightarrow{\alpha-\text{decay}} {}^{A-4}_{Z-2}\mathrm{Y} \xrightarrow{\beta-\text{decay}} {}^{A-4}_{Z-3}\mathrm{Z}$$

Initially, number of neutrons $N_\mathrm{i} = (A - Z)$

Now, number of neutrons, $N_f = A - 4 - Z + 3 = N_\mathrm{i} - 1$

86 **(a)**

$${}_{92}\mathrm{U}^{238} + {}_{0}\mathrm{n}^{1} \to {}_{92}\mathrm{U}^{239} \to {}_{-1}e^{0} + {}_{9}\mathrm{Np}^{239} \to {}_{-1}e^{0} + {}_{94}\mathrm{Pu}^{239}$$

87 **(b)**

$$\frac{N}{N_0} = \frac{1}{2^{5T/T}}$$

$$\frac{N}{N_0} = \frac{1}{2^5}$$

$$\therefore \frac{N}{N_0} \times 100 = \frac{100}{32} = 3.125$$

88 **(d)**

The α-particle emitting radioactive gas, thoron-220, decays to radium-216 an emits an α-particle. The reaction can be represented by

$${}^{220}_{90}\text{Th} \rightarrow {}^{4}_{2}\text{He} + {}^{216}_{66}\text{Ra}$$

By conservation of momentum, we have momentum of α-particle = momentum of recoiling nucleus Ra

$$\Rightarrow m_\alpha v_\alpha = m_\text{R} v_\text{R}$$

$$\Rightarrow \frac{v_\text{R}}{v_\alpha} = \frac{m_\alpha}{m_\text{R}} = \frac{4}{216} = \frac{1}{54}$$

The kinetic energy of Ra, E_R, is related to the kinetic energy of alpha particle E_α by

$$\frac{E_\text{R}}{E_\alpha} = \frac{\frac{1}{2} m_\text{R} v_\text{R}^2}{\frac{1}{2} m_\alpha v_\alpha^2} = \left(\frac{m_R}{m_\alpha}\right)\left(\frac{v_\text{R}}{m_\alpha}\right)^2 = \left(\frac{m_R}{m_\alpha}\right)\left(\frac{m_\alpha}{m_\text{R}}\right)^2$$

$$= \frac{m_\alpha}{m_\text{R}} = \frac{1}{54}$$

$$\therefore E_R = \frac{E_\alpha}{54}$$

89 **(a)**

Isotopes A and C have same number of protons

90 **(b)**

If the kinetic energy of each particle is k, then

$$2k + 2(0.511 \text{ MeV}) = \frac{hc}{\lambda} = \frac{12.4 \times 10^{-3} \text{MeV Å}}{5 \times 10^{-4} \text{Å}}$$

$$= 24.8 \text{ MeV}$$

$$\Rightarrow k = \frac{24.8 - 1.022}{2} = 11.9 \text{ MeV}$$

91 **(c)**

We know that in a nucleus, neutron converts into proton as follows:

$n \rightarrow \text{p}^+ \rightarrow \text{e}^-$

Thus, decay of neutron is responsible for β-radiation orgination

92 **(b)**

Total mass of the products = 2.0165 a. m. u., which is greater than the mass of the deuteron by 0.0024 a. m. u. The extra mass must be provided by the energy of the photon so that minimum possible frequency must be given by

$$v = \frac{0.0024 \text{ a. m. u.} c^2}{h} (1 \text{ a. m. u.} = 1.66 \times 10^{-27} \text{kg})$$

$$\Rightarrow v = 5.4 \times 10^{20} \text{ Hz}$$

93 **(c)**

Transformation occurs only when the same net energy is released, which is possible only when

$E_2 > 2E_1$

94 **(b)**

Mass of one atom of U^{235} is

235.121420 a. m. u

Mass of neutron = 1.008665 a. m. u.

Sum of the masses of U^{235} and neutron

= 236.130085 = 236.130 a. m. u.

Mass of one atom of U^{236} is

236.123050 a. m. u. = 236.123 a. m. u.

Mass defect = 236.136 − 236.123

= 0.007 a. m. u.

Therefore, energy required to remove one neutron is

0.007 × 931 MeV = 6.517 MeV = 6.5 MeV

95 **(c)**

Binding energy per nucleon of fission products is 8.5 MeV. Binding energy per nucleon of reactants = 7.6 MeV

Increase in binding energy per nucleon is

8.5 − 7.6 = 0.9 MeV

Energy released per nucleon in fission is **0.9** MeV

$\therefore$ Fractional energy released $= \frac{0.9}{931} = \frac{1}{1000}$

Percentage of mass converted into energy during fission

$$= \frac{1}{1000} \times 100 = 0.1\%$$

97 **(a)**

When a free neutron decays to a proton along with an electron and an antineutrino, the Q value of the reaction is positive which means the reaction is possible all by itself, while a free proton cannot convert itself into a neutron due to negative Q value

In beta minus decay, the electron originates from nucleus only, by the transformation of neutron into a proton, with simultaneous emission of an antineutrino

98 **(a)**

Nuclear density is constant hence, mass ∝ volume

Or $m \propto V$

99 **(b)**

$${}^{A}_{Z}X \xrightarrow{\text{Proton}} {}^{A}_{Z-1}Y \xrightarrow{2\alpha} {}^{A-8}_{A-5}Y$$

Given $A - 8 = 224$ and

$Z - 5 = 89 \Rightarrow A = 237, Z = 94$

100 **(a)**

Let $\frac{M_1}{M_2}$ (mass ratio) $= \frac{1}{2}$

2 days = 2 × 24 h= 48 h

For first substance, 4 half-life periods and for second substance 3 half-life periods are passed;

the masses are reduced to

$$M_1' = M_1 \times \left(\frac{1}{2}\right)^4$$

$$M_2' = M_2 \times \left(\frac{1}{2}\right)^3$$

$$\therefore \frac{M_1'}{M_2'} = \frac{M_1}{M_2} \times \frac{1}{2} = \frac{2}{1} \times \frac{1}{2} = \frac{1}{1}$$

102 **(c)**

The binding energy per nucleon is lowest for very light nuclei such as ^4_2He, is greatest around $A = 60$, and then decreases with increasing A

103 **(b)**

Number of α-particles per second = activity $= (-dN/dt) = N\lambda$

Where

$$N = \frac{6.0 \times 10^{23}}{210} \times 1 \times 10^{-3}$$

$$\lambda = 5.8 \times 10^{-8}\text{s}^{-1}$$

So,

$$A = N\lambda$$

$$= \frac{6.0 \times 10^{23}}{210} \times 1 \times 10^{-3} \times 5.8 \times 10^{-8}$$

$$= 1.7 \times 10^{11}$$

104 **(d)**

The emission of antineutrino is a must for the validity of different laws

105 **(a)**

Since scheme A releases more energy than scheme B, scheme A is more likely to occur. This is because the more the energy released, the more stable the daughter nucleus is. A heavy nucleus undergoes fission such that its products will be more stable than the parent nucleus

107 **(d)**

As we regard the decay process as a spontaneous and statistical process, therefore the decay can start any time after $t = 0$. Therefore, the answer is (d)

108 **(d)**

α-decay decreases mass number by 4 and reduces charge number by 2. β-decay keeps mass number unchanged and increases charge by 1. Clearly, option (d) is the right choice

109 **(b)**

For nucleus of $_8\text{O}^{16}$:

Mass = $(16)(1.67 \times 10 - 27)$kg

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

$$= \frac{4}{3}\pi(3 \times 10^{-15})^3\text{m}^3$$

$$= 36\pi \times 10^{-45}\text{m}^3$$

Density $= \frac{\text{mass}}{\text{volume}} = \frac{16 \times 67 \times 10^{-27}\text{kg}}{36\pi \times 10^{-46}\text{m}^3}$

$= 2.35 \times 10^{17}\text{kg m}^{-3}$

110 **(a)**

Let $\lambda_A = \lambda$ and $\lambda_B = 2\lambda$. Initially, rate of disintegration of A is λN_0 and that of B is $2\lambda\, N_0$. After one half-life of A, rate of disntigration of A will become $\frac{\lambda\, N_0}{2}$ (half-life of B = one-half the half-life of A). So, after one half-life of A or two half-lives of B,

$$\left(-\frac{dN}{dt}\right) = \left(-\frac{dN}{dt}\right)_B$$

$$\therefore n = 1$$

111 **(b)**

$$\frac{dN_2}{dt} = \lambda N_1 - 2\lambda N_2$$

For n_2 to be maximum,

$$\frac{dN_2}{dt} = 0$$

$\Rightarrow \lambda N_1 = 2\lambda N_2$ or $\frac{N_1}{N_2} = 2$

112 **(d)**

$$N_{x_1} = N_0 e^{-\lambda t}$$

$$N_{x_2} = N_0 e^{-\lambda t}$$

$$\frac{N_{x_1}}{N_{x_2}} = \frac{1}{e} = \frac{e^{-10\lambda t}}{e^{-\lambda t}} = e^{-9\lambda t}$$

$$9\lambda t = 1 \Rightarrow t = \frac{1}{9\lambda}$$

113 **(b)**

In 2 s only 90% nuclei are left behind. Thus, in next 2 s 90% of 900 or 810 nuclei will be left

114 **(c)**

$m(^{198}\text{Au}_{79}) = 197.968225$ u

$m(^{198}_{79}\text{Hg}) = 197.966752$ u

Mass defect,

$\Delta m = 1.473 \times 10^{-3}\text{u} = 1.371$ MeV

Energy of γ-proton = 0.412 MeV

Maximum kinetic energy of the electron emitted in the decay is

$E_e = 1.371 \text{ MeV} - 0.412 \text{ MeV} = 0.959 \text{ MeV}$

115 **(a)**

From given information,

$$\frac{dN}{dt} = \frac{-0.04N}{3600}$$

Computing above equation with standard decay equation,

$$\frac{dN}{dt} = -\lambda N$$

$$\lambda = 1.1 \times 10^{-5}\text{s}^{-1}$$

$$\therefore \tau = \frac{1}{\lambda} = \frac{3600}{0.04}\text{s} = 25 \text{ h}$$

116 **(d)**

Let the decay constants for the first and second processes be λ_1 and λ_2 and the effective decay constant for the combined process be λ. Then,

$\lambda_1 = \frac{\log_e 2}{t_1}, \lambda_2 = \frac{\log_e 2}{t_2}$ and $\lambda = \frac{\log_e 2}{t}$

Now, the probability for decay through first process in a small time interval dt is $\lambda_1 dt$ and the probability for decay through second process in the same time interval dt is $\lambda_2 dt$. The probability for decay by the combined process in the same time interval dt is $\lambda_1 dt + \lambda_2 dt$

But this is also equal to λdt

$\therefore\ \lambda dt = \lambda_1 dt + \lambda_2 dt$

$\therefore \lambda = \lambda_1 + \lambda_2$

Or $\frac{\log_e 2}{t} = \frac{\log_e 2}{t_1} + \frac{\log_e 2}{t_2}$

Or $\frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2}$ or $t = \frac{t_1 t_2}{t_1 + t_2}$

117 **(a)**

Number of radio nuclei become constant, when rate of production becomes equal to rate of decay, $X = \lambda N$

Or $N = \frac{X}{\lambda}$. Given $y = \frac{\ln 2}{\lambda}$

$$\Rightarrow N = \frac{XY}{\ln(2)}$$

119 **(a)**

$$\frac{dN_A}{dt} = (-\lambda N_A) + (-2\lambda N_A) + (-2\lambda N_A) = -6\lambda N_A$$

120 **(a)**

$$\frac{1}{\lambda_{H_2}} = RZ_H^2\left[\frac{1}{4} - \frac{1}{9}\right] = R(1)^2\left[\frac{5}{36}\right]$$

$$\frac{1}{\lambda_{He}} = RZ_{He}^2\left[\frac{1}{4} - \frac{1}{16}\right] = R(4)\left[\frac{3}{16}\right]$$

$$\frac{\lambda_{He}}{\lambda_{H_2}} = \frac{1}{4}\left[\frac{16}{3} \times \frac{5}{36}\right] = \frac{5}{27}$$

$$\lambda_{He} = \frac{5}{27} \times 6561 = 1215\ \text{Å}$$

121 **(c)**

Activity, $R = \lambda N$. Number of nuclei (N) per mole are equal for both the substances

$\therefore R \propto \lambda$

Or $\frac{R_1}{R_2} = \frac{\lambda_1}{\lambda_2} = \frac{4}{3}$

122 **(a)**

After the removal of first electron remaining atom will be hydrogen like atom

So energy required to remove second electron from the atom $E = 13.6 \times \frac{2^2}{1} = 54.4 eV$

$\therefore$ Total energy required $= 24.6 + 54.4 = 79\ eV$

123 **(b)**

Let number of α-decays are x and number of β-decays are y. Then,

$92 - 2x + y = 85$

Or $2x - y = 7$ (i)

and $238 - 4x = 210$

$\therefore x = 7$

Substituting this value in Eq. (1), we get $y = 7$

124 **(a)**

Probability of survival for any nucleus at time t is

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

So, in one mean life, required probability is

$$e^{-\lambda \times \frac{1}{\lambda}} = \frac{1}{e}$$

125 **(c)**

$$\frac{dN}{dt} = n - \lambda N$$

Because the population N is simultaneously increasing at rate n and decreasing due to decay at rate λN

$$\int_{N_0}^{N} \frac{dN}{n - \lambda N} = \int_0^t dt$$

$$\frac{1}{\lambda}\ln\left(\frac{n - \lambda N_0}{n - \lambda N}\right) = t$$

$$N = \frac{n}{\lambda} + \left(N_0 - \frac{n}{\lambda}\right)e^{-\lambda t}$$

126 **(c)**

β-particles are radioactive material emitted by the nucleus

127 **(b)**

Calculate time when it reaches a height of 1000 m, then use $A = \lambda N$

128 **(b)**

After two half-lives $\frac{1}{4}$ th fraction of nuclei will remain undecayed or $\frac{3}{4}$ th fraction will decay.

Hence , the probability that a nucleus decays in two half-lives is $\frac{3}{4}$.

129 **(b)**

$T_{1/2} = 3.8$ day

$$\therefore\ \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{3.8} = 0.182$$

If the initial number of atoms is $a = A_0$, then after time t the number of atoms is $a/20 = A$. We have to find t

$$t = \frac{2.303}{\lambda}\log\frac{A_0}{A} = \frac{2.303}{0.182}\log\frac{a}{a/20} = \frac{2.303}{0.182}\log 20$$

$= 16.46$ day

130 **(b)**

Decrease in mass number $= 232 - 208 = 24$

Number of α-particles emitted $= \frac{24}{4} = 6$

Due to emission of 6 particles, decrease in charge number is 12. But actual decrease in charge number is 8. Clearly, 4 β-particles are emitted

131 **(a)**

Mass defect,

$\Delta m = 20(1.007277 + 1.00866) - 39.97545$

$= 40.31874 - 39.97545$

$= 0.34329\ \text{a. m. u.}$

$\therefore$ Binding energy $= 0.34329 \times 931 = 319.6$ MeV

When one atom of Ca-40 completely dissociates, the energy to be supplied $= 319.6$ MeV

1 g of Ca-40 contains $\frac{6.023\times10^{23}}{40} = 1.506 \times 10^{22}$ atoms

The energy required for the dissociation of 1 g of Ca-40

$= 319.6 \times 1.506 \times 10^{22}$

$= 4.813 \times 10^{24}$ MeV

132 **(b)**

$$\frac{1}{122nm} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3R}{4}$$

$$\Rightarrow \frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{\infty^2}\right) = \frac{R}{9} \Rightarrow \frac{\lambda}{122} = \frac{3}{4} \times 9 = \frac{27}{4}$$

$\Rightarrow \lambda = 823\ nm$

133 **(b)**

Let R_0 be the initial activity. Then,

$R_1 = R_0 e^{-\lambda t_1}$

and $R_2 = R_0\ e^{-\lambda t_2}$

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

Or $R_2 = R_1 e^{\lambda(t_1 - t_2)}$

134 **(c)**

Radius R of a nucleus changes with the nucleon number A of the nucleus as

$R = 1.3 \times 10^{-15} \times A^{1/3}\text{m}$

Hence,

$$\frac{R_2}{R_1} = \left(\frac{A_2}{A_1}\right)^{1/3} = \left(\frac{128}{16}\right)^{1/3} = (8)^{1/3} = 2$$

$\therefore R_2 = 2R_1 = 2(3 \times 10^{-15})$ m

$= 6 \times 10^{-15}\text{m}$

135 **(c)**

Energy released is

$(80 \times 7 + 120 \times 8 - 200 \times 6.5) = 220$ MeV

136 **(c)**

All neutrons attract each other with the same strong nuclear force. So, the strong nuclear force holds together three protons and one neutron ($^4_3$Li) just as vigourously as it holds together two protons and two neutrons ($^4_2$He). Specifically, protons electrostastically repel other protons. This repulsion tries to make a nucleus fly apart. Since $^4_2$He contains only two protons, the attractive strong nuclear forces overcome the repulsion of the protons. Hence, the nucleus holds together. But in $^4_3$Li, the mutual repulsion of the three protons overcomes the strong nuclear attractions and the nucleus falls apart (or undergoes radioactive decay into a more stable nucleus). Therefore, the answer will be (c)

137 **(a)**

$$\frac{1}{16} = \frac{1}{2^{\frac{t}{100}}}$$

Or $\frac{1}{2^4} = \frac{1}{2^{t/100}}$ or $4 = \frac{t}{100}$

Or $t = 400\ \mu\text{s}$

138 **(c)**

$N = N_0 e^{-\lambda t}, N_\text{Y} = N_0(1 - e^{-\lambda t})$

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

Which decreases exponentially with time

139 **(c)**

Let N be the number of nuclei at any time t. Then,

$$\frac{dN}{dt} = 200 - \lambda N$$

$$\therefore \int_0^N \frac{dN}{200 - \lambda N} = \int_0^t dt$$

Or $N = \frac{200}{\lambda}(1 - e^{-\lambda t})$

Given: $N = 100$ and $\lambda = 1\ \text{s}^{-1}$

$\therefore 100 = 200(1 - e^{-t})$

Or $e^{-t} = \left(\frac{1}{2}\right)$ $\therefore t = \ln(2)$ s

140 **(d)**

Since no external force is present, so momentum conservation principle is completely applicable

$\therefore m\vec{v}_1 = m_1\vec{v}_1 + m_2\vec{v}_2$

Or $(m_1 + m_2)\overrightarrow{v_1} = m_1\vec{v}_1 + m_2\vec{v}_2$

141 **(b)**

$$\frac{N_0}{4} = \frac{N_0}{2n} \Rightarrow n = 2$$

Thus, 10 days = 2 half-lives

$\therefore$ Half-life = 8 days

142 **(b)**

The radioactive decay constant λ is given by

$$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{32}\text{h}^{-1}$$

From the equation $N = N_0 e^{-\lambda t}$, the fraction of a sample remaining after 16 h is given by

$$\frac{N}{N_0} = e^{-\lambda t} = e^{-\left(\frac{0.693}{32}\right)} = e^{-0.3465} = 0.71$$

143 **(d)**

Refer to the definition of mass defect

144 **(d)**

Disintegration of deuteron to a proton and a neutron can be represented by

$${}_1^2\mathrm{H} + \mathrm{Q} \rightarrow {}_1^1\mathrm{H} + {}_0^1\mathrm{n}$$

The energy captured is the γ-ray photon E_γ is given by

$$E_\gamma + 1876 = 939 + 940$$

$$\Rightarrow\ E_\gamma = (939 + 940) - 1876 = 3\ \mathrm{MeV}$$

145 **(c)**

$$\frac{A_0}{3} = A_0\left(\frac{1}{2}\right)^{\frac{9}{T_{1/2}}}$$

$$A' = \frac{A_0}{3}\left(\frac{1}{2}\right)^{\frac{9}{T_{1/2}}}$$

Dividing, we get

$$\frac{A' \times 3}{A_0} = \frac{1}{3} \text{ or } A' = \frac{A_0}{9}$$

146 **(b)**

$$t_{1/2} = \frac{0.639}{\lambda}$$

147 **(a)**

Two α-particles reduce mass number by 8

Therefore, new mass number $= 180 - 8 = 172$

Emission of two α-particles reduces charge number by 4

Emission of β-particles increases charge number by 1

Therefore, the new charge number $= 72 - 4 + 1 = 69$

148 **(b)**

A nucleus contains protons and neutrons with no antiprotons and antineutrons. Hence, answer can be either (b) or (d). Due to conservation of spin, the answer is (b)

149 **(b)**

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{64} = \left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^n \Rightarrow n = 6$$

After 6 half lives intensity emitted will be safe

$\therefore$ Total time taken $= 6 \times 2 = 12 hrs$

150 **(c)**

Let the kinetic energy of the α-particle be E_α and that of the thorium Th be E_{th}. The ratio of kinetic energies is

$$\frac{E_\alpha}{E_{\mathrm{th}}} = \frac{\frac{1}{2}m_\alpha v_\alpha^2}{\frac{1}{2}m_{\mathrm{th}} v_{\mathrm{th}}^2} = \left(\frac{m_\alpha}{m_{\mathrm{th}}}\right)\left(\frac{v_\alpha}{v_{\mathrm{th}}}\right) \quad \text{(i)}$$

By conservation of momentum, the momentum of α-particle and that of the recoiling thorium must be equal. Thus,

$$m_\alpha v_\alpha = m_{\mathrm{th}} v_{\mathrm{th}}$$

Or $\frac{v_\alpha}{v_{\mathrm{th}}} = \frac{m_{\mathrm{th}}}{m_\alpha}$ (ii)

Substituting Eq. (ii) in Eq. (i), we have

$$\frac{E_\alpha}{E_{\mathrm{th}}} = \left(\frac{m_\alpha}{m_{\mathrm{th}}}\right)\left(\frac{m_{\mathrm{th}}}{m_\alpha}\right)^2 = \frac{m_{\mathrm{th}}}{m_\alpha} = \frac{234}{4} = 58.5$$

Thus, the kinetic energy of the α-particle expressed as the fraction of the total kinetic energy T is the given by

$$E_\alpha = \frac{58.5}{1 + 58.5}T = \frac{58.5}{59.5}T = 0.98\,T$$

Which is slightly less than T

151 **(b)**

From $R = R_0\left(\frac{1}{2}\right)^n$, we have

$$1 = 64\left(\frac{1}{2}\right)^n$$

Or $n = 6 =$ number of half-lives

$$t = n \times t_{1/2} = 6 \times 2 = 12\ \mathrm{h}$$

152 **(b)**

The nuclear fission differs from other nuclear reaction in three respects

1. The nucleus is deeply divided into two large fission fragments or nuclei of roughly equal mass. The nuclei or fission fragments fly apart at great speed and thus posses large kinetic energies that carry off the greater part of the energy released

2. The mass decrease is appreciable and hence large energy is released

3. Other neutrons, called fission neutrons, are emitted in the process. Small amount of energy is released in the form of radiation

153 **(b)**

Fast neutrons can be easily slowed down by passing them through water. This is because of comparable masses the energy passed by neutron to water molecule is high

154 **(a)**

$$\frac{A_2}{A_1} = \frac{N_2}{N_1}$$

$$\frac{A_2}{10^3} = \frac{1}{2} \text{ or } A_2 = \frac{1000}{2} = 500\ \mathrm{s}^{-1}$$

155 **(b)**

Nuclear forces are charge independent

156 **(a)**

Maximum number of nuclei will be present when rate of decay = rate of formation

Or $\lambda N = \alpha$

$$\therefore N = \frac{\alpha}{\lambda}$$

157 **(b)**

$Q = (\Sigma B_r - \Sigma B_p)c^2$

Where $\Sigma B_r =$ sum of the masses of reactants

and $\Sigma B_p =$ sum of the masses of the products

$\Sigma B_r = 2 \times 2.014741 \text{ a.m.u.} = 4.0294892 \text{ a.m.u.}$

$\Sigma B_p = (3.016977 + 1.008987)\text{a.m.u.}$

$= 4.025964 \text{ a.m.u.}$

$\Sigma B_r - \Sigma B_p = (4.029482 - 4.025694) \text{ a.m.u.}$

$= 0.003518 \text{ a.m.u.}$

Decrease in mass appears as equivalent energy,

$\therefore Q = 0.003518 \times 931 \text{ MeV}$

$= 3.27 \text{ MeV}$

158 **(c)**

At closest distance of approach

Kinetic energy = Potential energy

$$\Rightarrow 5 \times 10^6 \times 1.6 \times 10^{-19} = \frac{1}{4\pi\varepsilon_0} \times \frac{(ze)(2e)}{r}$$

For uranium $z = 92$, so $r = 5.3 \times 10^{-12} cm$

159 **(d)**

Conserve the number of nucleons

160 **(b)**

The complete fission reaction is

$${}^{235}_{92}\text{U} + \text{n} \rightarrow {}^{94}_{40}\text{Zr} + {}^{140}_{58}\text{Ce} + 2\text{n} + 6\text{e}^{-1}$$

$Q = [m({}^{235}\text{U}) - m({}^{94}\text{Zr}) - m({}^{140}\text{Ce}) - m(\text{n})]c^2$

$= 208 \text{ MeV}$

161 **(b)**

Use conservation of linear momentum

162 **(b)**

Here, half-life of radium, $t = 1500$ years

Disintegration constant $\lambda = \frac{0.693}{T} = \frac{0.696}{1500}\text{year}^{-1}$

$N_0 = 1 \text{ g} \;\; N = 10 \text{ mg} = 1 \;\text{ centigram} = 10^{-2}\text{g}$

$\therefore N = 10 \text{ mg}$

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

163 **(c)**

The minimum energy needed to carry out an endothermic reaction is greater than the Q value of the reaction. This is because to conserve the momentum some extra energy has to be provided

$\text{KE}_{\text{min}} \left(1 + \frac{m}{M}\right) \times |Q|$, where m is the mass of the incident particle and M is the mass of target

164 **(a)**

As the alpha particle decays, the daughter nucleus recoils. In such a process, the momentum conservation holds good,

So,

$P_\alpha = P_D = P$

$K_\alpha = \frac{P^2}{2M_\alpha}$ and $K_D = \frac{P^2}{2M_D}$

As $M_D > M_\alpha$, so $K_\alpha > K_D$

165 **(d)**

$N_1 = N_0 e^{-10\lambda t}$ and $N_2 = N_0 e^{-\lambda t}$

$$\therefore \frac{N_1}{N_2} = \frac{e^{-10\lambda t}}{e^{-\lambda t}} = \frac{1}{e^{9\lambda t}}$$

Given,

$$\frac{N_1}{N_2} = \frac{1}{e} \Rightarrow \frac{1}{e^{9\lambda t}} = \frac{1}{e}$$

Or $9\lambda t = 1$ or $t = \left(\frac{1}{9\lambda}\right)$

166 **(c)**

Let n collisions are required for the given condition. Then,

$$\left(\frac{1}{2}\right)^n \times 2 \text{ MeV} = 0.04 \times 10^{-6}\text{MeV}$$

$$2^n = \frac{2}{0.04} \times 10^6 = 50 \times 10^6$$

After solving above equation, $n = 26$

167 **(c)**

For this substance 7 days correspond to 3.5 half-lives. Over 3 half-lifes the sample reduces to $\frac{1}{2^3} = \frac{1}{8}$ of its initial mass. After 4 half-lifes, the sample has only $\frac{1}{2^4} = \frac{1}{16}$ of its initial mass. Hence, after 3.5 half-lives the sample must contain somewhere between 1/8 and 1/16 of its initial mass

Hence, 5 g is somewhere between 1/8 and 1/16 of the initial mass

So, the initial mass is somewhere between

$8 \times 5 = 40$ g and $16 \times 5 = 80$ g

168 **(a)**

Fraction of nuclei which remain undecayed is

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

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

$$= e^{-\left(\frac{\ln 2}{T}\right)\left(\frac{T}{2}\right)}$$

$$= \frac{1}{e^{\ln\sqrt{2}}} = \frac{1}{\sqrt{2}}$$

169 **(c)**

Energy will be released when stability increases. This will happen when binding energy per nucleon increases

	Reactant	**Product**
Reaction (a)	60×8.5 MeV $= 510$ MeV	$20 \times 30 \times 5$ $= 300$ MeV
Reaction (b)	120×7.5 $= 900$ MeV	$(90 \times 8 +$ $30 \times 5)$ $= 870$ MeV
Reaction (c)	120×7.5 $= 900$ MeV	$2 \times 60 \times 8.5$ $= 1020$ MeV
Reaction (d)	90×8 $= 720$ MeV	$\left(\begin{matrix}60 \times 8.5 + \\ 30 \times 5\end{matrix}\right)$ $= 600$ MeV

170 **(d)**

After n half-lives, the radioactive nuclei remaining is $\frac{N_0}{2^n}$. So, number of nuclei disintegrated in n half-lives is $\left(N_0 - \frac{N_0}{2^n}\right)$

For $n = \frac{1}{2}$, the fraction disintegrated is $\left(1 - \frac{1}{\sqrt{2}}\right)$

171 **(b)**

$$T_{1/2} = \frac{0.693}{\lambda} \quad \text{or } T_{1/2} = 0.693\left[\frac{1}{\lambda}\right]$$

Or $T_{1/2} = 0.693\,\tau$

Clearly, $x = 0.693$

172 **(a)**

According to Avogadro's hypothesis,

$$N_0 = \frac{6.02 \times 10^{23}}{226} = 2.66 \times 10^{21}$$

Half-life $= T = \frac{0.693}{\lambda} = 1620$ years

$$\therefore\ \lambda = \frac{0.6931}{1620 \times 3.16 \times 10^7}$$

$= 1.35 \times 10^{-11}\text{s}^{-1}$

Because half-life is very much large as compared to its time interval, hence $N \approx N_0$. Now,

$$\frac{dN}{dt} = \lambda N \approx \lambda N_0$$

Or $dN \approx \lambda N_0 dt$

$= (1.35 \times 10^{-11})(2.66 \times 10^{21}) \times 1$

$= 3.61 \times 10^{10}$

173 **(c)**

$t = 0, N = N_0$

$t = 6.93, N = N_0/4$

$N_0/4$ is the sample left after two half-lives

$\therefore 2t_{1/2} = 6.93$

$$\Rightarrow 2 \times \frac{0.693}{\lambda} = 6.93 \Rightarrow \lambda = 0.2\ \text{min}^{-1}$$

$\Rightarrow t = 60$ min

$$\therefore N = N_0 e^{-\lambda t} = N_0 e^{-0.2 \times 60} = \frac{N_0}{e^{12}}$$

Multiple Correct Answers Type

174 **(c,d)**

Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less than the sum of masses of its constituent particles

${}^{20}_{10}\text{Ne}$ is made up of 10 protons plus 10 neutrons

Therefore, mass of ${}^{20}_{10}\text{Ne}$ nucleus,

$M_1 < 10(m_\text{p} + m_\text{n})$

Also, heavier the nucleus, more is the mass defect

$20(m_\text{n} + m_\text{p}) - M_2 > 10(m_\text{p} + m_\text{n}) - M_1$

Thus, $10(m_\text{n} + m_\text{p}) > M_2 - M_1$

Or $M_2 < M_1 + 10(m_\text{p} + m_\text{n})$

Now, since $M_1 < 10(m_\text{p} + m_\text{n})$

$\therefore\ M_2 < 2M_1$

175 **(a,b,c)**

In general, fission and fusion processes are exothermic reactions, i.e., energy is released. Hence, mass of products must be less than mass of the reactant nuclides, and BE/A of reactants < BE/A of products nuclides

176 **(a,c,d)**

First transition is from $n = 3$ to $n = 2$. Second transaction is from $n = 2$ to $n = 1$

$$\therefore \frac{E_1}{E_2} = c = \frac{1/2^2 - 1/3^2}{1/1^2 - 1/2^2}$$

$$= \frac{5/36}{3/4} = \frac{5}{36} \times \frac{4}{3} = \frac{5}{27}$$

As $p = \frac{E}{c}$, therefore,

$$\frac{p_1}{p_2} = b = \frac{E_1}{E_2} = c\ ie, b = c = \frac{5}{27}$$

As $E = \frac{hc}{\lambda} \therefore \lambda \propto \frac{1}{E}$

or $a = \frac{\lambda_1}{\lambda_2} = \frac{E_2}{E_1} = \frac{27}{5} = \frac{1}{c}$ or $c = \frac{1}{a}$

177 **(a,b,c,d)**

We have, $6.25\% = \frac{6.25}{100} = \frac{1}{16}$

The given time of 4 h thus equals 4 half-lives so that the half-life is 1 h

Since half-life $= \frac{\ln 2}{\text{decay constant}}$ and mean life $= \frac{1}{\text{decay constant}}$, after further 4 h, the amount left over would be $\frac{1}{2^4} \times \frac{1}{2^4}$, i. e., $\frac{1}{256}$ or $\frac{100}{256}$ or 0.39% of original amount

178 **(a,c,d)**

$$r_n = \frac{n^2 a_0}{z}$$

$$T_E = -\frac{13.6Z^2}{n^2}; L = \frac{nh}{2\pi}$$

$$PE \propto \frac{1}{n^2}$$

$|PE| = 2 \times |KE|$

Thus option (a), (c), (d) are correct

179 **(a,b,c)**

The last statement is incorrect because the amount of energy released per unit mass of the fuel is much more for fusion than for fission. Hence, (a), (b) and (c) are correct

181 **(a,b,c)**

If the nuclear reaction involving β-decay is n → p + e^{-1}, the spins on two sides are not equal as all the three (neutron, proton and electron) have spins of $+\frac{1}{2}$. So, to conserve angular momentum (spin), some other particle must be emitted.

Through experiments it has been observed that direction of emitted electron and recoiling nuclei are almost never exactly opposite as required for linear momentum to be conserved

During β-decay, the energy of electron is found to vary continuously from 0 to a maximum value (this maximum value is a characteristic of nuclide). To explain this experimental observation, we also need some other particle

182 **(a,b,c)**

We know,

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

Where, N = number of decayed nuclei in the sample at time t,

N_0 = initial number of nuclei

Hence, total number of undecayed nuclei $= (N_0 - N)$

Substituting it in (i), we get

$N_0 - N = N_0(1 - e^{-\lambda t})$

This shows that the total number of undecayed nuclei decays exponentially with time and total number of decayed unclei grows exponentially with time. Now,

$R = -\lambda N = \frac{dN}{dt}$ (R = activity)

Hence, activity (R) ∝ number of undecayed nuclei

Therefore, (a), (b), (c) are correct answers

184 **(a,c)**

Half-lives of both the samples would be same as half-life is property of radioactive material and is independent of number of nuclei present or its activity. Let $R_{0\mathrm{B}} = R_0$, then $R_{0\mathrm{A}} = 2B_0$, where R_0 denotes initial activity

Activity of A after 5 half-lives is

$$R_\mathrm{A} = \frac{R_{0\mathrm{A}}}{2^5} = \frac{2R_0}{2^5}a$$

Activity of B after 5 half-lives is

$$R_\mathrm{B} = \frac{R_{0\mathrm{B}}}{2^5} = \frac{R_0}{2^5}$$

$$\therefore \frac{R_\mathrm{A}}{R_\mathrm{B}} = \frac{2}{1}$$

185 **(a,c)**

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

For O^{16}, $R = R_0(16)^{1/3}$

For ${}_{54}\mathrm{X}^{128}$, $R' = R_0(128)^{1/3}$

$$R' = \left(\frac{128}{16}\right)^{1/3} R = 2R$$

$$\therefore V' = \frac{4}{3}\pi R^{1/3} = 8\mathrm{V}$$

186 **(b,d)**

If in nuclear reaction binding energy per nucleon increases, energy is released

187 **(a,c)**

The idea of ‘magic number’ has led to the shell model and the nuclides with these number of protons or neutrons have been compared with the ‘inert gases’ vis-à-vis stability in terms of ‘closed shells’

188 **(a,d)**

In nuclear fusion, two or more lighter nuclei are combined to form a relatively heavy nucleus and thus, releasing the energy

189 **(a,b,d)**

It has been observed that total mass of nucleus is always less than the sum of the masses of its nucleus. The energy difference between the nucleus and its constituent particles due to their mass difference is termed as the binding energy of the nucleus.

In other words, we can say that to break the nucleus into its constituent particles, some energy is needed to be supplied. This energy is termed as binding energy of the nucleus

For (a) more is the binding energy per nucleon, more is the energy required to break the nucleus and hence we can say the more stable the nucleus is

For (b), (c) and (d), in actual the binding energy is always positive but if it were zero, then nucleus will break spontaneously

190 **(b)**

Co^{60} is used for treatment of cancer

191 **(b,c)**

Statement (a) is incorrect. The ${}_2\mathrm{He}^4$ nucleus (or the α-particle) is exceptionally stable and has a much higher value of BE per nucleon than that for most other light nuclei. Statement (b) is correct but the reason of decrease in binding energy is different for the cases of smaller and larger values of A. The reason for the decrease in the BE per nucleon for nuclei with large A is that with an increase in the number of protons, the Coulomb repulsion increases. On the other hand, the decrease in the BE per nucleon for nuclei with small A is due to a surface effect: the nucleons at the surface being less strongly bound than those in the interior. Statement (c) is also correct. The energy required to remove one neutron (i.e., one nucleon) is the same as the binding energy per nucleon for a given isotope

Statement (d) is incorrect. To ensure both charge and mass number conservation, a proton must be produced as a by-product of the reaction:

${}_1\mathrm{D}^2 + {}_1\mathrm{D}^2 \rightarrow {}_1\mathrm{T}^3\,{}_1\mathrm{P}^1 + \mathrm{Q}$

192 **(a,d)**

In α-decay, the entire energy is carried away by the α-particles as its kinetic energy. In β^--decay, the energy is shared between the β-particle and the anti-neutrino. Hence, the speed of the β-particle will vary, depending on the energy of the anti-neutrino

193 **(a)**

Let percentage of ${}_5B^{10}$ be x and percentage of ${}_5B^{11} = (100 - x)$

$\therefore$ Average atomic weight

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

$10x + 110 - 11x = 1081$

$x = 1100 - 1081 = 19$

$\therefore\ 100 - x = 100 - 19 = 81$

194 **(b,c)**

Orbital angular momentum $(L) = n\frac{h}{2\pi}$

When $n = 1, L = \frac{h}{2\pi}$. When $n = 2, L = \frac{h}{\pi}$

195 **(a,c,d)**

All the statements are very conceptual statements related to different decays

196 **(b,c,d)**

Statement (a) is incorrect. In fact,

$A = Z + N$

Statements (b), (c) and (d) are correct; they are the definitions of isobars, isotopes and isotones

197 **(a,d)**

1. True, Cd absorbs neutrons
2. No, concrete reflects, does not slow down
3. 'Moderate the activity' is not correct. 'Moderator' in the sense of slowing the neutrons is different
4. True, it is a fact

198 **(a,c)**

$\lambda = (0.173\ \text{year})^{-1}$

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

As $t = \frac{1}{\lambda}$, hence

$$N = \frac{N_0}{e} = \frac{N_0}{2.178} = 0.37\,N_0$$

$$\Rightarrow T = \frac{0.693}{\lambda} = \frac{0.693}{0.173} = 4\ \text{years}$$

199 **(a,b,c)**

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

200 **(a,d)**

For an exothermic reaction

$X + x \rightarrow Y + y$

If K_i is the kinetic energy of incident particle x, then from energy conservation

$K_\mathrm{i} + (m_x + m_x)c^2 = K_\mathrm{Y} + K_\mathrm{y} + \left(M_\mathrm{Y} + m_\mathrm{y}\right)c^2$

$K_\mathrm{Y} + K_\mathrm{y} = K_\mathrm{i} + \left(m_x + M_\mathrm{X} - M_\mathrm{Y} - m_\mathrm{y}\right)c^2$

$K_\mathrm{Y} + K_y = K_\mathrm{i} + Q$

In any exothermic reaction, mass of the products is less than the mass of reactants, i.e., in products, the nucleons are more tightly bound and hence have greater BE per nucleon as compared to BE per nucleon of reactants. For endothermic reaction to be carried out, minimum energy given to the reactant must be greater than $|Q|$ value

201 **(a,b,c,d)**

We know that $E \propto \frac{1}{n^2}; P \propto \frac{1}{n}$ and $r \propto n^2$

$$Pr \propto \frac{1}{n}(n^2)\ ie, Pr \propto n$$

$$\frac{P}{E} \propto \frac{1/n}{1/n} ie, \frac{P}{E} \propto n$$

$Er \propto \frac{1}{n^2} \times n^2 ie, Er =$constant for all orbits.

$EPr \propto \frac{1}{n^2}.\frac{1}{n}n^2 ie, EPr$ is proportional to $1/n$

Assertion - Reasoning Type

202 **(b)**

Neutron is about 0.1 more massive than proton. But the unique thing about the neutron is that while it is heavy, it has no charge (it is neutral). This lack of charge gives it the ability to penetrate matter without interacting as compared to the beta particles or alpha particles

203 **(d)**

According to classical electromagnetic theory, an accelerated charged particle continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence they will be losing hteir energy continuously and the orbital radius will go on decreasing, form spiral and finally the electron will fall in the nucleus

204 **(a)**
The wavelength in Balmer series is given by

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right), n = 3,4,5 \dots$$

$$\frac{1}{\lambda_{\max}} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda_{\max}} = \frac{36}{5R} = \frac{36 \times 1}{5 \times 1.097 \times 10^7} = 6563 \text{ Å}$$

and $\frac{1}{\lambda_{\min}} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$

$$\lambda_{\min} = \frac{4}{R} = \frac{4}{1.097 \times 10^7} = 3646 \text{ Å}$$

205 **(b)**
β-particles, being emitted with very high speed compared to α-particles, pass for very little time near the atoms of the medium. So the probability of the atoms being ionized is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth

206 **(c)**
In fusion, lighter nuclei are used so fusion is not possible with ^{35}Cl. Also binding energy of ^{35}Cl is not too small

207 **(b)**
When the atom gets appropriate energy from outside, then this electron rises to some higher energy level. Now it can return either directly to the lower energy level or come to the lowest energy level after passing through other lower energy levels, hence all possible transitions take place in the source and many lines are seen in the spectrum

208 **(a)**
Substituting $m = 1 \text{ amu} = 1.67 \times 10^{-24}$kg and

$c = 3 \times 10^8 \text{ ms}^{-1}$in the energy-mass equivalence relation

$$E = mc^2$$

$$= 1.67 \times 10^{-27} \times (3 \times 10^8)^2$$

$$= 1.67 \times 10^{-27} \times 9 \times 10^{16} \text{J}$$

$$= \frac{1.67 \times 10^{-27} \times 9 \times 10^{16}}{1.6 \times 10^{-13}} \text{MeV} = 931 \text{ MeV}$$

209 **(b)**
Bohr postulated that electrons in stationary orbits around the nucleus do not radiate.

This is the one of Bohr's postulate. According to this the moving electrons radiates only when they go from one orbit to the next lower orbit

211 **(c)**
Nuclear foce is nearly same for all nucleus

212 **(a)**
Here, both the statements are correct and statement II correctly explains Statement I

213 **(a)**
Statement II, is true by definition and correctly explains Statement I, namely, $_{\text{Z}}\text{X}^4$ undergoes 2 α-decay, 2 β-decays (negative β) and 2 γ-decays. As a result, the daughter product is $_{Z-2}\text{X}^{A-\text{B}}$

215 **(a)**
Experimentally, it is found that the average radius of a nucleus is given by

$R = R_0 A^{1/3}$ where $R_0 = 1.1 \times 10^{-15} M = 1.1 fm$

and A = mass number

216 **(b)**
Electron capture occurs more often than positron emission in heavy elements. This is because if positron emission is energetically allowed, electron capture is necessarily allowed, but the reverse is not true, *i. e.*, when electron capture is energetically allowed, positron emission is not necessarily allowed

217 **(a)**
From Bohr's theory the energy of hydrogen atom in the n^{th}state is given by $E_n = \frac{13.6}{n^2}$eV. For an atom of atomic number Z, with one electron in the outer orbit (singly ionised He or double ionised lithium) we use $E_n = -\frac{13.6Z^2}{n^2}$ eV,where Z is atomic number. Hence, ground state energy of

doubly ionised lithium is $\frac{-13.6\times 9}{1^2} = -122.4$ eV

Ionisation potential (potential to be applied to electron to overcome this energy) is 122.4V.

218 **(a)**
Statement I is true, Statement II is true; Statement II is a correct explanation for Statement I

219 **(a)**
The radius of nucleus is given by $R = R_0 A^{1/3}$ where R_0 is a constant $= 1.1 \times 10^{-15}$m. For different nuclei mass number A is different, therefore R is different

220 **(b)**
β-particles are emitted with very high velocity (up to 0.99 c). So, according to Einstein's theory of relatively, the mass of a β-particle is much higher compared to its rest mass (m_0). The velocity of electrons obtained by other means is very small compared to c (velocity of light). So its mass remains nearly m_0. But β-paricle and electron both are similar particles

221 **(a)**
Factual

222 **(c)**
From the reaction hydrogen is converted into helium, with the nucleus releasing two positions and energy. Because of positron emission it cannot be $\beta -$ decay. The energy emitted and participation of light nuclei correspond to the fusion reaction.

223 **(a)**
When fission of heavy nucleus takes place, it splits itself into two lighter nuclei which are having too many neutrons and are highly unstable. To attain stability, they decay neutrons and hence try to achieve N/Z ratio somewhat greater than 1

224 **(c)**
Nuclear stability depends upon the ratio of neutron to proton. If the n/p ratio is more than the critical value, then a neutron gets converted into a proton forming a β^- particle in the process $n \to p + e^-$

The β^- particle (e^-) is emitted from the nucleus in some radioactive transformation. So electrons do not exist in the nucleus but they result in some nuclear transformation

225 **(a)**
From the relation,

$$\lambda = \frac{0.6931}{T}$$

$$\therefore\ \lambda = \frac{0.6931}{30} = 0.0231 \text{ day}^{-1}$$

226 **(a)**
${}_{38}\text{Sr}^{90}$decays to ${}_{39}\text{Y}^{90}$when β-rays emission is occurred. Sr gets absorbed in bones along with calcium which causes impairment of the production of red blood cells. So, assertion is true.

Now, $\text{Sr}^{90} \xrightarrow{\beta} \text{Y}^{90}$

Sr decays to Yttrium Sr ^{90}emits β-rays of very high energy. Bone marrow is damaged by these high energetic β-particles. So, reason is also true

228 **(c)**
According to postulates of Bohr's atom model, the electron revolves around the nucleus in fixed orbit of definite radii. As long as the electron is in a certain orbit it does not radiate any energy

229 **(d)**
The penetrating power is maximum in case of gamma rays because gamma rays are electromagnetic radiations of very small wavelength

230 **(c)**
Radioactivity $= -\frac{dN}{dt} = \lambda N = \frac{0.693N}{T_{1/2}}$

$$= \frac{0.693 \times 10^8}{50} = \frac{0.693 \times 1.2 \times 10^8}{60}$$
$$= 0.693 \times 2 \times 10^6$$

Radioactivity is proportional to $1/T_{1/2}$, and not to $T_{1/2}$

231 **(a)**
In α-particle scattering experiment, Rutherford found a small number of α-particles which were scattered back through an angle approaching to 180°. This is possible only if the positive charges are concentrated at the centre or nucleus of the atom

232 **(b)**

5. If Assertion is True, Reason is True, Reason is correct explanation of 1
6. If Assertion is True, Reason is True, Reason is not correct explanation of 1
7. If Assertion is True, Reason is False
8. If Assertion is False, Reason is True

233 **(a)**

Statement II is correctly explaining Statement I

More probability of decay means faster decay process and hence shorter half-life

234 **(b)**

Fission of U^{235} occurs by slow neutrons only (of energy about 1 eV) or even by thermal neutrons (of energy bout 0.025eV). Fission of $^{238}_{92}U$ is brought about by a fast neutron. $^{235}_{92}U$ has odd mass number and even atomic number, hence it is an even-odd nucleus whereas $^{238}_{92}U$ has even mass number and even atomic number, hence it is an even-even nucleus.

235 **(a)**

We know that an electron is very light particle as compared to an α-particle. Hence electron cannot scatter the α-particle at large angles, according to law of conservation of momentum. On the other hands, mass of nucleus is comparable with the mass of α-particle, hence only the nucleus of atom is responsible for scattering of α-particles

236 **(d)**

The whole mass of the atom is concentrated at nucleus and $M_{nucleus} <$ (Sum of the masses of nucleons) because, when nucleons combine some energy is wasted

237 **(a)**

As in a nucleus, nucleons are bounded by short-range nuclear force, so a given nucleon is in interaction only with neighboring nucleons. So, detaching a nucleon from a nucleus is irrespective of the fact that how many nucleons are present in the nucleus. Moreover, due to short-range nuclear force only, the E_b/A versus A curve is slowly varying for $A > 40$

While, in atoms electrons are bound with nucleus by Coulomb's force which is a long-range force and depends on the number of protons in the nucleus and electron separation from the nucleus. If we take the average of the energies required to detach all the electrons from the outermost shell to the innermost K shell, then this average increases rapidly with increase in atomic number

238 **(b)**

Rutherford confirmed that the repulsive force on α-particle due to nucleus varies with distance according to inverse square law and that the positive charges are concentrated at the centre and not distributed throughout the atom

239 **(d)**

Number of half-lives

$$n = \frac{t}{T} = \frac{200}{100} = 2$$

The fraction left undecayed is given

$$\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^2 = \frac{1}{4} = \frac{1}{4} \times 100\% = 25\%$$

240 **(c)**

In particle situation , at least three particles take place in transformation, so energy for β-particle+ energy of third particle= $E_1 - E_2$

Hence, energy of β-particle $\leq E_1 - E_2$

241 **(a)**

Here, statement I is correct and Statement II is wrong can be directly concluded from binding energy/nucleon curve.

242 **(d)**

Atomic mass and mass number are different. Mass number is simply representing number of nucleons, while atomic mass is the average of the masses of isotopes of a given element and has units of u (atomic mass unit)

243 **(a)**

If the half-life of a radioactive isotope is small as compared to the age of organic sample, then over the age of the sample the activity of radioactive isotope becomes very small and hence is impossible to detect. While this process will not arise if we use radioactive isotope having larger half-life for dating with organic samples

244 **(a)**

In α=decay, the mass number decreases by 4 and atomic number decreases by 2. In β-decay, the mass number does not change but atomic number changes by 1.In α-decay the atomic and mass number remain unchanged.

The reaction can be summarised as

$$_{Z}X^{A} \xrightarrow{2\alpha} {}_{Z-4}M^{A-B}$$
$$\xrightarrow{2\beta} {}_{Z-2}Y^{A-8} \xrightarrow{2\gamma} {}_{Z-2}Y^{A-8}$$

Thus, at a far extent reason explain assertion but not completely

245 **(b)**

In a nuclear fission, when a bigger nucleus is fissioned into two light weight nuclei, then due to mass defect some energy is released. According to concept of binding energy, fission can occur because the total mass energy will decrease; that is ΔE_{bn}(binding energy) will increase. We see that for high mass nuclide ($A = 240$), the binding energy per nucleon is about 7.6MeV/nucleon. For the middle weight nuclides ($A = 120$), it is about 8.5 MeV/nucleon. Thus, binding energy of fission fragments is larger than the total binding energy of the parent nucleus

246 **(d)**

Here, $N = N_0 \left(\frac{1}{2}\right)^{t/T}$

or $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ ...(i)

where T is the half-life period and $\frac{N}{N_0}$ is fraction of atoms left after time t. Here , $T = 40$ days and $\frac{N}{N_0} = \frac{25}{100} = \frac{1}{4}$

Putting the values of T and $\frac{N}{N_0}$ in Eq. (i), we get

$$\frac{1}{4} = \left(\frac{1}{2}\right)^{t/40} \text{ or } \left(\frac{1}{2}\right)^{2} = \left(\frac{1}{2}\right)^{t/40}$$

or $\frac{t}{40} = 2$ or $t = 80$ days

Matrix Match Type

247 **(a)**

(A) (p) Capacitor is charged, hence its energy is increased

(q) The temperature is increased, henc its energy is increased or as the external positive work is done, hence energy increases

(r) The temperature decreases, its energy is decreased

(s) All natural process, energy of the system decreases

(t) The current is produced. Hence energy of the system increases

(B) (p), (r), (s) no mechanical energy is provided to the system

(q) The mechanical energy is provided which increases the temperature and hence random motion of molecules

(t) Mechanical work is done to change the magnetic field, which increases the mechanical energy of electron and these electrons strike with stationary positive charge and energy is converted in random motion

(C) (s) Internal binding energy is converted into mechanical energy

(D) (s) Mass changes only in nuclear process

248 **(c)**

1. In the given spontaneous radioactive decay, the number of protons remain constant and all conservation principles are decayed

2. In fusion reaction of two hydrogen nuclei, a proton is decreased as a position shall be emitted in the reaction. All the three conservation principles are obeyed

3. In the given fission reaction, the number of protons remain constant and all conservation principles are obeyed

4. In beta negative decay, a neutron transforms into a proton within the nucleus and the electron is ejected out

249 **(d)**

$$E_1 = [2m({}_1\mathrm{H}^2) - m({}_1\mathrm{H}^3) - m({}_1\mathrm{H}^1)]931.5 \text{ MeV}$$
$$= 4 \text{ MeV}$$
$$E_2 = [-m({}_2\mathrm{He}^4) - m({}_0\mathrm{n}^1) + m({}_1\mathrm{H}^3)$$
$$+ m({}_1\mathrm{H}^2)] \times 931.5 \text{ meV}$$
$$= 17.6 \text{ MeV}$$
$$E_3 = [-m({}_2\mathrm{He}^3) - m({}_0\mathrm{n}^1) + 2m({}_1\mathrm{H}^2)]$$
$$\times 931.5 \text{ meV} = 3.3 \text{ MeV}$$
$$E_4 = [m({}_2\mathrm{He}^3) - m({}_1\mathrm{H}^2) - m({}_2\mathrm{He}^4)$$
$$- m({}_1\mathrm{H}^1)] \times 931.5 \text{ MeV}$$
$$= 18.3 \text{ MeV}$$

250 **(a)**

1. Thermal energy of air molecules at room temperature:

$$kT = 1.38 \times 10^{-23} \times 300 \text{ J} = 0.025 \text{ eV}$$

2. Binding energy of heavy nuclei per nucleon ≈ 7 MeV

3. X-ray wavelength ≈ 1 Å

$$E = \frac{hc}{\lambda} \simeq 12 \text{ KeV}$$

4. For visible light: wavelength s ≈ 6000 Å

$$E = \frac{hc}{\lambda} \simeq 2 \text{ eV}$$

251 **(b)**

Stability of nucleus is decided by

1. Mass defect → greater → stability greater

2. Neutron-proton ratio, i.e., $e\frac{N}{P} \simeq 1 = 1 \rightarrow$ More stable

3. Packing fraction = negative → more stable

4. Binding energy per nucleon greater → greater stability

For radioactive substance binding energy per nucleon is minimum. So, they are unstable

For bound orbit, total energy is always negative

Stopping potential is the particular negative potential when no electron reaches the plate (i.e., anode)

252 **(c)**

In nuclear fusion, two lighter nuclei fuse and make big nuclei. In this, mass defect is converted into energy according to $E = mc^2$

In nuclear fission, heavy nuclei split into two or more than two smaller nuclei. In this process, mass is converted into energy according to $E = mc^2$

In β-decay, neutron proton ratio decreases, so nucleus becomes more stable

Both nuclear fission and nuclear fusion are exothermic reactions

253 **(d)**

For all types of waves, sound wave, light wave, string wave the term related is frequency, which is given only in one option. Other phenomenon are property matching.

Photoelectric effect proves photon character of light

γ-rays can only be produced from nucleus

In case of k capture x-rays are emitted

254 **(a)**

Binding energy per nucleon for middle order element is maximum because middle order element is most stable

So, (a) → (q)

Nuclear force depends only on spin of nucleons

So, (b) → (s)

For nuclear fission, $\frac{Z^2}{A}$ is greater than 15

So, (c) → (t)

Magic numbers are explained by Shell model

So, (d) → (q)

255 **(b)**

In all the reactions in Column II:

Mass of products will be less than original mass of the system. The mass converts into energy, hence binding energy increases

Basically, in all four reactions mentioned in Column II, energy is released and hence for all $m_{\text{products}} > m_{\text{original system}}$

As energy is released in all 4 reactions, BE/nucleons increases in all

Mass number and charge number are conserved in all processes

Linked Comprehension Type

256 **(d)**

As $E \propto \frac{1}{n^2}$

$$\therefore\ E_2 = -\frac{13.6}{2^2} \text{ eV} = -3.4 \text{ eV}$$

257 **(c)**

$N = A - Z = 197 - 79 = 118$

258 **(a)**

$$\frac{dN_x}{dt} = K - \lambda N_x$$

$$N_{\text{X}} = \frac{1}{\lambda}[K - K - \lambda N_0)e^{-\lambda t}]$$

$$\frac{dN_Y}{dt} = \lambda N_{\text{X}}$$

$$N_{\text{Y}} = K_t + \left(\frac{K - \lambda N_0}{\lambda}\right)e^{-\lambda t} - \frac{K - \lambda N_0}{\lambda}$$

259 **(a)**

$$\frac{dN}{dt} = q_0 t - \lambda N; \frac{dN}{dt} + \lambda N = q_0 t$$

260 **(c)**

From the graph and the fact that the n/p (=no. of neutrons/no. of protons) ratio for magnesium is 27/12, which is greater than 1 (=unit slope)

261 **(b)**

In equilibrium,

Rate of decay = rate of production

262 **(d)**

Radioactivity is independent of all external conditions. When a nucleus undergoes an α-decay, its atomic number decreases by 2 and in beta decay, atomic number increases by 1

263 **(a,b,c,d)**

All options are basic properties of nuclear forces. So, all options are correct

264 **(d)**

According to the passage, subatomic reactions do not conserve mass. So, we cannot find the third particle's mass by setting m_{neutron} equal to $m_{\text{proton}} + m_{\text{electron}} + m_{\text{third particle}}$. By constrast, the total energy in this case, the sum of 'mass energy' and kinetic energy, is conserved. If E denotes total energy, then

$$E_{\text{neutron}} = E_{\text{proton}} + E_{\text{electron}} + E_{\text{third particle}}$$

The neutron has energy 949.97 MeV. The proton has energy $939.67 \text{ MeV} + 0.01 \text{ MeV} = 939.69 \text{ MeV}$. The electron has energy $0.51 \text{ MeV} = 0.39 \text{ MeV} = 0.90 \text{ MeV}$. Therefore, the third particle has energy

$$E_{\text{third particle}} = E_{\text{neutron}} - E_{\text{proton}} - \text{Electron}$$

We just found the third particle's total energy, the sum of its mass energy and kinetic energy. Without more information, we cannot figure out how much of that energy is mass energy

265 **(d)**

Nuclear reactions conserve total charge and also conserve the total approximate mass (as measured by the atomic mass number). Therefore, since the uranium, xenon, and strontium nuclei have atomic masses 236, 140 and 94, the 'other particles' must have total atomic mass A such that

$236 = 140 + 94 + A$

So, $A = 2$. The other particles are two nucleons. This narrows down the answer to options (b), (c) and (d). For nuclei, the atomic number —i.e., the number of protons—tells us the charge. So, the other particles must have total charge Z such that

$92 = 54 + 38 + Z$ or $Z = 0$

In summary, the other particles have total atomic mass 2 and total charge 0. Only option (d) fits this description

266 **(c)**

If the particles are treated as point charges,

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

$Q_1 = 2e$ (alpha particle), $q_2 = 82e$ (gold nucleus), $r = 6.5 \times 10^{-14}$ m

$$\therefore U = (8.987 \times 10^8 \text{N m}^2\text{C}^2) \times \frac{(2 \times 82)(1.602 \times 10^{-19}\text{C})}{6.50 \times 10^{-14}\text{m}} = 5.82 \times 10^{-13} \text{ J}$$

Or $U = 5.82 \times 10^{-13} \text{ J} \times \left(\frac{1 \text{ eV}}{1.602 \times 10^{-19}\text{J}}\right) = 3.63 \times 10^6 \text{eV} = 3.63 \text{ MeV}$

267 **(a)**

Use conservation of energy and momentum

Momentum of a photon $= h/\lambda$

268 **(d)**

$$\frac{dN}{dt} = \lambda N(t)$$

From the given data,

$20000 = \lambda N(0)$

$14800 = \lambda N(0.5 \text{ h})$

$$\frac{N}{N_0} = \frac{148}{200}$$

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

$$\therefore e^{-\lambda t} = \frac{148}{200}$$

Or $\lambda = \frac{\left(\ln\frac{200}{148}\right)}{t} \approx 1.6 \times 10^{-4}\text{decays s}^{-1}$

Half-life, $T = \frac{0.693}{\lambda} = 4340 \text{ s} = 1.2 \text{ h}$

269 **(d)**

The high temperature maintained inside the reactor core

270 **(a)**

$$E = \frac{p^2}{2m}; p = \frac{h}{\lambda} \Rightarrow E = \frac{h^2}{2m\lambda^2}$$

For standing waves $\lambda = \frac{2a}{n} \Rightarrow E = \frac{h^2n^2}{8ma^2} \Rightarrow E \propto a^{-2}$

271 **(c)**

$$E_n = -\frac{13.6}{n^2}(z^2)$$

In first excited state $E_{H_2} = -3.4eV$ and $E_{He} = -13.6\, eV$

272 **(d)**

$$I\omega = \frac{nh}{2\pi}$$

Rotational kinetic energy $= \frac{1}{2}I\omega^2 = \frac{1}{2}\frac{n^2h^2}{4\pi^2 I} = \frac{n^2h^2}{8\pi^2 I}$

273 **(c)**

KE_{max} of β^-

$Q = 0.8 \times 10^6\, eV$

$KE_P + KE_{\beta^-} + KE_{\overline{v}} = Q$

KE_P is almost zero

When $KE_{\beta^-} = 0$

Then $KE_{\overline{v}} = Q - KE_P \cong Q$

Integer Answer Type

274 **(4)**

We have $\frac{t}{t_{1/2}} = \frac{40 \text{ hours}}{20 \text{ hours}} = 2$

Thus, $A = \frac{A_0}{2^{t/t_{1/2}}} = \frac{A_0}{2^2} = \frac{A_0}{4}$

So, one fourth of the original activity will remain after 40 hours

275 **(0)**

The activity of the sample at time t is given by

$A = A_0 e^{-\lambda t}$

Where λ is the decay constant and A_0 is the activity at time $t = 0$ when the capacitor plates the connected. The charge on the capacitor at time t is given by

$Q = Q_0 e^{-t/CR}$

Where Q_0 is the charge at $t = 0$ and $C = 100$ μF

Thus,

$$\frac{Q}{A} = \frac{Q_0}{A_0} \frac{e^{-t/CR}}{e^{-\lambda t}}$$

It is independent of t if $\lambda = \frac{1}{CR}$

Or $R = \frac{1}{\lambda C} = \frac{t_{av}}{C} = \frac{20 \times 10^{-3}}{100 \times 10^{-6}\text{F}} = 200\ \Omega$

276 **(8)**

$$\begin{tikzcd}
x \arrow[r, "t_1", "\alpha"'] \arrow[d, "t_2"', "\beta"] & {} \\
{} &
\end{tikzcd}$$

$6h = 3(t_{\text{eq}})$

$$\Rightarrow N = \frac{N_0}{(2)^3} \Rightarrow \frac{N_0}{N} = 8$$

277 **(2)**

$R_1 = \lambda N_1, R_2 = \lambda N_2,$

No of atoms decayed in $(T_1 - T_2)$

$$= N_1 - N_2 = \frac{R_1 - R_2}{\lambda} = \frac{(R_1 - R_2)T}{\ln 2}$$

$$= \frac{2(R_1 - R_2)T}{\ln 4}$$

Hence $n = 2$

278 **(2)**

In one half-life the number of active nuclei reduces to half the original number. Thus, in two half-lives the number is reduced to $\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)$ of the original number. The number of remaining active nuclei is, therefore,

$$8.0 \times 10^{18} \times \left(\frac{1}{2}\right) = 2 \times 10^{18}$$

279 **(7)**

x and y are number of α-decays and β-decays respectively

$92 - 2x + y = 85$ (i)

Or $2x - y = 7$ (ii)

Similarly, $238 - 4x = 210$

$x = 7$, put in (i) we get $y = 7$

280 **(1)**

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

$\frac{dN}{dt} = 10^{10} = N_0(\lambda)e^{-10^{-9}t}$, at $(t = 0)$

$10^{10} = N_0 10^{-9} \Rightarrow N_0 = 10^{19}$

Mass of sample $= N_0$ (mass of the atom)

$= N_0 10^{-25}$

$= 10^{-6} kgm = 10^{-6} \times 10^3 gm = 10^{-3} gm = 1mg$

281 **(6)**

Effective decay constant will be sum of all different decay constants

So $\lambda_{\text{eff}} = \lambda + 2\lambda + 3\lambda = 6\lambda$, hence $n = 6$

282 **(6)**

We have to find the time at which

$\lambda_A N_A = \lambda_B N_B$

$$\left(\frac{\ln 2}{T_A}\right)\left(4N_0 e^{-\lambda_A t}\right) = (N_0)\left(\frac{\ln 2}{T_B}\right)\left(e^{-\lambda_B t}\right)$$

$e^{(\lambda_A - \lambda_B)t} = 8$

$(\lambda_A - \lambda_B)t = \ln 8 = 3(\ln 2)$

$$\left(\frac{\ln 2}{1} - \frac{\ln 2}{2}\right)t = 3\ln(2) \Rightarrow t = 6 \text{ minutes}$$