27

Nuclei

TOPIC 1 Composition and Size of the Nuclei

1. The radius R of a nucleus of mass number A can be estimated by the formula $R = (1.3 \times 10^{-15})A^{1/3}$ m. It follows that the mass density of a nucleus is of the order of : $(M_{\text{prot.}} \cong M_{\text{neut.}} \simeq 1.67 \times 10^{-27}$ kg) **[Sep. 03, 2020 (II)]**
 (a) 10^3 kg m^{-3} (b) 10^{10} kg m^{-3}
 (c) 10^{24} kg m^{-3} (d) 10^{17} kg m^{-3}
2. The ratio of the mass densities of nuclei of ^{40}Ca and ^{16}O is close to : **[8 April 2019 II]**
 (a) 1 (b) 0.1 (c) 5 (d) 2
3. An unstable heavy nucleus at rest breaks into two nuclei which move away with velocities in the ratio of 8:27. The ratio of the radii of the nuclei (assumed to be spherical) is: **[Online April 15, 2018]**
 (a) 8 : 27 (b) 2 : 3 (c) 3 : 2 (d) 4 : 9
4. Which of the following are the constituents of the nucleus? **[2007]**
 (a) Electrons and protons (b) Neutrons and protons
 (c) Electrons and neutrons (d) Neutrons and positrons
5. If radius of the $^{27}_{13}$Al nucleus is estimated to be 3.6 fermi then the radius of $^{125}_{52}$Te nucleus be nearly **[2005]**
 (a) 8 fermi (b) 6 fermi
 (c) 5 fermi (d) 4 fermi

TOPIC 2 Mass-Energy Equivalence and Nuclear Reactions

6. You are given that mass of $^7_3$Li $= 7.0160$ u,
 Mass of $^4_2$He $= 4.0026$ u
 and Mass of $^1_1$H $= 1.0079$ u.
 When 20 g of $^7_3$Li is converted into $^4_2$He by proton capture, the energy liberated, (in kWh), is :
 [Mass of nucleon = 1 GeV/c^2] **[Sep. 06, 2020 (I)]**
 (a) 4.5×10^5 (b) 8×10^6
 (c) 6.82×10^5 (d) 1.33×10^6
7. Given the masses of various atomic particles $m_p = 1.0072$ u, $m_n = 1.0087$ u, $m_e = 0.000548$ u, $m_{\bar{\nu}} = 0$, $m_d = 2.0141$ u, where p ≡ proton, n ≡ neutron, e ≡ electron, $\bar{\nu}$ ≡ antineutrino and d ≡ deuteron. Which of the following process is allowed by momentum and energy conservation? **[Sep. 06, 2020 (II)]**
 (a) $n + n \to$ deuterium atom (electron bound to the nucleus)
 (b) $p \to n + e^+ + \bar{\nu}$
 (c) $n + p \to d + \gamma$
 (d) $e^+ + e^- \to \gamma$
8. Find the Binding energy per neucleon for $^{120}_{50}$Sn. Mass of proton $m_p = 1.00783$ U, mass of neutron $m_n = 1.00867$ U and mass of tin nucleus $m_{Sn} = 119.902199$ U.
 (take 1U = 931 MeV) **[Sep. 04, 2020 (II)]**
 (a) 7.5 MeV (b) 9.0 MeV
 (c) 8.0 MeV (d) 8.5 MeV
9. In a reactor, 2 kg of $_{92}$U^{235} fuel is fully used up in 30 days. The energy released per fission is 200 MeV. Given that the Avogadro number, N = 6.023×10^{26} per kilo mole and 1 eV = 1.6×10^{-19} J. The power output of the reactor is close to: **[Sep. 02, 2020 (I)]**
 (a) 35 MW (b) 60 MW
 (c) 125 MW (d) 54 MW
10. Consider the nuclear fission
 $Ne^{20} \to 2He^4 + C^{12}$
 Given that the binding energy/nucleon of Ne^{20}, He^4 and C^{12} are, respectively, 8.03 MeV, 7.07 MeV and 7.86 MeV, identify the correct statement: **[10 Jan. 2019 II]**
 (a) energy of 12.4 MeV will be supplied
 (b) 8.3 MeV energy will be released
 (c) energy of 3.6 MeV will be released
 (d) energy of 11.9 MeV has to be supplied

11. Imagine that a reactor converts all given mass into energy and that it operates at a power level of 10^9 watt. The mass of the fuel consumed per hour in the reactor will be : (velocity of light, c is 3×10^8 m/s) **[Online April 9, 2017]**

(a) 0.96 gm (b) 0.8 gm
(c) 4×10^{-2} gm (d) 6.6×10^{-5} gm

12. Two deuterons undergo nuclear fusion to form a Helium nucleus. Energy released in this process is : (given binding energy per nucleon for deuteron=1.1 MeV and for helium=7.0 MeV) **[Online April 8, 2017]**

(a) 30.2 MeV (b) 32.4 MeV
(c) 23.6 MeV (d) 25.8 MeV

13. When Uranium is bombarded with neutrons, it undergoes fission. The fission reaction can be written as :

$${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3x + Q(\text{energy})$$

where three particles named x are produced and energy Q is released. What is the name of the particle x ? **[Online April 9, 2013]**

(a) electron (b) α-particle
(c) neutron (d) neutrino

14. Assume that a neutron breaks into a proton and an electron. The energy released during this process is : (mass of neutron = 1.6725×10^{-27} kg, mass of proton = 1.6725×10^{-27} kg, mass of electron = 9×10^{-31} kg). **[2012]**

(a) 0.51 MeV (b) 7.10 MeV
(c) 6.30 MeV (d) 5.4 MeV

15. Ionisation energy of Li (Lithium) atom in ground state is 5.4 eV. Binding energy of an electron in Li^+ ion in ground state is 75.6 eV. Energy required to remove all three electrons of Lithium (Li) atom is **[Online May 19, 2012]**

(a) 81.0 eV (b) 135.4 eV
(c) 203.4 eV (d) 156.6 eV

16. After absorbing a slowly moving neutron of mass m_N (momentum ≈ 0) a nucleus of mass M breaks into two nuclei of masses m_1 and $5m_1$ ($6m_1 = M + m_N$) respectively. If the de Broglie wavelength of the nucleus with mass m_1 is λ, the de Broglie wavelength of the nucleus will be **[2011]**

(a) 5λ (b) $\lambda/5$ (c) λ (d) 25λ

DIRECTIONS: Questions number 17-18 are based on the following paragraph.

A nucleus of mass $M + \Delta m$ is at rest and decays into two daughter nuclei of equal mass $\frac{M}{2}$ each. Speed of light is c. **[2010]**

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

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

18. The speed of daughter nuclei is

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

19. **Statement-1:** Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion and
Statement-2 : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z. **[2008]**

(a) Statement-1 is false, Statement-2 is true
(b) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1
(c) Statement-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1
(d) Statement-1 is true, Statement-2 is false

20. If M_O is the mass of an oxygen isotope ${}_8O^{17}$, M_P and M_N are the masses of a proton and a neutron respectively, the nuclear binding energy of the isotope is **[2007]**

(a) $(M_O - 17M_N)c^2$ (b) $(M_O - 8M_P)c^2$
(c) $(M_O - 8M_P - 9M_N)c^2$ (d) M_Oc^2

21. When ${}_3Li^7$ nuclei are bombarded by protons, and the resultant nuclei are ${}_4Be^8$, the emitted particles will be **[2006]**

(a) alpha particles (b) beta particles
(c) gamma photons (d) neutrons

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

$$p + {}_3^7Li \longrightarrow 2\,{}_2^4He$$

energy of proton must be **[2006]**

(a) 28.24 MeV (b) 17.28 MeV
(c) 1.46 MeV (d) 39.2 MeV

23. A nuclear transformation is denoted by $X(n, \alpha)\,{}_3^7Li$. Which of the following is the nucleus of element X ? **[2005]**

(a) ${}_5^{10}B$ (b) ${}^{12}C_6$ (c) ${}_4^{11}Be$ (d) ${}_5^9B$

24. A nucleus disintegrated into two nuclear parts which have their velocities in the ratio of 2 : 1. The ratio of their nuclear sizes will be **[2004]**

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

25. The binding energy per nucleon of deuteron $\left({}_1^2H\right)$ and helium nucleus $\left({}_2^4He\right)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is **[2004]**

(a) 23.6 MeV (b) 26.9 MeV
(c) 13.9 MeV (d) 19.2 MeV

26. When a U^{238} nucleus originally at rest, decays by emitting an alpha particle having a speed 'u', the recoil speed of the residual nucleus is **[2003]**

(a) $\frac{4u}{238}$ (b) $-\frac{4u}{234}$
(c) $\frac{4u}{234}$ (d) $-\frac{4u}{238}$

27. In the nuclear fusion reaction

$$^2_1H + ^3_1H \rightarrow ^4_2He + n$$

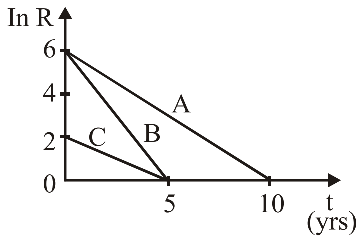
given that the repulsive potential energy between the two nuclei is $\sim 7.7 \times 10^{-14}$ J, the temperature at which the gases must be heated to initiate the reaction is nearly

[Boltzmann's Constant $k = 1.38 \times 10^{-23}$ J/K] **[2003]**

(a) 10^7 K (b) 10^5 K (c) 10^3 K (d) 10^9 K

TOPIC 3 Radioactivity

28. Acitvities of three radioactive substances A, B and C are represented by the curves A, B and C, in the figure. Then their half-lives $T_{\frac{1}{2}}(A) : T_{\frac{1}{2}}(B) : T_{\frac{1}{2}}(C)$ are in the ratio : **[Sep. 05, 2020 (I)]**



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

29. A radioactive nucleus decays by two different processes. The half life for the first process is 10 s and that for the second is 100 s. The effective half life of the nucleus is close to : **[Sep. 05, 2020 (II)]**

(a) 9 sec. (b) 6 sec.
(c) 55 sec. (d) 12 sec.

30. In a radioactive material, fraction of active material remaining after time *t* is 9/16. The fraction that was remaining after *t*/2 is : **[Sep. 03, 2020 (I)]**

(a) $\frac{4}{5}$ (b) $\frac{3}{5}$ (c) $\frac{3}{4}$ (d) $\frac{7}{8}$

31. The activity of a radioactive sample falls from 700 s^{-1} to 500 s^{-1} in 30 minutes. Its half life is close to: **[7 Jan. 2020, II]**

(a) 72 min (b) 62 min
(c) 66 min (d) 52 min

32. Two radioactive materials A and B have decay constants 10 λ and λ, respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of A to that of B will be 1/e after a time : **[10 April 2019, I]**

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

33. Two radioactive substances A and B have decay constants 5λ and λ respectively. At $t = 0$, a sample has the same number of the two nuclei. The time taken for the ratio of the number of nuclei to become $\left(\frac{1}{e}\right)^2$ will be :

[10 April 2019, II]

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

34. In a radioactive decay chain, the initial nucleus is $^{232}_{90}Th$. At the end there are 6 α-particles and 4 β-particles which are emitted. If the end nucleus is ^A_ZX, A and Z are given by:

[12 Jan. 2019, II]

(a) A = 208 ; Z = 80 (b) A = 202 ; Z = 80
(c) A = 208 ; Z = 82 (d) A = 200; Z = 81

35. Using a nuclear counter the count rate of emitted particles from a radioactive source is measured. At t = 0 it was 1600 counts per second and t = 8 seconds it was 100 counts per second. The count rate observed, as counts per second, at t = 6 seconds is close to: **[10 Jan. 2019 I]**

(a) 200 (b) 150 (c) 400 (d) 360

36. A sample of radioactive material A, that has an activity of 10 mCi (1 Ci = 3.7×10^{10} decays/s), has twice the number of nuclei as another sample of a different radioactive material B which has an acitvity of 20 mCi. The correct choices for half-lives of A and B would then be respectively: **[9 Jan. 2019 I]**

(a) 5 days and 10 days (b) 10 days and 40 days
(c) 20 days and 5 days (d) 20 days and 10 days

37. At a given instant, say t = 0, two radioactive substances A and B have equal activities. The ratio $\frac{R_B}{R_A}$ of their activities after time t itself decays with time t as e^{-3t}. If the half-life of A is $ln2$, the half-life of B is:

[9 Jan. 2019, II]

(a) $4ln2$ (b) $\frac{ln2}{2}$ (c) $\frac{ln2}{4}$ (d) $2ln2$

38. At some instant, a radioactive sample S_1 having an activity 5μCi has twice the number of nuclei as another sample S_2 which has an activity of 10μCi. The half lives of S_1 and S_2 are **[Online April 16, 2018]**

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

39. A solution containing active cobalt $^{60}_{27}Co$ having activity of 0.8 μCi and decay constant λ is injected in an animal's body. If 1cm^3 of blood is drawn from the animal's body after 10 hrs of injection, the activity found was 300 decays per minute. What is the volume of blood that is flowing in the body? (1Ci = 3.7×10^{10} decay per second and at t = 10 hrs $e^{-\lambda t} = 0.84$) **[Online April 15, 2018]**

(a) 6 litres (b) 7 litres (c) 4 litres (d) 5 litres

40. A radioactive nucleus A with a half life T, decays into a nucleus B. At t = 0, there is no nucleus B. At sometime t, the ratio of the number of B to that of A is 0.3. Then, t is given by **[2017]**

(a) $t = T\log(1.3)$ (b) $t = \dfrac{T}{\log(1.3)}$

(c) $t = T\dfrac{\log 2}{\log 1.3}$ (d) $t = \dfrac{\log 1.3}{\log 2}$

41. Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed number of A and B nuclei will be : **[2016]**

(a) 1 : 4 (b) 5 : 4 (c) 1 : 16 (d) 4 : 1

42. Let N_β be the number of β particles emitted by 1 gram of Na^{24} radioactive nuclei (half life = 15 hrs) in 7.5 hours, N_β is close to (Avogadro number = 6.023×10^{23}/g. mole): **[Online April 11, 2015]**

(a) 6.2×10^{21} (b) 7.5×10^{21}
(c) 1.25×10^{22} (d) 1.75×10^{22}

43. A piece of wood from a recently cut tree shows 20 decays per minute. A wooden piece of same size placed in a museum (obtained from a tree cut many years back) shows 2 decays per minute. If half life of C^{14} is 5730 years, then age of the wooden piece placed in the museum is approximately: **[Online April 19, 2014]**

(a) 10439 years (b) 13094 years
(c) 19039 years (d) 39049 years

44. A piece of bone of an animal from a ruin is found to have ^{14}C activity of 12 disintegrations per minute per gm of its carbon content. The ^{14}C activity of a living animal is 16 disintegrations per minute per gm. How long ago nearly did the animal die? (Given half life of ^{14}C is $t_{1/2} = 5760$ years) **[Online April 12, 2014]**

(a) 1672 years (b) 2391 years
(c) 3291 years (d) 4453 years

45. A radioactive nuclei with decay constant 0.5/s is being produced at a constant rate of 100 nuclei/s. If at t = 0 there were no nuclei, the time when there are 50 nuclei is: **[Online April 11, 2014]**

(a) 1 s (b) $2\ln\left(\dfrac{4}{3}\right)$ s

(c) $\ln 2$ s (d) $\ln\left(\dfrac{4}{3}\right)$ s

46. The half-life of a radioactive element A is the same as the mean-life of another radioactive element B. Initially both substances have the same number of atoms, then : **[Online April 22, 2013]**

(a) A and B decay at the same rate always.
(b) A and B decay at the same rate initially.
(c) A will decay at a faster rate than B.
(d) B will decay at a faster rate than A.

47. The counting rate observed from a radioactive source at $t = 0$ was 1600 counts s^{-1}, and $t = 8$ s, it was 100 counts s^{-1}. The counting rate observed as counts s^{-1} at $t = 6$ s will be **[Online May 26, 2012]**

(a) 250 (b) 400 (c) 300 (d) 200

48. The decay constants of a radioactive substance for α and β emission are λ_α and λ_β respectively. If the substance emits α and β simultaneously, then the average half life of the material will be **[Online May 19, 2012]**

(a) $\dfrac{2T_\alpha T_\beta}{T_\alpha + T_\beta}$ (b) $T_\alpha + T_\beta$

(c) $\dfrac{T_\alpha T_\beta}{T_\alpha + T_\beta}$ (d) $\dfrac{1}{2}\left(T_\alpha + T_\beta\right)$

49. Which of the following Statements is correct? **[Online May 12, 2012]**

(a) The rate of radioactive decay cannot be controlled but that of nuclear fission can be controlled.
(b) Nuclear forces are short range, attractive and charge dependent.
(c) Nuclei of atoms having same number of neutrons are known as isobars.
(d) Wavelength of matter waves is given by de Broglie formula but that of photons is not given by the same formula

50. A sample originally contained 10^{20} radioactive atoms, which emit α-particles. The ratio of α-particles emitted in the third year to that emitted during the second year is 0.3. How many α-particles were emitted in the first year? **[Online May 7, 2012]**

(a) 3×10^{18} (b) 3×10^{19}
(c) 5×10^{18} (d) 7×10^{19}

51. The half life of a radioactive substance is 20 minutes. The approximate time interval $(t_2 - t_1)$ between the time t_2 when $\frac{2}{3}$ of it had decayed and time t_1 when $\frac{1}{3}$ of it had decayed is: **[2011]**

(a) 14 min (b) 20 min (c) 28 min (d) 7 min

52. **Statement - 1 :** A nucleus having energy E_1 decays by 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 β^- decay at least three particles must take part in the transformation. **[2011 RS]**

(a) Statement-1 is correct but statement-2 is not correct.
(b) Statement-1 and statement-2 both are correct and statement-2 is the correct explanation of statement-1.
(c) Statement-1 is correct, statement-2 is correct and statement-2 is not the correct explanation of Statement-1
(d) Statement-1 is incorrect, statement-2 is correct.

53. A radioactive nucleus (initial mass number A and atomic number Z emits 3 α - particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be **[2010]**

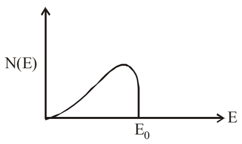
(a) $\frac{A-Z-8}{Z-4}$ (b) $\frac{A-Z-4}{Z-8}$

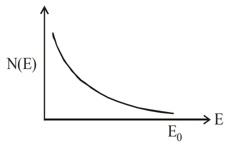
(c) $\frac{A-Z-12}{Z-4}$ (d) $\frac{A-Z-4}{Z-2}$

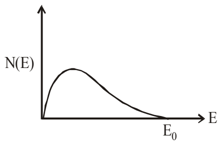
54. The half-life period of a radio-active element X is same as the mean life time of another radio-active element Y. Initially they have the same number of atoms. Then **[2007]**

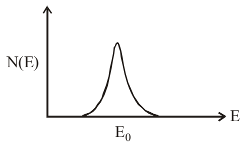
(a) X and Y decay at same rate always
(b) X will decay faster than Y
(c) Y will decay faster than X
(d) X and Y have same decay rate initially

55. The energy spectrum of β-particles [number N(E) as a function of β-energy E] emitted from a radioactive source is **[2006]**

(a) 

(b) 

(c) 

(d) 

56. Starting with a sample of pure $^{66}\mathrm{Cu}$, $\frac{7}{8}$ of it decays into Zn in 15 minutes. The corresponding half life is **[2005]**

(a) 15 minutes (b) 10 minutes
(c) $7\frac{1}{2}$ minutes (d) 5 minutes

57. The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to $\frac{I}{8}$. The thickness of lead which will reduce the intensity to $\frac{I}{2}$ will be **[2005]**

(a) 9mm (b) 6mm
(c) 12mm (d) 18mm

58. Which of the following **cannot** be emitted by radioactive substances during their decay? **[2003]**

(a) Protons (b) Neutrinoes
(c) Helium nuclei (d) Electrons

59. A nucleus with Z= 92 emits the following in a sequence:

$\alpha, \beta^-, \beta^-\ \alpha, \alpha, \alpha, \alpha, \alpha, \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$

Then Z of the resulting nucleus is **[2003]**

(a) 76 (b) 78 (c) 82 (d) 74

60. A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minutes, the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is **[2003]**

(a) 0.4 ln 2 (b) 0.2 ln 2
(c) 0.1 ln 2 (d) 0.8 ln 2

61. At a specific instant emission of radioactive compound is deflected in a magnetic field. The compound can emit

(i) electrons (ii) protons
(iii) He^{2+} (iv) neutrons

The emission at instant can be **[2002]**

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

62. If N_0 is the original mass of the substance of half-life period $t_{1/2}$ = 5 years, then the amount of substance left after 15 years is **[2002]**

(a) $N_0/8$ (b) $N_0/16$ (c) $N_0/2$ (d) $N_0/4$

Hints & Solutions

1. **(d)** Density of nucleus, $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{mA}{\frac{4}{3}\pi R^3}$

$\Rightarrow \rho = \frac{mA}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$ $\quad (\because R = R_0 A^{1/3})$

Here m = mass of a nucleon

$\therefore \rho = \frac{3 \times 1.67 \times 10^{-27}}{4 \times 3.14 \times (1.3 \times 10^{-15})^3}$ (Given, $R_0 = 1.3 \times 10^{-15}$)

$\Rightarrow \rho = 2.38 \times 10^{17}\ \text{kg/m}^3$

2. **(a)** Nuclear density is independent of atomic number.
3. **(c)** Let heavy nucleus breaks into two nuclei of mass m_1 and m_2 and move away with velocities V_1 and V_2 respectively.

According to question, $\frac{V_1}{V_2} = \frac{8}{27}$

$m_1 V_1 = m_2 V_2$ (Law of momentum conservation)

$\Rightarrow \frac{m_1}{m_2} = \frac{V_2}{V_1} = \frac{27}{8}$

$\frac{\rho \times \frac{4}{3}\pi R_1^3}{\rho \times \frac{4}{3}\pi R_2^3}$ $\quad \left(\because \text{ density } \rho = \frac{\text{mass}}{\text{volume}}\right)$

$\Rightarrow \left(\frac{R_1}{R_2}\right) = \left(\frac{27}{8}\right)^{\frac{1}{3}} = \left(\frac{3}{2}\right)^{3 \times \frac{1}{3}} \quad \therefore \frac{R_1}{R_2} = \frac{3}{2}$

4. **(b)**
5. **(b)** Radius of a nucleus,

$R = R_0 (A)^{1/3}$

Here, R_0 is a constant

A = atomic mass number

$\therefore \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$

$\Rightarrow R_2 = \frac{5}{3} \times 3.6 = 6$ fermi

6. **(d)** ${}^7_3\text{Li} + {}^1_1\text{H} \longrightarrow 2\left({}^4_2\text{He}\right)$

$\Delta m \rightarrow [m_{\text{Li}} + m_{\text{H}}] - 2[M_{\text{He}}]$

Energy released $= \Delta mc^2$

In use of 1 g Li energy released $= \frac{\Delta mc^2}{m_{\text{Li}}}$

In use of 20 g energy released $= \frac{\Delta mc^2}{m_{\text{Li}}} \times 20$ g

$= \frac{[(7.016 + 1.0079) - 2 \times 4.0026]u \times c^2}{7.016 \times 1.6 \times 10^{-24}} \times 20$ g

$= \left(\frac{0.0187 \times 1.6 \times 10^{-19} \times 10^9}{7.016 \times 1.6 \times 10^{-24}} \times 20\right) = 480 \times 10^{10}$ J

$\because 1\ \text{J} = 2.778 \times 10^{-7}$ kWh

$\therefore$ Energy released $= 480 \times 10^{10} \times 2.778 \times 10^{-7}$
$= 1.33 \times 10^6$ kWh

7. **(c)** For the momentum and energy conservation, mass defect (Δm) should be positive. Since some energy is lost in every process.

$(m_p + m_n) > m_d$

8. **(d)** Mass defect,

$\Delta m = (50 m_p + 70 m_n) - (m_{sn})$

$= (50 \times 1.00783 + 70 \times 1.008) - (119.902199)$

$= 1.096$

Binding energy $= (\Delta m)C^2 = (\Delta m) \times 931 = 1020.56$

$\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{1020.5631}{120} = 8.5$ MeV

9. **(b)** Power output of the reactor,

$P = \frac{\text{energy}}{\text{time}}$

$= \frac{2}{235} \times \frac{6.023 \times 10^{26} \times 200 \times 1.6 \times 10^{-19}}{30 \times 24 \times 60 \times 60} \simeq 60\,\text{MW}$

10. **(d)**

11. **(c)** Power level of reactor, $\text{P} = \frac{\text{E}}{\Delta \text{t}} = \frac{\Delta \text{mc}^2}{\Delta \text{t}}$

mass of the fuel consumed per hour in the reactor,

$\frac{\Delta \text{m}}{\Delta \text{t}} = \frac{\text{P}}{\text{c}^2} = \frac{10^9}{(3 \times 10^8)^2} = 4 \times 10^{-2}$ gm

12. **(c)** ${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_2\text{He}^4$

Total binding energy of two deuterium nuclei = 1.1×4 = 4.4 MeV

Binding energy of a (${}_2\text{He}^4$) nuclei = $4 \times 7 = 28$ MeV

Energy released in this process = $28 - 4.4 = 23.6$ MeV

13. **(c)** Nuclear fission equation

$$_{92}U^{135} + {}_0n^1 \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_0n^1 + Q(\text{energy})$$

Hence particle x is neutron.

14. **(a)** ${}_0^1n \longrightarrow {}_1^1H + {}_{-1}e^0 + \bar{\nu} + Q$

The mass defect during the process

$$\Delta m = m_n - m_H - m_e = 1.6725 \times 10^{-27} - (1.6725 \times 10^{-27} + 9 \times 10^{-31}\text{kg})$$

$= -9 \times 10^{-31}$ kg

The energy released during the process

$E = \Delta mc^2$

$E = 9 \times 10^{-31} \times 9 \times 10^{16} = 81 \times 10^{-15}$ Joules

$$E = \frac{81 \times 10^{-15}}{1.6 \times 10^{-19}} = 0.511\text{MeV}$$

15. **(d)**

16. **(c)** Initial momentum of system, $p_i = 0$

Let p_1 and p_2 be the momentum of broken nuclei of masses m_1 and $5m_1$ respectively.

$p_f = p_1 + p_2$

From the conservation of momentum

$p_i = p_f$

$0 = p_1 + p_2$

$p_1 = -p_2$

From de Broglie relation, wavelength

$$\lambda_1 = \frac{h}{p_1} \text{ and } \lambda_2 = \frac{h}{p_2}$$

$|\lambda_1| = |\lambda_2|$

$\lambda_1 = \lambda_2 = \lambda.$

17. **(c)** In nuclear fission, the binding energy per nucleon of daughter nuclei is always greater than the parent nucleus.

18. **(b)** Mass defect, $\Delta M = \left[(M + \Delta m) - \left(\frac{M}{2} + \frac{M}{2}\right)\right]$

$= [M + \Delta m - M] = \Delta m$

Energy released, $Q = \Delta Mc^2 = \Delta mc^2$ ...(i)

From the law of conservation of momentum

$$(M + \Delta m) \times 0 = \frac{M}{2}v_1 - \frac{M}{2} \times v_2$$

$\Rightarrow v_1 = v_2$

Now, $Q = \frac{1}{2}\left(\frac{M}{2}\right)v_1^2 + \frac{1}{2}\left(\frac{M}{2}\right)v_2^2 - \frac{1}{2}$

$(M + \Delta m) \times (0)^2$

$= \frac{M}{2}v_1^2\,(\because v_1 = v_2)$ ...(ii)

From equation (i) and (ii), we get

$$\left(\frac{M}{2}\right)v_1^2 = \Delta mc^2$$

$$\Rightarrow v_1^2 = \frac{2\Delta mc^2}{M} \qquad \Rightarrow V_1 = c\sqrt{\frac{2\Delta m}{M}}$$

19. **(d)** We know that energy is released when heavy nuclei undergo fission or light nuclei undergo fusion. Therefore statement (1) is correct.

The second statement is false because for heavy nuclei the binding energy per nucleon decreases with increasing Z and for light nuclei, B.E/nucleon increases with increasing Z.

20. **(c)** Number of protons in oxygen isotope, $Z = 8$

Number of neutrons $= 17 - 8 = 9$

Binding energy

$= [ZM_P + (A - Z)M_N - M]c^2$

$= [8M_P + (17 - 8)M_N - M]c^2$

$= [8M_P + 9M_N - M]c^2$

$= [8M_P + 9M_N - M_o]c^2$

21. **(c)** ${}_3^7Li + {}_1^1p \longrightarrow {}_4^8Be + {}_0^0\gamma$

We see that both proton number and mass number are equal in both sides, so emitted particle should be massless gamma photons.

22. **(b)** Given,

Binding energy per nucleon of ${}_3^7Li = 5.60$ MeV

Binding energy per nucleon of ${}_2^4He = 7.06$ MeV

Let E be the energy of proton, then

$E + 7 \times 5.6 = 2 \times [4 \times 7.06]$

$\Rightarrow E = 56.48 - 39.2 = 17.28\text{MeV}$

23. **(a)** ${}_ZX^A + {}_0n^1 \longrightarrow {}_3Li^7 + {}_2He^4$

Using conservation of mass number

$A + 1 = 4 + 7$

$\Rightarrow A = 10$

Using conservation of charge number

$Z + 0 = 2 + 3 \qquad \Rightarrow Z = 5$

It is boron ${}_5B^{10}$

24. **(b)** Given :

$$\frac{v_1}{v_2} = \frac{2}{1}$$

From conservation of momentum $m_1v_1 = m_2v_2$

$$\Rightarrow \left(\frac{m_1}{m_2}\right) = \left(\frac{v_2}{v_1}\right) = \frac{1}{2}$$

We know that mass of nucleus, $m \propto A$

Nuclear size $R \propto A^{1/3} \propto m^{1/3}$

$$\frac{R_1}{R_2} = \left(\frac{m_1}{m_2}\right)^{1/3} \Rightarrow \frac{R_1^3}{R_2^3} = \frac{1}{2} \quad \Rightarrow \left(\frac{R_1}{R_2}\right) = \left(\frac{1}{2}\right)^{1/3}$$

25. **(a)** The chemical reaction of process is $2{}_1^2\text{H} \rightarrow {}_2^4\text{He}$
Binding energy of two deuterons,
$4 \times 1.1 = 4.4$ MeV
Binding energy of helium nucleus $= 4 \times 7 = 28$ MeV
Energy released $= 28 - 4.4 = 23.6$ MeV

26. **(c)** Mass of α particle, $m_\alpha = 4\,u$
Mass of nucleus after fission, $m_n = 234u$ From conservation of linear momentum we have
$238 \times 0 = 4\,u + 234\,v$

$$\therefore\ v = -\frac{4}{234}u$$

$$\therefore\ \text{Speed} = |\vec{v}| = \frac{4}{234}u$$

27. **(d)** The average kinetic energy per molecule at temperature T is

$$= \frac{3}{2}kT$$

Where k = Boltzmann's constant
This kinetic energy should be able to provide the repulsive potential energy

$$\therefore\ \frac{3}{2}kT = 7.7 \times 10^{-14}$$

$$\Rightarrow T = \frac{2 \times 7.7 \times 10^{-14}}{3 \times 1.38 \times 10^{-23}} = 3.7 \times 10^{9} K$$

28. **(c)** Since, $R = R_0 e^{-\lambda t}$

$$\ln R = \ln R_0 + (-\lambda \ln t)$$

$$\lambda = \frac{\ln 2}{t_{1/2}} = \text{Slope}$$

$$\lambda_A = \frac{6}{10} \Rightarrow T_A = \frac{10}{6}\ln 2$$

$$\lambda_B = \frac{6}{5} \Rightarrow T_B = \frac{5\ln 2}{6}$$

$$\lambda_C = \frac{2}{5} \Rightarrow T_C = \frac{5\ln 2}{6}$$

$$\therefore T_{\frac{1}{2}A} : T_{\frac{1}{2}B} : T_{\frac{1}{2}C} = \frac{10}{6} : \frac{5}{6} : \frac{15}{6} = 2:1:3$$

29. **(a)** Let λ_1 and λ_2 be the decay constants of two process. N be the number of nuclei left undecayed after two process. From the law of radioactive decay we have

$$-\frac{dN}{dt} = \lambda_1 N + \lambda_2 N \qquad \left[\because -\frac{dN}{dt} = \lambda N\right]$$

$$\Rightarrow -\frac{dN}{dt} = (\lambda_1 + \lambda_2)N$$

$$\Rightarrow \lambda_{\text{eq.}} = (\lambda_1 + \lambda_2)$$

$$\Rightarrow \frac{\ln 2}{T} = \frac{\ln 2}{T_1} + \frac{\ln 2}{T_2} \qquad \left(\because \lambda = \frac{\ln 2}{T}\right)$$

$$\Rightarrow \frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2}$$

$$\Rightarrow \frac{1}{T} = \frac{1}{10} + \frac{1}{100} = \frac{11}{100} \quad [\text{Given: } T_1 = 10\text{ s} \ \&\ T_2 = 100\text{ s}]$$

$$\Rightarrow T = \frac{100}{11} = 9 \text{ sec.}$$

30. **(c)** As we know, for first order decay, $N(t) = N_0 e^{-\lambda t}$
According to question,

$$\frac{N(t)}{N_0} = \frac{9}{16} = e^{-\lambda t}$$

After time, $t/2$;

$$N(t/2) = N_0 e^{-\lambda(t/2)}$$

$$\frac{N(t/2)}{N_0} = \sqrt{e^{-\lambda t}} = \sqrt{\frac{9}{16}}$$

$$\therefore N(t/2) = \frac{3}{4}N_0$$

31. **(b)** We know that

Activity, $A = A_0 e^{-\lambda t}$

$$A = A_0 e^{-tIn2/T_{1/2}} \left(\because \lambda = \frac{In_2}{T_{1/2}}\right)$$

$$\Rightarrow\ 500 = 700\, e^{-tIn2/T_{1/2}}$$

$$\Rightarrow\ In\frac{7}{5} = \frac{30In2}{T_{1/2}} \qquad (\because\ t = 30 \text{ minute})$$

$$\Rightarrow\ T_{1/2} = 30\frac{In\,2}{In\,1.4} = 61.8 \text{ minute}$$

$(\because \ln 2 = 0.693$ and $\ln.1.4 = 0.336)$

$$\Rightarrow\ T_{1/2} \approx 62 \text{ minute}$$

32. **(a)** As, $N = N_0 e^{-\lambda t}$

$$\text{so, } \frac{N_A}{N_B} = e^{(\lambda_B - \lambda_A)t} = \frac{1}{e} \Rightarrow (\lambda_B - \lambda_A)t = -1$$

$$\Rightarrow (\lambda_A - \lambda_B) \cdot t = 1$$

$$\Rightarrow t = \frac{1}{(\lambda_B - \lambda_A)}\ t = \frac{1}{10\lambda - \lambda} = \frac{1}{9\lambda}$$

33. **(a)** Let N_1 and N_2 be the number of radioactive nuclei of substance at anytime t.

$$N_1(\text{at } t) = N_0 e^{-5\lambda t} \qquad \text{(i)}$$

$$N_2(\text{at } t) = N_0 e^{-\lambda t} \qquad \text{(ii)}$$

Dividing equation (i) by (ii), we get

$$\frac{N_1}{N_2}=\frac{1}{e^2}=e^{-4\lambda t}\Rightarrow 4\lambda t=2$$

$$\Rightarrow t=\frac{2}{4\lambda}=\left(\frac{1}{2\lambda}\right)$$

34. **(c)** When one α- particle emitted then danghter nuclei has 4 unit less mass number (A) and 2 unit less atomic (z) number (z).

$${}^{232}_{90}Th\rightarrow {}^{208}_{78}Y+6{}^{4}_{2}He$$

$${}^{208}_{78}Y\rightarrow {}^{208}_{82}X+4\beta \text{ praticle}$$

35. **(a)** According to question, at t = 0, $A0=\frac{dN}{dt}$ =1600 C/s

and at t = 8s, A = 100 C/s

$$\therefore \frac{A}{A_0}=\frac{1}{16}\text{ in } 8s$$

Therefore half life period, t1/2 = 2s

$$\therefore \text{Activity at } t=6s=1600\left(\frac{1}{2}\right)^3=200C/s$$

36. **(c)** Activity A = 1 N

For material, A 10 = (2 N0)lA

For material, B 20 = N0lB

$$\Rightarrow \lambda_B=4\lambda_A\ \therefore T_{1/2 A}=4T_{1/2 B}\left[\because T_{1/2}=\frac{0.693}{\lambda}\right]$$

i.e. 20 days half-lives for A and 5 days $\left(T_{1/2}\right)_B$ For material B.

37. **(c)** Half life of A = $\ell n2$

$$(t_{1/2})A=\frac{\ell n2}{\lambda}$$

$\therefore\ \lambda_A = 1$

at t = 0 $R_A = R_B$

$N_Ae^{-\lambda AT}=N_Be^{-\lambda BT}$

$N_A = N_B$ at t = 0

$$\text{At } t=t\ \ \frac{R_B}{R_A}=\frac{N_0e^{-\lambda_B t}}{N_0e^{-\lambda_A t}}$$

$$e^{-(\lambda_B-\lambda_A)t}=e^{-3t}$$

$$\Rightarrow \lambda_B-\lambda_A=3$$

$$\lambda_B=3+\lambda_A=4$$

$$(t_{1/2})_B=\frac{\ell n2}{\lambda_B}=\frac{\ell n2}{4}$$

38. **(b)** Given : $N_1 = 2N_2$

Activity of radioactive substance = λN

$$\text{Half life period } t=\frac{\ln 2}{\lambda}\ \text{ or, } \lambda=\frac{\ln 2}{T}$$

$$\lambda_1N_1=\frac{\ln 2}{t_1}\times N_1=5\mu c_i \quad .....(i)$$

$$\lambda_2N_2=\frac{\ln 2}{t_2}\times N_2=10\mu c_i \quad .....(ii)$$

Dividing equation (ii) by (i)

$$\frac{t_2}{t_1}\times\frac{N_1}{N_2}=\frac{1}{2}$$

$$\frac{t_2}{t_1}=\frac{1}{4}\Rightarrow t_1=4t_2$$

i.e., Half life of S_1 is four times of sample S_2.

Hence 5 years and 20 years.

39. **(d)** Let initial activity = No = 0.8 μ ci

$0.8\times3.7\times10^4$ dps

Activity in 1 cm^3 of blood at t = 10 hr,

$$n=\frac{300}{60}\text{ dps}=5\text{ dps}$$

N = Activity of whole blood at time t = 10 hr.

$$\text{Total volume of the blood in the person, } V=\frac{N}{n}$$

$$=\frac{N_0e-\lambda t}{n}=\frac{0.8\times3.7\times10^4\times0.7927}{5}\cong 5\text{ litres}$$

40. **(d)** Let initially there are total N_0 number of nuclei

At time t

$$\frac{N_B}{N_A}=0.3(\text{given})$$

$$\Rightarrow N_B=0.3N_A$$

$$N_0=N_A+N_B=N_A+0.3N_A$$

$$\therefore N_A=\frac{N_0}{1.3}$$

As we know $N_t=N_0e^{-\lambda t}$

$$\text{or, } \frac{N_0}{1.3}=N_0e^{-\lambda t}$$

$$\frac{1}{1.3}=e^{-\lambda t}\quad\Rightarrow\ ln(1.3)=\lambda t$$

$$\text{or, } t=\frac{ln(1.3)}{\lambda}\quad\Rightarrow\ t=\frac{ln(1.3)}{\frac{ln(2)}{T}}=\frac{ln(1.3)}{ln(2)}T$$

41. **(b)** For $A_{t1/2}$ = 20 min, t = 80 min, number of half lifes n = 4

$\therefore$ Nuclei remaining = $\frac{N_0}{2^4}$. Therefore nuclei decayed

$$=N_0-\frac{N_0}{2^4}$$

For $B_{t1/2}$ = 40 min., t = 80 min, number of half lifes n = 2

$\therefore$ Nuclei remaining $=\frac{N_0}{2^2}$. Therefore nuclei decayed

$=N_0-\frac{N_0}{2^2}$

$$\therefore \text{Required ratio}=\frac{N_0-\frac{N_0}{2^4}}{N_0-\frac{N_0}{2^2}}=\frac{1-\frac{1}{16}}{1-\frac{1}{4}}=\frac{15}{16}\times\frac{4}{3}=\frac{5}{4}$$

42. **(b)** We know that $N_\beta = N_0\,(1-e^{-\lambda t})$

$$N_\beta=\frac{6.023\times10^{23}}{24}\left[1-e^{\frac{\ell n\,2}{15}\times 7.5}\right]$$

on solving we get,
$N_\beta = 7.4\times10^{21}$

43. **(c)** **Given:** $\frac{dN_0}{dt}=20$ decays/min

$\frac{dN}{dt}=2$ decays/min

$T_{1/2}=5730$ years
As we know,

$N=N_0e^{-\lambda t}$

$\text{Log}\frac{N_0}{N}=\lambda t$

$\therefore\ t=\frac{1}{\lambda}\text{Log}\frac{N_0}{N}$

$=\frac{2.303\times T_{1/2}}{0.693}\times\text{Log}_{10}\frac{N_0}{N}$

But $\frac{\frac{dN_0}{dt}}{\frac{dN}{dt}}=\frac{N_0}{N}=\frac{20}{2}=10$

$\therefore\ t=\frac{2.303\times5730}{0.693}\times1$

$=19039$ years

44. **(b)** Given, for ^{14}C
$A_0=16$ dis min^{-1} g^{-1}
$A=12$ dis min^{-1} g^{-1}
$t_{1/2}=5760$ years

Now, $\lambda=\frac{0.693}{t_{1/2}}$

$\lambda=\frac{0.693}{5760}$ per year

Then, from, $t=\frac{2.303}{\lambda}\log_{10}\frac{A_0}{A}$

$=\frac{2.303\times5760}{0.693}\log_{10}\frac{16}{12}$

$=\frac{2.303\times5760}{0.693}\log_{10}1.333$

$=\frac{2.303\times5760\times0.1249}{0.693}=2390.81\approx2391$ years.

45. **(b)** Let N be the number of nuclei at any time t then,

$\frac{dN}{dt}=100-\lambda N$ or $\int_0^N\frac{dN}{(100-\lambda N)}=\int_0^t dt$

$-\frac{1}{\lambda}[\log(100-\lambda N)]_0^N=t$

$\log(100-\lambda N)-\log100=-\lambda t$

$\log\frac{100-\lambda N}{100}=-\lambda t$

$\frac{100-\lambda N}{100}=e^{-\lambda t}$ $\quad 1-\frac{\lambda N}{100}=e^{-\lambda t}$

$N=\frac{100}{\lambda}(1-e^{-\lambda}t)$

As, $N=50$ and $\lambda=0.5$/sec

$\therefore\quad 50=\frac{100}{0.5}(1-e^{-0.5t})$

Solving we get,

$t=2\ln\left(\frac{4}{3}\right)$ sec

46. **(d)** $(T_{1/2})_A=(t_{mean})_B$

$\Rightarrow\frac{0.693}{\lambda_A}=\frac{1}{\lambda_B}\Rightarrow\lambda_A=0.693\lambda_B$

or $\quad\lambda_A<\lambda_B$

Also rate of decay = λN
Initially number of atoms (N) of both are equal but since $\lambda_B>\lambda_A$, therefore B will decay at a faster rate than A

47. **(d)** As we know,

$$\left[\frac{N}{N_0}\right]=\left[\frac{1}{2}\right]^n \qquad ...(i)$$

n = no. of half life
N - no. of atoms left
N_0 - initial no. of atoms
By radioactive decay law,

$$\frac{dN}{dt} = kN$$

k - disintegration constant

$$\therefore \quad \frac{\frac{dN}{dt}}{\frac{dN_0}{dt}} = \frac{N}{N_0} \qquad \text{...(ii)}$$

From (i) and (ii) we get

$$\frac{\frac{dN}{dt}}{\frac{dN_0}{dt}} = \left[\frac{1}{2}\right]^n$$

$$\text{or, } \left[\frac{100}{1600}\right] = \left[\frac{1}{2}\right]^n \Rightarrow \left[\frac{1}{2}\right]^4 = \left[\frac{1}{2}\right]^n$$

$\therefore n = 4$, Therefore, in 8 seconds 4 half life had occurred in which counting rate reduces to 100 counts s^{-1}.

$\therefore$ Half life, $T_{\frac{1}{2}} = 2$ sec

In 6 sec, 3 half life will occur

$$\therefore \left[\frac{\frac{dN}{dt}}{1600}\right] = \left[\frac{1}{2}\right]^3 \Rightarrow \frac{dN}{dt} = 200 \text{ counts } s^{-1}$$

48. (c) $T_{av} = \dfrac{T_\alpha T_\beta}{T_\alpha + T_\beta}$

If α and B are emitted simultaneously.

49. (a) Radioactive decay is a continuous process. Rate of radioactive decay cannot be controlled. Nuclear fission can be controlled but not of nuclear fusion.

50. (b)

51. (b) Number of undecayed atom after time t_2 ;

$$\frac{N_0}{3} = N_0 e^{-\lambda t_2} \qquad \text{...(i)}$$

Number of undecayed atom after time t_1;

$$\frac{2N_0}{3} = N_0 e^{-\lambda t_1} \qquad \text{...(ii)}$$

Dividing (ii) by (i), we get

$$2 = e^{\lambda(t_2 - t_1)}$$

$\Rightarrow$ In $2 = \lambda(t_2 - t_1)$
$\Rightarrow t_2 - t_1 =$ In $2/\lambda$

52. (b) Statement-1: A nucleus having energy E_1 decays by β- emission to daughter nucleus having energy E_2 then β- rays are emitted with continuous energy spectrum with energy $E_1 - E_2$.
Statement-2: For energy conservation and momentum conservation at least three particles, daughter nucleus, β particle and antineutrino are required.

53. (b) When a radioactive nucleus emits 1 α-particle, the mass number decreases by 4 units and atomic number decreases by 2 units. When a radioactive nucleus emits 1 positron the atomic number decreases by 1 unit but mass number remains constant.
$\therefore$ Mass number of final nucleus $= A - 12$
Atomic number of final nucleus $= Z - 8$
$\therefore$ Number of neutrons, $N_n = (A-12) - (Z-8) = A - Z - 4$
Number of protons, $N_p = Z - 8$

$$\therefore \text{ Required ratio} = \frac{N_n}{N_p} = \frac{A - Z - 4}{Z - 8}$$

54. (c) Let λ_X and λ_Y be the decay constant of X and Y.
Half life of X, = average life of Y

$$T_{1/2} = T_{av}$$

$$\Rightarrow \frac{0.693}{\lambda_X} = \frac{1}{\lambda_Y}$$

$$\Rightarrow \lambda_X = (0.693).\lambda_Y$$

$\therefore \lambda_X < \lambda_Y$.
Now, the rate of decay is given by

$$-\left(\frac{dN}{dt}\right)_x = \lambda_X N_0$$

$$-\left(\frac{dN}{dt}\right)_y = \lambda_y N_0$$

As the rate of decay is directly proportional to decay constant, Y will decay faster than X.

55. (c) The range of energy of β-particles is from zero to some maximum value.

56. (d) It is given that

$\frac{7}{8}$ of Cu decays in 15 minutes.

$\therefore$ Cu left undecayed is

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

$\therefore$ No. of half lifes = 3

$$n = \frac{t}{T} \Rightarrow 3 = \frac{15}{T}$$

$$\Rightarrow T = \text{half life period} = \frac{15}{3} = 5 \text{ minutes}$$

57. (c) Let intensity of gamma radiation from source be I_0.

Intensity $I = I_0.e^{-\mu d}$,

Where d is the thickness of lead.
Applying logarithm on both sides,

$$-\mu d = \log\left(\frac{I}{I_0}\right)$$

For $d = 36$ mm, intensity $= \frac{I}{8}$

$$-\mu \times 36 = \log\left(\frac{I/8}{I}\right) \quad ....(i)$$

For intensity $I/2$, thickness $= d$

$$-\mu \times d = \log\left(\frac{I/2}{I}\right) \quad ....(ii)$$

Dividing (i) by (ii),

$$\frac{36}{d} = \frac{\log\left(\frac{1}{8}\right)}{\log\left(\frac{1}{2}\right)} = \frac{3\log\left(\frac{1}{2}\right)}{\log\left(\frac{1}{2}\right)} = 3 \text{ or } d = \frac{36}{3} = 12 \text{ mm}$$

58. **(a)** The radioactive substances emit α -particles (Helium nucleus), β-particles (electrons) and neutrinoes. Protons cannot be emitted by radioactive substances during their decay.

59. **(b)** The number of α-particles released = 8

Decrease in atomic number = 8 × 2 = 16

The number of β^--particles released = 4

Increase in atomic number = 4 × 1 = 4

Also the number of β^+ particles released is 2, which should decrease the atomic number by 2.

Therefore the final atomic number of resulting nucleus

$= Z - 16 + 4 - 2 = Z - 14$

$= 92 - 14 = 78$

60. **(a)** Initial activity, $A_o = 5000$ disintegration per minute

Activity after 5 min, $A = 1250$ disintegration per minute

$A = A_o e^{-\lambda t}$

$$\Rightarrow e^{-\lambda t} = \frac{A_o}{A}$$

$$\Rightarrow \lambda = \frac{1}{t}\log_e \frac{A_o}{A} = \frac{1}{5}\log_e \frac{5000}{1250}$$

$$= \frac{2}{5}\log_e 2 = 0.4 \log_e 2$$

61. **(a)** Charged particles are deflected in magnetic field. Electrons, protons and He^{2+} all are charged species. Hence, correct option is (a).

62. **(a)** After every half-life, the mass of the substance reduces to half its initial value.

$$N_0 \xrightarrow{\text{5 years}} \frac{N_0}{2} \xrightarrow{\text{5 years}} \frac{N_0/2}{2}$$

$$= \frac{N_0}{4} \xrightarrow{\text{5years}} \frac{N_0/4}{2} = \frac{N_0}{8}$$