CHAPTER

18 Atoms and Nuclei

1. An electron from various excited states of hydrogen atom emit radiation to come to the ground state. Let λ_n, λ_g be the de Broglie wavelength of the electron in the n^{th} state and the ground state respectively. Let Λ_n be the wavelength of the emitted photon in the transition from the n^{th} state to the ground state. For large n, (A, B are constants)
(a) $\Lambda_n \approx A + \frac{B}{\lambda_n^2}$ (b) $\Lambda_n \approx A + B\lambda_n$
(c) $\Lambda_n^2 \approx A + B\lambda_n^2$ (d) $\Lambda_n^2 \approx \lambda$ *(2018)*

2. If the series limit frequency of the Lyman series is υ_L, then the series limit frequency of the Pfund series is
(a) $25\ \upsilon_L$ (b) $16\ \upsilon_L$ (c) $\upsilon_L/16$ (d) $\upsilon_L/25$ *(2018)*

3. It is found that if a neutron suffers an elastic collinear collision with deuterium at rest, fractional loss of its energy is p_d ; while for its similar collision with carbon nucleus at rest, fractional loss of energy is p_c. The values of p_d and p_c are respectively
(a) (0.89, 0.28) (b) (0.28, 0.89)
(c) (0, 0) (d) (0, 1) *(2018)*

4. A solution containing active cobalt $^{60}_{27}\text{Co}$ having activity of 0.8 μCi and decay constant λ is injected in an animal's body. If 1 cm^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 ? (1 Ci = 3.7×10^{10} decays per second and at t = 10 hrs, $e^{-\lambda t} = 0.84$).
(a) 4 litres (b) 7 litres (c) 5 litres (d) 6 litres *(Online 2018)*

5. The energy required to remove the electron from a singly ionized Helium atom is 2.2 times the energy required to remove an electron from Helium atom. The total energy required to ionize the Helium atom completely is
(a) 34 eV (b) 79 eV (c) 20 eV (d) 109 eV *(Online 2018)*

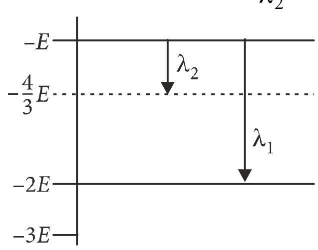
6. Muon (μ^-) is a negatively charged ($|q| = |e|$) particle with a mass $m_\mu = 200\ m_e$, where m_e is the mass of the electron and e is the electronic charge. If μ^- is bound to a proton to form a hydrogen like atom, identify the correct statements.
(A) Radius of the muonic orbit is 200 times smaller than that of the electron.
(B) The speed of the μ^- in the n^{th} orbit is $\frac{1}{200}$ times that of the electron in the n^{th} orbit.
(C) The ionization energy of muonic atom is 200 times more than that of an hydrogen atom.
(D) The momentum of the muon in the n^{th} orbit is 200 times more than that of the electron.
(a) A, B, D (b) B, D
(c) A, C, D (d) C, D *(Online 2018)*

7. 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
(a) 3 : 2 (b) 2 : 3 (c) 4 : 9 (d) 8 : 27 *(Online 2018)*

8. Both the nucleus and the atom of some element are in their respective first excited states. They get de-excited by emitting photons of wavelengths λ_N, λ_A respectively. The ratio is $\frac{\lambda_N}{\lambda_A}$ closest to
(a) 10 (b) 10^{-6} (c) 10^{-10} (d) 10^{-1} *(Online 2018)*

9. At some instant, a radioactive sample S_1 having an activity 5 μCi 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 are
(a) 20 years and 10 years, respectively
(b) 10 years and 20 years, respectively
(c) 20 years and 5 years, respectively
(d) 5 years and 20 years, respectively *(Online 2018)*

10. Some energy levels of a molecule are shown in the figure. The ratio of the wavelengths $r = \frac{\lambda_1}{\lambda_2}$ is given by



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

(2017)

11. 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

(a) $t=\frac{T}{2}\frac{\log 2}{\log(1.3)}$ (b) $t=T\frac{\log(1.3)}{\log 2}$

(c) $t = T \log(1.3)$ (d) $t=\frac{T}{\log(1.3)}$ *(2017)*

12. According to Bohr's theory, the time averaged magnetic field at the centre (i.e. nucleus) of a hydrogen atom due to the motion of electrons in the n^{th} orbit is proportional to (n = principal quantum number)

(a) n^{-2} (b) n^{-3}

(c) n^{-4} (d) n^{-5} *(Online 2017)*

13. 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)

(a) 25.8 MeV (b) 32.4 MeV

(c) 30.2 MeV (d) 23.6 MeV

(Online 2017)

14. 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)

(a) 4×10^{-2} gm (b) 6.6×10^{-5} gm

(c) 0.8 gm (d) 0.96 gm

(Online 2017)

15. The acceleration of an electron in the first orbit of hydrogen atom ($n = 1$) is

(a) $\frac{h^2}{\pi^2 m^2 r^3}$ (b) $\frac{h^2}{4\pi^2 m^2 r^3}$

(c) $\frac{h^2}{4\pi m^2 r^3}$ (d) $\frac{h^2}{8\pi^2 m^2 r^3}$

(Online 2017)

16. 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 numbers of A and B nuclei will be

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

(2016)

17. A hydrogen atom makes a transition from $n = 2$ to $n = 1$ and emits a photon. This photon strikes a doubly ionized lithium atom ($Z = 3$) in excited state and completely removes the orbiting electron. The least quantum number for the excited state of the ion for the process is

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

(Online 2016)

18. A neutron moving with a speed 'v' makes a head on collision with a stationary hydrogen atom in ground state. The minimum kinetic energy of the neutron for which inelastic collision will take place is

(a) 20.4 eV (b) 10.2 eV

(c) 12.1 eV (d) 16.8 eV *(Online 2016)*

19. As an electron makes a transition from an excited state to the ground state of a hydrogen -like atom/ion

(a) kinetic energy decreases, potential energy increases but total energy remains same

(b) kinetic energy and total energy decrease but potential energy increases

(c) its kinetic energy increases but potential energy and total energy decrease

(d) kinetic energy, potential energy and total energy decrease.

(2015)

20. If one were to apply Bohr model to a particle of mass m and charge q moving in a plane under the influence of a magnetic field B, the energy of the charged particle in the n^{th} level will be

(a) $\left(\frac{X}{7\pi}\right)$ (b) $\left(\frac{X}{9\pi}\right)$

(c) $\left(\frac{X}{=\pi}\right)$ (d) $\left(\frac{X}{\pi}\right)$

(Online 2015)

21. 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)

(a) 6.2×10^{21} (b) 7.5×10^{21}

(c) 1.25×10^{22} (d) 1.75×10^{22}

(Online 2015)

22. The radiation corresponding to $3 \to 2$ transition of hydrogen atom falls on a metal surface to produce photoelectrons. These electrons are made to enter a magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by these electrons is 10.0 mm, the work function of the metal is close to

(a) 1.6 eV (b) 1.8 eV (c) 1.1 eV (d) 0.8 eV

(2014)

23. Hydrogen (${}_1H^1$), Deuterium (${}_1H^2$), singly ionised Helium $({}_2He^4)^+$ and doubly ionised lithium $(3Li^6)^{++}$ all have one electron around the nucleus. Consider an electron transition from $n = 2$ to $n = 1$. If the wavelengths of emitted radiation are λ_1, λ_2, λ_3 and λ_4 respectively then approximately which one of the following is correct?

(a) $\lambda_1 = 2\lambda_2 = 3\lambda_3 = 4\lambda_4$ (b) $4\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$

(c) $\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$ (d) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$

(2014)

24. In a hydrogen like atom electron makes transition from an energy level with quantum number n to another with quantum number $(n - 1)$. If $n >> 1$, the frequency of radiation emitted is proportional to

(a) $\frac{1}{n^3}$ (b) $\frac{1}{n}$ (c) $\frac{1}{n^2}$ (d) $\frac{1}{n^{3/2}}$

(2013)

25. Hydrogen atom is excited from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be
(a) 3 (b) 5 (c) 6 (d) 2 *(2012)*

26. 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)
(a) 7.10 MeV (b) 6.30 MeV
(c) 5.4 MeV (d) 0.73 MeV *(2012)*

27. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r. If we calculate its rotational energy by applying Bohr's rule of angular momentum quantization, its energy will be given by (n is an integer)
(a) $\dfrac{n^2h^2}{2(m_1+m_2)r^2}$ (b) $\dfrac{2n^2h^2}{(m_1+m_2)r^2}$
(c) $\dfrac{(m_1+m_2)n^2h^2}{2m_1m_2r^2}$ (d) $\dfrac{(m_1+m_2)^2n^2h^2}{2m_1^2m_2^2r^2}$ *(2012)*

28. Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is
(a) 12.1 eV (b) 36.3 eV
(c) 108.8 eV (d) 122.4 eV *(2011)*

29. 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 has decayed and time t_1 when $\frac{1}{3}$ of it had decayed is
(a) 7 min (b) 14 min
(c) 20 min (d) 28 min *(2011)*

30. A radioactive nucleus (initial mass number A and atomic number Z) emits 3α-particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be
(a) $\dfrac{A-Z-4}{Z-2}$ (b) $\dfrac{A-Z-8}{Z-4}$
(c) $\dfrac{A-Z-4}{Z-8}$ (d) $\dfrac{A-Z-12}{Z-4}$ *(2010)*

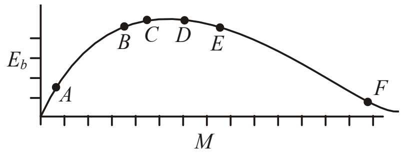
Directions : Questions number 31-32 are based on the following paragraph.

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.

31. The speed of daughter nuclei is
(a) $c\sqrt{\dfrac{\Delta m}{M+\Delta m}}$ (b) $c\dfrac{\Delta m}{M+\Delta m}$
(c) $c\sqrt{\dfrac{2\Delta m}{M}}$ (d) $c\sqrt{\dfrac{\Delta m}{M}}$

32. The binding energy per nucleon for the parent nucleus is E_1 and that for the daughter nuclei is E_2. Then
(a) $E_1 = 2E_2$ (b) $E_2 = 2E_1$
(c) $E_1 > E_2$ (d) $E_2 > E_1$ *(2010)*

33. The transition from the state $n = 4$ to $n = 3$ in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from
(a) $2 \to 1$ (b) $3 \to 2$
(c) $4 \to 2$ (d) $5 \to 4$ *(2009)*

34. 

The above is a plot of binding energy per nucleon E_b, against the nuclear mass M; A, B, C, D, E, F correspond to different nuclei. Consider four reactions
(i) $A + B \to C + \varepsilon$ (ii) $C \to A + B + \varepsilon$
(iii) $D + E \to F + \varepsilon$ (iv) $F \to D + E + \varepsilon$
where ε is the energy released. In which reactions is ε positive?
(a) (i) and (iv) (b) (i) and (iii)
(c) (ii) and (iv) (d) (ii) and (iii) *(2009)*

Directions : Question 35 contains statement-1 and statement-2. Of the four choices given, choose the one that best describes the two statements.

35. Statement-1 : Energy is released when heavy nuclei undergo fission or 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.
(a) Statement-1 is true, statement-2 is false.
(b) Statement-1 is false, statement-2 is true.
(c) Statement-1 is true, statement-2 is true; statement 2 is a correct explanation for statement-1.
(d) Statement-1 is true, statement-2 is true; statement-2 is not a correct explanation for statement-1.
(2008)

36. Suppose an electron is attracted towards the origin by a force k/r where k is a constant and r is the distance of the electron from the origin. By applying Bohr model to this system, the radius of the n^{th} orbital of the electron is found to be r_n and the kinetic energy of the electron to be T_n. Then which of the following is true?
(a) $T_n \propto \frac{1}{n}$, $r_n \propto n^2$ (b) $T_n \propto \frac{1}{n^2}$, $r_n \propto n^2$
(c) T_n independent of n, $r_n \propto n$
(d) $T_n \propto \frac{1}{n}$, $r_n \propto n$ *(2008)*

37. Which of the following transitions in hydrogen atoms emit photons of highest frequency ?
(a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 6$
(c) $n = 6$ to $n = 2$ (d) $n = 2$ to $n = 1$ *(2007)*

38. 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
(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. *(2007)*

39. In gamma ray emission from a nucleus
(a) only the proton number changes
(b) both the neutron number and the proton number change
(c) there is no change in the proton number and the neutron number
(d) only the neutron number changes. *(2007)*

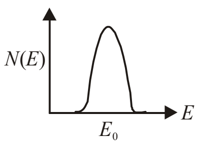
40. If M_O is the mass of an oxygen isotope ${}_8O^{17}$, M_P and M_N are the masses of a proton and a neutron respectively, the nuclear binding energy of the isotope is
(a) $(M_O - 17\,M_N)\,c^2$ (b) $(M_O - 8\,M_P)\,c^2$
(c) $(M_O - 8\,M_P - 9\,M_N)\,c^2$ (d) $M_O\,c^2$ *(2007)*

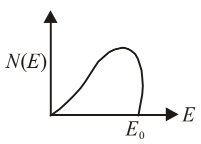
41. If the binding energy per nucleon in ${}^7_3\text{Li}$ and ${}^4_2\text{He}$ nuclei are 5.60 MeV and 7.06 MeV respectively, then in the reaction : $p + {}^7_3\text{Li} \rightarrow 2\,{}^4_2\text{He}$, energy of proton must be
(a) 39.2 MeV (b) 28.24 MeV
(c) 17.28 MeV (d) 1.46 MeV *(2006)*

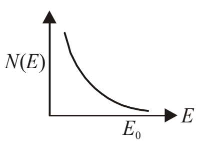
42. The 'rad' is the correct unit used to report the measurement of
(a) the rate of decay of radioactive source
(b) the ability of a beam of gamma ray photons to produce ions in a target
(c) the energy delivered by radiation to target
(d) the biological effect of radiation. *(2006)*

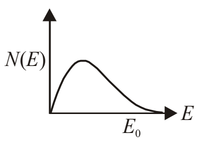
43. When ${}_3\text{Li}^7$ nuclei are bombarded by protons, and the resultant nuclei are ${}_4\text{Be}^8$, the emitted particles will be
(a) neutrons (b) alpha particles
(c) beta particles (d) gamma photons *(2006)*

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

(a) 

(b) 

(c) 

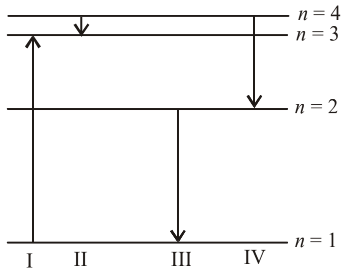
(d) 

(2006)

45. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to
(a) $1/Ze$ (b) v^2 (c) $1/m$ (d) $1/v^4$ *(2006)*

46. A nuclear transformation is denoted by $X(n, \alpha)\,{}^7_3\text{Li}$. Which of the following is the nucleus of element X?
(a) ${}^9_5\text{B}$ (b) ${}^{11}_4\text{Be}$ (c) ${}^{12}_6\text{C}$ (d) ${}^{10}_5\text{B}$ *(2005)*

47. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy?



(a) I (b) II (c) III (d) IV *(2005)*

48. Starting with a sample of pure ${}^{66}\text{Cu}$, 7/8 of it decays into Zn in 15 minutes. The corresponding half-life is
(a) 5 minutes (b) $7\frac{1}{2}$ minutes
(c) 10 minutes (d) 14 minutes *(2005)*

49. The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to $I/8$. The thickness of lead which will reduce the intensity to $I/2$ will be
(a) 18 mm (b) 12 mm
(c) 6 mm (d) 9 mm *(2005)*

50. If radius of the ${}^{27}_{13}\text{Al}$ nucleus is estimated to be 3.6 fermi then the radius of ${}^{125}_{52}\text{Al}$ nucleus be nearly
(a) 4 fermi (b) 5 fermi
(c) 6 fermi (d) 8 fermi *(2005)*

51. An α-particle of energy 5 MeV is scattered through 180° by a fixed uranium nucleus. The distance of the closest approach is of the order of
(a) 1 Å (b) 10^{-10} cm
(c) 10^{-12} cm (d) 10^{-15} cm. *(2004)*

52. The binding energy per nucleon of deuteron $\left({}^2_1\text{H}\right)$ and helium nucleus $\left({}^4_2\text{He}\right)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is
(a) 13.9 MeV (b) 26.9 MeV
(c) 23.6 MeV (d) 19.2 MeV *(2004)*

53. A nucleus disintegrates into two nuclear parts which have their velocities in the ratio 2 : 1. The ratio of their nuclear sizes will be
(a) $2^{1/3} : 1$ (b) $1 : 3^{1/2}$ (c) $3^{1/2} : 1$ (d) $1 : 2^{1/3}$ *(2004)*

54. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is
(a) 30.6 eV (b) 13.6 eV
(c) 3.4 eV (d) 122.4 eV *(2003)*

55. The wavelengths involved in the spectrum of deuterium ($^2_1$D) are slightly different from that of hydrogen spectrum, because
(a) size of the two nuclei are different
(b) nuclear forces are different in the two cases
(c) masses of the two nuclei are different
(d) attraction between the electron and the nucleus is different in the two cases.
(2003)

56. Which of the following atoms has the lowest ionization potential?
(a) $^{14}_{7}$N (b) $^{133}_{55}$Cs (c) $^{40}_{18}$Ar (d) $^{16}_{8}$O *(2003)*

57. In the nuclear fusion reaction,
$^2_1\text{H}+^3_1\text{H} \rightarrow ^4_2\text{He}+n$ given that the repulsive potential energy between the two nuclei is ~ 7.7×10^{-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]
(a) 10^7 K (b) 10^5 K
(c) 10^3 K (d) 10^9 K *(2003)*

58. Which of the following cannot be emitted by radioactive substances during their decay?
(a) protons (b) neutrinos
(c) helium nuclei (d) electrons *(2003)*

59. A nucleus with $Z = 92$ emits the following in a sequence: $\alpha, \alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha, \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$. The Z of the resulting nucleus is
(a) 76 (b) 78
(c) 82 (d) 74 *(2003)*

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
(a) 0.4 ln 2 (b) 0.2 ln 2
(c) 0.1 ln 2 (d) 0.8 ln 2 *(2003)*

61. When U^{238} nucleus originally at rest, decays by emitting an alpha particle having a speed u, the recoil speed of the residual nucleus is
(a) $\frac{4u}{238}$ (b) $-\frac{4u}{234}$ (c) $\frac{4u}{234}$ (d) $-\frac{4u}{238}$ *(2003)*

62. Which of the following radiations has the least wavelength?
(a) γ-rays (b) β-rays
(c) α-rays (d) X-rays *(2003)*

63. 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
(a) $N_0/8$ (b) $N_0/16$ (c) $N_0/2$ (d) $N_0/4$ *(2002)*

64. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from $n = 2$ is
(a) 10.2 eV (b) 0 eV
(c) 3.4 eV (d) 6.8 eV *(2002)*

65. 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 the instant can be
(a) i, ii, iii (b) i, ii, iii, iv
(c) iv (d) ii, iii *(2002)*

ANSWER KEY

1. (a)	**2.** (d)	**3.** (a)	**4.** (c)	**5.** (b)	**6.** (c)	**7.** (a)	**8.** (b)	**9.** (c)	**10.** (d)	**11.** (b)	**12.** (d)
13. (d)	**14.** (a)	**15.** (b)	**16.** (d)	**17.** (b)	**18.** (a)	**19.** (c)	**20.** (b)	**21.** (b)	**22.** (c)	**23.** (d)	**24.** (a)
25. (c)	**26.** (*)	**27.** (c)	**28.** (c)	**29.** (c)	**30.** (c)	**31.** (c)	**32.** (d)	**33.** (d)	**34.** (a)	**35.** (a)	**36.** (c)
37. (d)	**38.** (b)	**39.** (c)	**40.** (c)	**41.** (c)	**42.** (d)	**43.** (d)	**44.** (d)	**45.** (c)	**46.** (d)	**47.** (c)	**48.** (a)
49. (b)	**50.** (c)	**51.** (c)	**52.** (c)	**53.** (d)	**54.** (a)	**55.** (c)	**56.** (b)	**57.** (d)	**58.** (a)	**59.** (b)	**60.** (a)
61. (b)	**62.** (a)	**63.** (a)	**64.** (c)	**65.** (a)							

Explanations

1. (a): Momentum of electron in different states

$$p_n = \frac{h}{\lambda_n},\ p_g = \frac{h}{\lambda_g}$$

Kinetic energy, $K = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

Total energy in an orbit of hydrogen atom, $E = -K = -\frac{h^2}{2m\lambda^2}$

$$E_n - E_g = \frac{h^2}{2m}\left(\frac{1}{\lambda_g^2} - \frac{1}{\lambda_n^2}\right)$$

$$\frac{h^2}{2m}\left(\frac{\lambda_n^2 - \lambda_g^2}{\lambda_g^2\,\lambda_n^2}\right) = \frac{hc}{\Lambda_n};\quad \Lambda_n = \frac{2mc}{h}\left(\frac{\lambda_g^2\,\lambda_n^2}{\lambda_n^2 - \lambda_g^2}\right)$$

$$\Lambda_n = \frac{2mc\lambda_g^2}{h}\left[1 - \frac{\lambda_g^2}{\lambda_n^2}\right]^{-1} = \frac{2mc\lambda_g^2}{h}\left[1 + \frac{\lambda_g^2}{\lambda_n^2}\right]\quad (\because\ \lambda_g << \lambda_n)$$

$$= \frac{2mc\lambda_g^2}{h} + \left(\frac{2mc\lambda_g^4}{h}\right)\frac{1}{\lambda_n^2} = A + \frac{B}{\lambda_n^2}$$

where A and B are $A = \frac{2mc\lambda_g^2}{h},\ B = \frac{2mc\lambda_g^4}{h}$

2. (d): Frequency of emitted photon in a hydrogen atom is given by $\upsilon = Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For Lyman series, series limit condition is given by $n_2 = \infty$, $n_1 = 1$.

$$\therefore\ \upsilon_L = Rc\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = Rc \qquad \text{...(i)}$$

For Pfund series, series limit condition is given by, $n_2 = \infty$, $n_1 = 5$

$$\therefore\ \upsilon_P = Rc\left(\frac{1}{5^2} - \frac{1}{\infty^2}\right) = \frac{Rc}{25} \qquad \text{...(ii)}$$

From equation (i) and (ii), $\upsilon_P = \frac{\upsilon_L}{25}$

3. (a): Let initial speed of neutron is v_0 and kinetic energy is K.

For 1[st] collision : $\underset{m}{(n)} \xrightarrow{v_0} \underset{2m}{(D)} \Rightarrow \underset{m}{(n)} \xrightarrow{v_1} \underset{2m}{(D)} \xrightarrow{v_2}$

Using momentum conservation principle,

$$mv_0 = mv_1 + 2mv_2 \Rightarrow v_1 + 2v_2 = v_0 \qquad \text{...(i)}$$

As, $e = 1$; $\therefore$ $v_2 - v_1 = v_0$ ...(ii)

From eqns. (i) and (ii), we get $\Rightarrow$ $v_2 = \frac{2v_0}{3}$; $v_1 = -\frac{v_0}{3}$

Fractional loss of energy $= \dfrac{\frac{1}{2}mv_0^2 - \frac{1}{2}m\left(-\frac{v_0}{3}\right)^2}{\frac{1}{2}mv_0^2}$

$$\Rightarrow\ p_d = \frac{8}{9} \approx 0.89$$

For 2[nd] collision : $\underset{m}{(n)} \xrightarrow{v_0} \underset{12m}{(C)} \Rightarrow \underset{m}{(n)} \xrightarrow{v_1} \underset{12m}{(C)} \xrightarrow{v_2}$

Using momentum conservation principle,

$$mv_0 = mv_1 + 12mv_2 \Rightarrow v_1 + 12v_2 = v_0 \qquad \text{...(i)}$$

As $e = 1$; $\therefore$ $v_2 - v_1 = v_0$ ...(ii)

From eqns. (i) and (ii), we get $v_2 = \frac{2v_0}{13}$; $v_1 = \frac{-11v_0}{13}$

Now fraction loss of energy

$$p_c = \frac{\frac{1}{2}mv_0^2 - \frac{1}{2}m\left(-\frac{11v_0}{13}\right)^2}{\frac{1}{2}mv_0^2} = \frac{48}{169} \approx 0.28$$

4. (c): Let total volume of blood is V.

Initial activity $A_0 = 0.8\ \mu$Ci

Its activity at time t, $A = A_0e^{-\lambda t}$

Activity of x volume, $A_1 = \left(\frac{A}{V}\right)x = x\left(\frac{A_0}{V}\right)e^{-\lambda t}$

$$V = x\left(\frac{A_0}{A_1}\right)e^{-\lambda t} \text{ or } V = (1\text{cm}^3)\left(\frac{8\times10^{-7}\times3.7\times10^{10}}{300/60}\right)(0.84)$$

$= 4.97 \times 10^3$ cm^3 = 4.97 litres ≈ 5 litres

5. (b): Energy required to remove an electron from singly ionized helium atom = 54.4 eV.

Energy required to remove the electron from helium atom = x eV

Given 54.4 eV = $2.2x \Rightarrow x$ = 24.73 eV

Total energy required to ionize helium atom

= 54.4 + 24.73 = 79.13 eV

6. (c)

7. (a): As, $\frac{v_1}{v_2} = \frac{8}{27}$; $\frac{r_1}{r_2} = ?$

Using law of conservation of linear momentum, $0 = m_1v_1 - m_2v_2$

(As both are moving in opposite directions.)

$$\text{or } \frac{m_1}{m_2} = \frac{v_2}{v_1} = \frac{27}{8} \text{ or } \frac{\rho\left(\frac{4}{3}\pi r_1^3\right)}{\rho\left(\frac{4}{3}\pi r_2^3\right)} = \frac{27}{8}\quad \therefore\quad \frac{r_1}{r_2} = \frac{3}{2}$$

8. (b): As photon energy, $E = \frac{hc}{\lambda}$ $\therefore$ $\frac{\lambda_N}{\lambda_A} = \frac{E_A}{E_N}$

where E_A and E_N are energies of photons from atom and nucleus respectively. E_N is of the order of MeV and E_a in few eV.

So $\frac{\lambda_N}{\lambda_A} = 10^{-6}$

9. (c): As per question, $N_1 = 2N_2$

Also $A_1 = 5\ \mu$Ci, $A_2 = 10\ \mu$Ci

$$\text{As, } A = \lambda N = \frac{\ln 2}{T_{1/2}}N\quad \therefore\quad \frac{A_1}{A_2} = \frac{(T_{1/2})_2}{(T_{1/2})_1}\times\frac{N_1}{N_2}$$

$$\frac{(T_{1/2})_1}{(T_{1/2})_2} = \frac{N_1}{N_2}\times\frac{A_2}{A_1} = 2\times2 = 4$$

10. (d): We know, $\lambda = \frac{hc}{E}$ *i.e.* $\lambda \propto \frac{1}{\text{energy difference}}$

Now, $\lambda_1 = \frac{hc}{-E-(-2E)} = \frac{hc}{E}$ ...(i)

$\lambda_2 = \frac{hc}{-E-\left(-\frac{4}{3}E\right)} = \frac{hc}{\left(\frac{E}{3}\right)}$ ...(ii)

Dividing eqn. (i) by eq. (ii), we get $\frac{\lambda_1}{\lambda_2} = \frac{1}{3}$

11. (b): Let N_A and N_B be the number of molecules of A and B after time t.

Also, after time t, $\frac{N_B}{N_A} = 0.3$

Also, let N_0 be the total number of nucleus initially.
After time $t, N_A + N_B = N_0$

$N_A + 0.3N_A = N_0 \quad \therefore \quad N_A = \frac{N_0}{1.3}$

Also, rate of disintegration of A

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

$\Rightarrow \quad \frac{N_0}{1.3} = N_0 e^{-\lambda t};\ \frac{1}{1.3} = e^{-\lambda t}$ or $\ln(1.3) = \lambda t$ or $t = \frac{\ln(1.3)}{\lambda}$

$\therefore \quad t = \frac{T\ln(1.3)}{\ln(2)} = \frac{T\log(1.3)}{\log 2} \quad \left(\because \text{ half-life } T = \frac{\ln 2}{\lambda}\right)$

12. (d): Magnetic field at the centre, $B_n = \frac{\mu_0 I}{2r_n}$

For a hydrogen atom, radius of n^{th} orbit is given by

$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2} \quad \therefore r_n \propto n^2$

$I = \frac{e}{T} = \frac{e}{2\pi r_n / v_n} = \frac{ev_n}{2\pi r_n}$

Also, $v_n \propto n^{-1}$ $\therefore$ $I \propto n^{-3}$ Hence, $B_n \propto n^{-5}$

13. (d): ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4$
Energy released $= 4(\text{B.E.}({}_1{}^2\text{H})) - 4(\text{B.E.}({}_2{}^4\text{He}))$
$= 4 \times 7 - 4 \times 1.1 = 23.6$ MeV

14. (a): Here, $P = 10^9$ W, $c = 3 \times 10^8$ m s^{-1}, $\frac{\Delta m}{\Delta t} = ?$

We know, $P = \frac{E}{\Delta t} = \frac{\Delta mc^2}{\Delta t} \therefore \frac{\Delta m}{\Delta t} = \frac{P}{c^2} = \frac{10^9}{\left(3\times10^8\right)^2} = \frac{10^{-7}}{9}\text{kg s}^{-1}$

$= \frac{10^{-7}}{9} \times 1000 \times 3600$ g h^{-1} $= 4 \times 10^{-2}$ g h^{-1}

15. (b): For first orbit of hydrogen atom ($n = 1$),

$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$ ...(i)

$mvr = \frac{h}{2\pi}$ ...(ii)

Squaring equation (ii), we get $m^2v^2r^2 = \frac{h^2}{4\pi^2}$

Dividing both sides by r^3, we get

$\frac{m^2v^2}{r} = \frac{h^2}{4\pi^2 r^3} \Rightarrow \frac{v^2}{r} = \frac{h^2}{4\pi^2 r^3 m^2}$

This is required acceleration of the electron.

16. (d): Half life of A, $T_{1/2(A)} = 20$ min
Half life of B, $T_{1/2(B)} = 40$ min
Initially, number of nuclei in each sample $= N$
Now, 80 min $= 4T_{1/2(A)} = 2T_{1/2(B)}$
Number of active nuclei after four half lives of A, $k_W = \frac{k}{7^9} = \frac{k}{6;}$

$\therefore$ Number of decayed nuclei $= N - N_A = \frac{6:}{6;}k$

Number of active nuclei after two half lives of B,

$k_X = \frac{k}{7^7} = \frac{k}{9}$

$\therefore$ Number of decayed nuclei $= N - N_B = \frac{8}{9}k$

$\therefore$ Required ratio $= \frac{\frac{6:}{6;}k}{\frac{8}{9}k} = \frac{:}{9}$

17. (b) : Energy of emitted photon

$E = \left[\frac{1}{1^2} - \frac{1}{2^2}\right] \times 13.6 \text{ eV} = \frac{3}{4} \times 13.6 \text{ eV}$

Energy required to completely remove the electron from n^{th} excited state of doubly ionized lithium,

$E' = \frac{13.6Z^2}{n^2}\text{ eV} = \frac{13.6 \times 9}{n^2}\text{ eV}$

As $E \geq E'$

$\frac{3}{4} \times 13.6 \geq \frac{13.6 \times 9}{n^2} \Rightarrow n^2 \geq 3 \times 4$ or $n \geq \sqrt{12} = 3.5$

$\therefore$ Least quantum number for the excited state = 4.

18. (a) : Using conservation of linear momentum,

Total momentum before collision
= Total momentum after collision

$mv = (m + m)\, v'$

$v' = \frac{v}{2}$

Loss in kinetic energy during the process,

$\Delta K = \frac{1}{2}mv^2 - \frac{1}{2}(2m)\left(\frac{v}{2}\right)^2 = \frac{1}{4}mv^2$

For minimum kinetic energy of neutron, lost kinetic energy should be used by the electron to jump from first orbit to second orbit.

$\Rightarrow \quad \frac{1}{4}mv^2 = (13.6 - 3.4)\text{ eV} = 10.2\text{ eV}$

$\therefore \quad \frac{1}{2}mv^2 = 20.4\text{ eV} = \text{K.E. of neutron for inelastic collision.}$

19. (c) : For an electron in n^{th} excited state of hydrogen atom,

kinetic energy $= \frac{e^2}{8\pi \in_0 n^2 a_0}$

potential energy $= \frac{-e^2}{4\pi \in_0 n^2 a_0}$ and total energy $= \frac{-e^2}{8\pi \in_0 n^2 a_0}$

where a_0 is Bohr radius.
As electron makes a transition from an excited state to the ground state, n decreases. Therefore kinetic energy increases but potential energy and total energy decrease.

20. (b) : $mvR = \frac{}{7\pi}$ ...(i)

and $qvB = \frac{7}{o}E \quad qB = \frac{}{o}$ ...(ii)

From eqns. (i) and (ii), we get $X\left(\frac{}{7\pi}\right) =$

$\frac{6}{7} \quad ^{7} = \frac{6}{9\pi} \quad X \therefore E = \left(\frac{X}{9\pi}\right)$

21. (b) : Omr xurq=6: $t \sim = \frac{53>8}{\lambda}$ $\therefore \lambda = 0.0462$ hr^{-1}

$k_5 = \frac{6}{79}$ y {xq–{ r Vm, t = 7.5 hrs

Number of β-particles disintegrated, $N_\beta = N_0(1 - e^{-\lambda t})$

$= \left(\frac{6}{79} \text{y {xq–}}\right) 6- {}^{-5359;7\times<3}. = \left(\frac{6}{79}\text{y {xq–}}\right) 6- {}^{-538:}.$

= 0.0122 moles = 0.0122 × 6.023 × 10^{23} $\therefore N_\beta = 7.4 \times 10^{21}$

22. (c) : Radius of a charged particle moving in a constant magnetic field is given by

$$R = \frac{mv}{qB} \text{ or } R^2 = \frac{m^2v^2}{q^2B^2} = \frac{2m\left(\frac{1}{2}mv^2\right)}{q^2B^2} = \frac{2m(\text{K.E.})}{q^2B^2}$$

$$\Rightarrow \quad \text{K.E.} = \frac{q^2B^2R^2}{2m} \Rightarrow \quad \text{K.E.}_{\text{max}} = \frac{q^2B^2R^2_{\text{max}}}{2m} = 0.80 \text{ eV}$$

Energy of photon corresponding transition from orbit 3 → 2 in hydrogen atom.

$$E = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.89 \text{ eV}$$

Using Einstein photoelectric equation.

$E = \text{K.E.}_{\text{max}} + \phi$

$\Rightarrow \quad 1.89 = 0.8 + \phi \quad \Rightarrow \quad \phi = 1.09 \approx 1.1$ eV

23. (d) : As, $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n^2}\right]$

Here, n_1 and n are same in each case and R is constant.

$\therefore \quad \frac{1}{\lambda} \propto \frac{1}{Z^2} \Rightarrow \lambda \propto Z^2 \quad \Rightarrow \quad \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$

24. (a) : In a hydrogen like atom, when an electron makes an transition from an energy level with n to $n - 1$, the frequency of emitted radiation is

$$\upsilon = RcZ^2\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = RcZ^2\left[\frac{n^2-(n-1)^2}{(n^2)(n-1)^2}\right] = \frac{RcZ^2(2n-1)}{n^2(n-1)}$$

As $n >> 1$

$\therefore \quad \upsilon = \frac{RcZ^2 2n}{n^4} = \frac{2RcZ^2}{n^3} \quad$ or $\quad \upsilon \propto \frac{1}{n^3}$

25. (c) : Number of spectral lines in the emission spectra,

$$N = \frac{n(n-1)}{2}$$

Here, $n = 4 \;\therefore\; N = \frac{4(4-1)}{2} = 6$

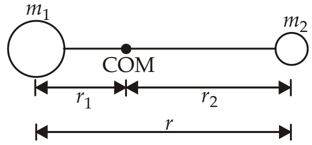
26. (*): Mass defect, $\Delta m = m_p + m_e - m_n$
= (1.6725 × 10^{-27} + 9 × 10^{-31} – 1.6725 × 10^{-27}) kg
= 9 × 10^{-31} kg

Energy released = Δmc^2 = 9 × 10^{-31} × (3 × 10^8)^2 J

$$= \frac{9\times10^{-31}\times9\times10^{16}}{1.6\times10^{-13}} \text{ MeV} = 0.51 \text{ MeV}$$

* None of the given option is correct.

27. (c) : A diatomic molecule consists of two atoms of masses m_1 and m_2 at a distance r apart. Let r_1 and r_2 be the distances of the atoms from the centre of mass.
The moment of inertia of this molecule about an axis passing through its centre of mass and perpendicular to a line joining the atoms is



$I = m_1r_1^2 + m_2r_2^2$

As $m_1r_1 = m_2r_2$

or $r_1 = \frac{m_2}{m_1}r_2$

$\because \quad r_1 + r_2 = r \quad \therefore \quad r_1 = \frac{m_2}{m_1}(r - r_1)$

On rearranging, we get $r_1 = \frac{m_2r}{m_1 + m_2}$

Similarly, $r_2 = \frac{m_1r}{m_1 + m_2}$

Therefore, the moment of inertia can be written as

$$I = m_1\left(\frac{m_2r}{m_1+m_2}\right)^2 + m_2\left(\frac{m_1r}{m_1+m_2}\right)^2 = \frac{m_1m_2}{m_1+m_2}r^2 \quad \text{...(i)}$$

According to Bohr's quantisation condition

$$L = \frac{nh}{2\pi} \quad \text{or} \quad L^2 = \frac{n^2h^2}{4\pi^2} \quad \text{...(ii)}$$

Rotational energy, $E = \frac{L^2}{2I}$

$E = \frac{n^2h^2}{8\pi^2 I}$ (Using (ii))

$= \frac{n^2h^2(m_1+m_2)}{8\pi^2(m_1m_2)r^2}$ (Using (i))

$= \frac{n^2\hbar^2(m_1+m_2)}{2m_1m_2r^2} \quad \left(\because \; \hbar = \frac{h}{2\pi}\right)$

In the question instead of h, $\hbar$ should be given.

28. (c) : Using, $E_n = -\frac{13.6Z^2}{n^2}$ eV

Here, $Z = 3$ (For Li^{++}) $\therefore \quad E_1 = -\frac{13.6(3)^2}{(1)^2}$ eV

$E_1 = -122.4$ eV and $E_3 = \frac{-13.6\times(3)^2}{(3)^2} = -13.6$ eV

$\Delta E = E_3 - E_1 = -13.6 + 122.4 = 108.8$ eV

29. (c) : Number of undecayed atoms after time t_2,

$$\frac{N_0}{3} = N_0e^{-\lambda t_2} \quad \text{...(i)}$$

Number of undecayed atoms after time t_1,

$$\frac{2}{3}N_0 = N_0e^{-\lambda t_1} \quad \text{...(ii)}$$

Dividing (ii) by (i), we get $2 = e^{\lambda(t_2 - t_1)}$ or $\ln 2 = \lambda(t_2 - t_1)$

or $(t_2 - t_1) = \frac{\ln 2}{\lambda}$

As per question, $t_{1/2}$ = half life time = 20 min

$\therefore \quad t_2 - t_1 = 20$ min $\quad \left[\because \; t_{1/2} = \frac{\ln 2}{\lambda}\right]$

30. (c) : When a radioactive nucleus emits an alpha particle, its mass number decreases by 4 while the atomic number decreases by 2.
When a radioactive nucleus, emits a β^+ particle (or positron (e^+)) its mass number remains unchanged while the atomic number decreases by 1.

$\therefore \ {}^{A}_{Z}X \xrightarrow{3\alpha} {}^{A-12}_{Z-6}Y \xrightarrow{2e^+} {}^{A-12}_{Z-8}W$

In the final nucleus,
Number of protons, $N_p = Z - 8$
Number of neutrons, $N_n = A - 12 - (Z - 8) = A - Z - 4$

$\therefore \ \dfrac{N_n}{N_p} = \dfrac{A - Z - 4}{Z - 8}$

31. (c) : Mass defect, $\Delta M = \left[(M + \Delta m) - \left(\dfrac{M}{2} + \dfrac{M}{2}\right)\right]$

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

Energy released, $Q = \Delta Mc^2 = \Delta mc^2$ ...(i)
According to law of conservation of momentum, we get

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

Also, $Q = \dfrac{1}{2}\left(\dfrac{M}{2}\right)v_1^2 + \dfrac{1}{2}\left(\dfrac{M}{2}\right)v_2^2 - \dfrac{1}{2}(M + \Delta m) \times (0)^2$

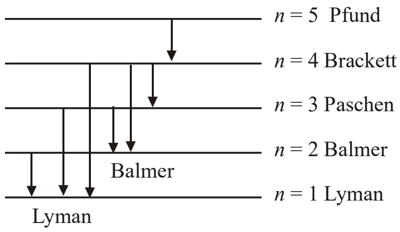
$= \dfrac{M}{2}v_1^2 \qquad (\because \ v_1 = v_2)$ ...(ii)

Equating equations (i) and (ii), we get $\left(\dfrac{M}{2}\right)v_1^2 = \Delta mc^2$

$v_1^2 = \dfrac{2\Delta mc^2}{M} \Rightarrow v_1 = c\sqrt{\dfrac{2\Delta m}{M}}$

32. (d) : After decay, the daughter nuclei will be more stable, hence binding energy per nucleon of daughter nuclei is more than that of their parent nucleus.
Hence, $E_2 > E_1$.

33. (d) :



Transition $4 \to 3$ is in Paschen series. This is not in the ultraviolet region but this is in infrared region.
Transition $5 \to 4$ will also be in infrared region (Brackett).

34. (a) : When two nucleons combine to form a third one, and energy is released, one has fusion reaction. If a single nucleus splits into two, one has fission. The possibility of fusion is more for light elements and fission takes place for heavy elements. Out of the choices given for fusion, only A and B are light elements and D and E are heavy elements. Therefore $A + B \to C + \varepsilon$ is correct. In the possibility of fission is only for F and not C. Therefore

$F \to D + E + \varepsilon$ is the correct choice.

35. (a) : Statement-1 states that energy is released when heavy nuclei undergo fission and light nuclei undergo fusion is correct. Statement-2 is wrong.
The binding energy per nucleon, B/A, starts at a small value, rises to a maximum at ^{62}Ni, then decreases to 7.5 MeV for the heavy nuclei. The answer is (a).

36. (c) : Supposing that the force of attraction in Bohr atom does not follow inverse square law but inversely proportional to r, $\dfrac{1}{4\pi\varepsilon_0}\dfrac{e^2}{r}$ would have been $= \dfrac{mv^2}{r}$

$\therefore \ mv^2 = \dfrac{e^2}{4\pi\varepsilon_0} = k \Rightarrow \dfrac{1}{2}mv^2 = \dfrac{1}{2}k$

This is independent of n.

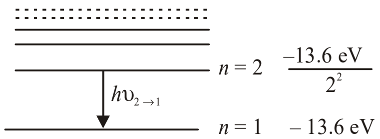
From $mvr_n = \dfrac{nh}{2\pi}$, as mv is independent of r, $r_n \propto n$.

37. (d) : $h\upsilon_{2\to 1} = -13.6\left(\dfrac{1}{2^2} - \dfrac{1}{1^2}\right)$ eV $= +13.6 \times \dfrac{3}{4}$eV $= 10.2$ eV

Emission is $n = 2 \to n = 1$ *i.e.*, higher n to lower n.
Transition from lower to higher levels are absorption lines.

$-13.6\left(\dfrac{1}{6^2} - \dfrac{1}{2^2}\right) = +13.6 \times \dfrac{2}{9}$

This is $< E_{n=2} \to E_{n=1}$



38. (b) : $T_{1/2}$, half life of $X = \tau_Y$, mean life of Y

$\dfrac{\ln 2}{\lambda_X} = \dfrac{1}{\lambda_Y} \Rightarrow \lambda_X = \lambda_Y \ln 2$

$\lambda_X > \lambda_Y \therefore \ A_X = A_0 e^{-\lambda_X t}$; $A_Y = A_0 e^{-\lambda_Y t}$

X will decay faster than Y.

39. (c) : γ-ray emission takes place due to deexcitation of the nucleus. Therefore during γ-ray emission, there is no change in the proton and neutron number.

40. (c) : Binding energy $= [ZM_P + (A - Z)\ M_N - M]c^2$
$= [8M_P + (17 - 8)\ M_N - M_O]c^2$
$= (8M_P + 9M_N - M_O)c^2$
[But the option given is negative of this].

41. (c) : Binding energy of ${}^7_3\text{Li} = 7 \times 5.60 = 39.2$ MeV

Binding energy of ${}^4_2\text{He} = 4 \times 7.06 = 28.24$ MeV

$\therefore$ Energy of proton = Energy of $\left[2({}^4_2\text{He}) - {}^7_3\text{Li}\right]$

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

42. (d) : The biological effect of radiation is measured in 'rad'.

43. (d) : ${}_3\text{Li}^7 + {}_1\text{H}^1 \to {}_4\text{Be}^8 + {}_ZX^A$

Z for the unknown X nucleus $= (3 + 1) - 4 = 0$
A for the unknown X nucleus $= (7 + 1) - 8 = 0$
Hence particle emitted has zero Z and zero A
It is a gamma photon.

44. (d) : Graph (d) represents the variation.

45. (c) : For closest approach, kinetic energy is converted into potential energy

$\therefore \ \dfrac{1}{2}mv^2 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r_0} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{(Ze)(2e)}{r_0}$

or $r_0 = \dfrac{4Ze^2}{4\pi\varepsilon_0 mv^2} = \dfrac{Ze^2}{\pi\varepsilon_0 v^2}\left(\dfrac{1}{m}\right)$

or r_0 is proportional to $\left(\dfrac{1}{m}\right)$

46. (d) : The nuclear transformation is given by

$${}_{Z}^{A}X + {}_{0}^{1}n \rightarrow {}_{2}^{4}\text{He} + {}_{3}^{7}\text{Li}$$

According to conservation of mass number

$A + 1 = 4 + 7$ or $A = 10$

According to conservation of charge number

$Z + 0 \rightarrow 2 + 3$ or $Z = 5$

So the nucleus of the element be ${}_{5}^{10}\text{B}$.

47. (c) : I is showing absorption photon.
From rest of three, III having maximum energy from

$$\Delta E \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

48. (a) : $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$

$$\therefore \quad \frac{1}{8} = \left(\frac{1}{2}\right)^{15/T} \Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{15/T} \quad \therefore \frac{15}{T} = 3 \Rightarrow T = 5 \text{ min}$$

49. (b) : $\because \; I = I_0 e^{-kx} \Rightarrow \frac{I}{I_0} = e^{-kx} \quad \therefore \; \ln\left(\frac{I}{I_0}\right) = -kx$

In first case

$\ln\left(\frac{1}{8}\right) = -k \times 36$; $\ln(2^{-3}) = -k \times 36$

or $3\ln 2 = k \times 36$ ...(i)

In second case, $\ln\left(\frac{1}{2}\right) = -k \times x$ or $\ln(2^{-1}) = -kx$

or $\ln 2 = kx$ ...(ii)

From (i) and (ii)

$3 \times (kx) = k \times 36$ or $x = 12$ mm

50. (c) : R is proportional to $A^{1/3}$ where A is mass number

$3.6 = R_0 (27)^{1/3} = 3R_0$, for ${}_{13}^{27}\text{Al}$

Again $R = R_0 (125)^{1/3}$, for ${}_{52}^{125}\text{Al}$ $\therefore$ $R = \frac{(3 \cdot 6)}{3} \times 5 = 6$ fermi

51. (c) : Kinetic energy is converted into potential energy at closest approach

$\therefore$ K.E. = P.E.

$$5 \text{ MeV} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

or $\quad 5 \times 10^6 \times e = \frac{(9 \times 10^9) \times (92e)(2e)}{r}$

or $\quad r = \frac{9 \times 10^9 \times 92 \times 2 \times e}{5 \times 10^6} = \frac{9 \times 10^9 \times 92 \times 2 \times (1.6 \times 10^{-19})}{5 \times 10^6}$

$\therefore \quad r = 5.3 \times 10^{-14}$ m $= 5.3 \times 10^{-12}$ cm

52. (c) : Total binding energy for (each deuteron)

$= 2 \times 1.1 = 2.2$ MeV

Total binding energy for helium $= 4 \times 7 = 28$ MeV

$\therefore$ Energy released $= 28 - (2 \times 2.2)$

$= 28 - 4.4 = 23.6$ MeV

53. (d) : Momentum is conserved during disintegration

$\therefore \quad m_1 v_1 = m_2 v_2$ ...(i)

For an atom, $R = R_0 A^{1/3}$

$\therefore \quad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{m_1}{m_2}\right)^{1/3} = \left(\frac{v_2}{v_1}\right)^{1/3}$, from (i)

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

54. (a) : Energy $E_2 = \frac{-Z^2 E_0}{n^2} = \frac{-(3)^2 \times 13.6}{(2)^2} = -30.6$ eV

$\therefore \quad$ Energy required $= 30.6$ eV

55. (c) : Masses of ${}_1\text{H}^1$ and ${}_1\text{D}^2$ are different. Hence the corresponding wavelengths are different.

56. (b) : ${}_{55}^{133}\text{Cs}$ has the lowest ionization potential. Of the four atoms given, Cs has the largest size. Electrons in the outer most orbit are at large distance from nucleus in a large-size atom. Hence the ionization potential is the least.

57. (d) : At temperature T, molecules of a gas acquire a kinetic energy $= \frac{3}{2}kT$ where k = Boltzmann's constant

$\therefore \quad$ To initiate the fusion reaction $\frac{3}{2}kT = 7.7 \times 10^{-14}$ J

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

58. (a) : Protons are not emitted during radioactive decay.

59. (b) : The nucleus emits 8α particles *i.e.*, $8({}_2\text{He}^4)$

$\therefore$ Decrease in $Z = 8 \times 2 = 16$ ...(i)

Four β^- particles are emitted *i.e.*, $4({}_{-1}\beta^0)$

$\therefore$ Increase in $Z = 4 \times 1 = 4$ ...(ii)

2 positrons are emitted i.e., $2({}_1\beta^0)$

$\therefore$ Decrease in $Z = 2 \times 1 = 2$ ...(iii)

$\therefore$ Z of resultant nucleus $= 92 - 16 + 4 - 2 = 78$

60. (a) : Let decay constant per minute $= \lambda$

Disintegration rate, initially $= 5000$

$\therefore \quad N_0\lambda = 5000$ ...(i)

Disintegration rate, finally $= 1250$

$\therefore \quad N\lambda = 1250$ ...(ii)

$\therefore \quad \frac{N\lambda}{N_0\lambda} = \frac{1250}{5000} = \frac{1}{4}$

or $\quad \frac{N}{N_0} = \frac{1}{4} \Rightarrow \frac{N_0 e^{-5\lambda}}{N_0} = \frac{1}{4} \Rightarrow e^{-5\lambda} = (4)^{-1}$

$\therefore \quad 5\lambda = \ln 4 = 2\ln 2 \quad \therefore \quad \lambda = \frac{2}{5}\ln 2 = 0.4 \ln 2$

61. (b) : Linear momentum is conserved

α-particle $= {}_2^4\text{He}$

$\text{U}^{238} \rightarrow \text{X}^{234} + \text{He}^4$

$\therefore \quad (238 \times 0) = (238 \times v) + 4u$ or $v = -\frac{4u}{234}$

62. (a) : Gamma rays have the least wavelength.

63. (a) : $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} = \left(\frac{1}{2}\right)^{15/5} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

$\therefore \quad N = N_0/8$

64. (c) : $E_n = \frac{13.6}{n^2} \Rightarrow E_2 = \frac{13.6}{(2)^2} = 3.4$ eV

65. (a) : Neutrons are electrically neutral. They are not deflected by magnetic field. Hence (a) represents the answer.